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Coal transition in Australia: an overview of issues

CCEP Working Paper 1811
Sep 2018

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Abstract

Australia produces and exports large amounts of thermal coal. This industry is likely to be in long term decline. This paper provides an overview of Australian coal production and exports and discusses issues for the transition of the coal industry. It sketches possible scenarios for declining domestic use of thermal coal, and summarizes a case study of the closure of the Hazelwood power station and the programs to help the regional social and economic adjustment.

Acknowledgments:

This report is based on several individual research papers that have been published as working papers or are in preparation. Support by the Coal Transitions project managed by IDDRI and ClimateStrategies, with funding provided by the KR Foundation, is gratefully acknowledged. This working paper originally appeared as a project report published by IDDRI.

JEL Classification:

J08; Q40; R10

Suggested Citation:

Jotzo, F., Mazouz, S. and Wiseman, J. et al (2018), Coal transition in Australia: an overview of issues, CCEP Working Paper 1903, Sep 2018. Crawford School of Public Policy, The Australian National University.

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Coal transition in Australia

*Preparing for the looming domestic coal phase-out
and falling export demand*

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Executive Summary

Coal plays a large role in Australia's domestic energy system, and Australia is a large exporter of coal. Australian coal output is over 500 million tonnes per year. Almost all coking coal produced and around 70% of steam coal produced is exported. Australia supplies about a fifth of the global steam coal trade. The remainder is used mostly for electricity generation, where it accounts for around 60% of total power output.

Coal production in Australia is likely to be on a long term declining trajectory. Export demand is a function of economic, technological and policy developments in other countries, all of which point to the likelihood of falling coal use over time, especially for steam coal. There is a clear prospect of lower coal export demand. It is uncertain how international developments will affect Australia steam coal exports, and there is a clear risk of strong reductions in exports demand. But Australia has very large and readily accessible renewable energy resources which promises to be the country's energy future.

The picture is clearer for domestic coal use. Australia's coal fired power plant fleet is relatively old with about half the plants and about two thirds of overall generating capacity older than 30 years. At the same time, renewable power has become competitive, and Australia has practically unlimited opportunities for renewable energy installations. New coal fired power stations would not be commercially viable in competition with renewables, and existing coal plants are likely to come under increasing economic pressure as the amount of renewable electricity generation increases. This is likely to cause accelerated closure of coal fired power plants.

This report presents two scenarios for coal use in Australia. The "moderate" scenario has coal power plant capacity and coal use declining rapidly through the 2020s and 2030s. Coal use would be less than half the present level by 2030, and decline by over 90% by 2040. This scenario is based on average plant lifetimes gradually declining as renewables become still cheaper than they already are, and comprising a quickly rising share of power generation. This scenario is broadly compatible with the 2030 emissions target as per Australia's NDC to the Paris Agreement. A "faster" scenario has plant lifetimes diminishing more quickly, with coal use reduced by around 30% compared to today by 2025, reduced by

two thirds by 2030, and falling to very low levels during the 2030s. It illustrates a stronger 2030 target, in line with the global objective to ratchet up national contributions towards the global "two degrees or less" goal.

Market are expected to be the key in driving the transition away from coal, as renewable power is developing a cost advantage relative to the ageing coal fired power plant fleet. Suitable policy can help achieve coal transition more reliably and smoothly; conversely there is a risk that policy designed to protect existing industrial structures could unnecessarily delay the transition and keep high emitting installations for longer than necessary.

The report also describes and analyses the closure of the Hazelwood power station, Australia's largest and the latest of ten closures of coal power stations in Australia so far. The relatively sudden closure has highlighted the issues faced by communities and worker. Various government funded adjustment programmes have been put in place, and the episode highlights both successful strategies and the limitations to forward-looking transition policy in Australia's present political and institutional context. We also report econometric analysis on the effect of coal plant closures on regional unemployment, finding a relatively small but persistent increase in unemployment rates on average, after controlling for other variables.

Implications for policy include the following. For exports, Australian governments should refrain from providing subsidies or other preferential treatment for coal mines and coal transport infrastructure. Mindful of the growing risk that international coal demand may drop off as a result of alternatives becoming cheaper and more desirable and of climate change policy, policy should be supportive of economic diversification in regions where coal is economically important.

For domestic coal use, mostly in electricity, governments should strive to put in place stable policy frameworks to help guide and facilitate the transition. This would include putting in place a predictable policy treatment of carbon dioxide emissions that can link in with a possible future economy-wide emissions price signal; mechanisms to encourage predictable and orderly closure of coal fired power stations and socially acceptable transition for local communities; and helping to create

suitable market and regulatory frameworks to facilitate the infrastructure investments necessary for an efficient

and reliable energy system in the transition from coal to renewables.

1. Introduction

Australia has large and relatively easily recoverable coal reserves. Domestic electricity generation is dominated by coal, and coal is also used in minerals and metals processing industries. Australia is a major exporter of both coking coal and thermal coal. Exports have continued to grow while domestic consumption remained stable, and export volumes are now far larger than domestic coal use.

The rates of growth of coal production have slowed down. Near-term projections for coal exports and have been revised downwards, and with it the outlook for production.

Over the medium term, domestic coal use is poised to decline as ageing coal fired power stations are replaced with renewable energy installations which now produce electricity at lower costs than new coal plants would. Direct coal use in industry is also poised to decline. While domestic coal use has begun its structural decline, exports of coal may remain at high levels as today for some time. Longer term, the future for Australia's coal production depends on global demand. Several factors point to likely future reductions in global demand for thermal coal, including increasing cost competitiveness of renewable energy in many parts of the world, international efforts to reduce greenhouse gas emissions, and increasing concern about air pollution especially in the cities of developing and industrializing countries. Australian exports could decline along with global demand. The outlook for metallurgical coal is likely to be more stable, though longer term it could be significantly affected by new technologies for producing steel.

There is uncertainty about the speed of future global coal demand reductions and even greater uncertainty about how global coal demand will translate into demand for coal exports, and how Australia's exports will develop relative to global export demand. Over the long term, transition out of coal appears inevitable; being prepared for a possibly rapid reduction in coal production, use and exports is prudent risk management.

Coal production is a large, regionally concentrated industry. The coal industry has been prominent and influential in the Australian policy discourse and in policymaking. Policies to reduce greenhouse gas emissions have met with resistance from the coal industry, and to date there has been no public policy effort to come to grips with the likely long term decline of coal exports.

Meanwhile however, a number of coal fired power stations have been closed down and not replaced by new coal using plants. Recent coal plant closures in Australian have been associated with somewhat higher unemployment rates following the closure, however this has not always been the case. The closures have caused concerns about local economic and social impacts. Government funded programs were put in place to support workers and communities, but this happened in a largely ad-hoc fashion after the events. Future closures of coal plants, mines and associated infrastructure will present similar challenges at much larger scale.

At the same time, transition in the energy sector presents tremendous opportunities for Australia. The country is rich in renewable energy resources, which in the future could support a zero-carbon electricity supply as well energy intensive export industries.

This report provides an overview of Australia's coal production, use and exports; sets out scenarios for future domestic coal use, explores what international coal demand scenarios may imply for Australia; provides an evaluation of emerging experiences with Australian policy responses to coal transition, in the form of lessons from a case study of the closure of the Hazelwood power station, as well as an econometric study of the effects of coal plant closure on regional unemployment; and discusses the role of policy in various aspects of the coal transition.

This report builds on analysis in several research papers produced for the Coal Transitions project, and presents quantitative scenarios specifically derived for the Coal Transitions project.

2. Coal in the National Context

2.1. Role of coal in the national energy system

Australia has large coal reserves, with recoverable black coal reserves estimated at 68 310 Mt in 2015 (Economic Demonstrated Resources), an increase of 9% from the previous year ranking 5th behind the United States, China, India and Russia for recoverable economic coal resources (GA 2016).

The recoverable brown coal resource is even larger at an estimated 76 508 Mt as of 2015 (Economic Demonstrated Resources), an increase of 73% from 2014 (following a major review of coal reserves). Australia is ranked second in the world in terms of recoverable brown coal, accounting for 24% of the world's lignite reserves in 2015, behind Russia (29%) and followed by Germany (11%) and the United States (10%) (GA 2016).

Australia is also one of the world's largest coal producers, with 421Mt or 7% of the world's total produced in 2015 (see [Figure 1](#)).

The majority of the coal produced in Australia is thermal coal (dominated by black coal for export), with coking coal accounting for 38% of total Australian production in 2015 (see [Figure 2](#)).

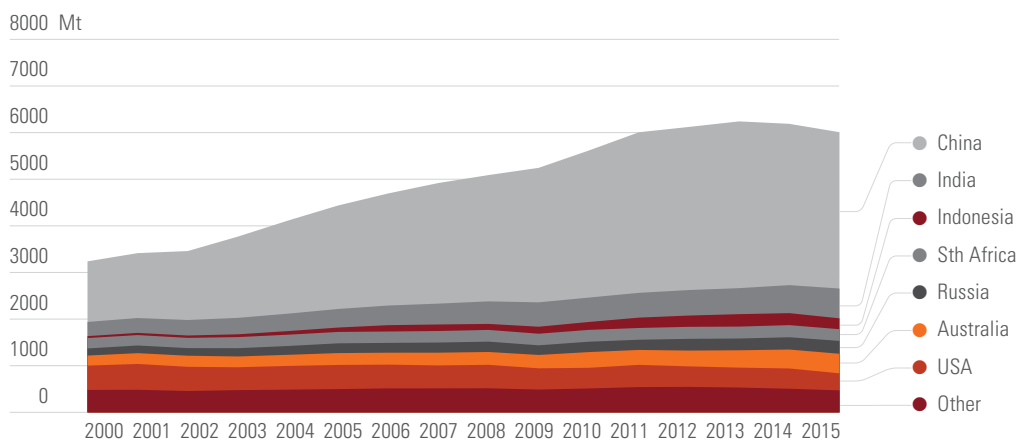
Most of the coal produced in Australia is destined for export with coking and black coal exports making up

roughly equal shares of exports by weight. Both, coking and thermal coal exports expanded considerably in the recent past, growing by almost 40% over the four years to 2015 ([Figure 3](#)). This has positioned Australia as one of the largest coal exporters in the world, accounting for a fifth (19.3%) of world thermal coal trade in the financial year ending 2016 and 60% of world metallurgical coal trade in 2016 (OCE 2017).

However, even this explosive growth was not sufficient to meet the official forecasts for Australian production and exports. These have been revised down with every publication from 2012 to the latest 2017 forecast which now predicts relatively flat production and exports over the five year forecasting horizon ([Figure 4](#) and [Figure 5](#)). Domestic coal use is dominated by electricity generation with over 90% of black coal and virtually all brown coal used to supply electricity in 2014-15 (in aggregate 94% of coal was used in electricity generation with the remaining 6% being burned in coke ovens and used directly in industry).

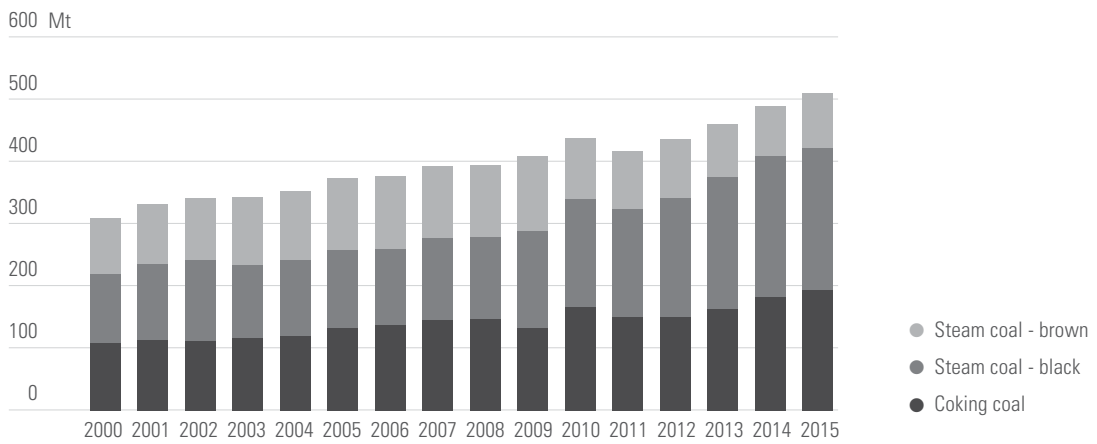
While gas and renewables shares in electricity production have been growing over time, coal still accounted for 63% of total generation in the financial year ending 2015, down from highs of over 80% fifteen years prior ([Figure 7](#)).

Figure 1. World coal production by top producing country



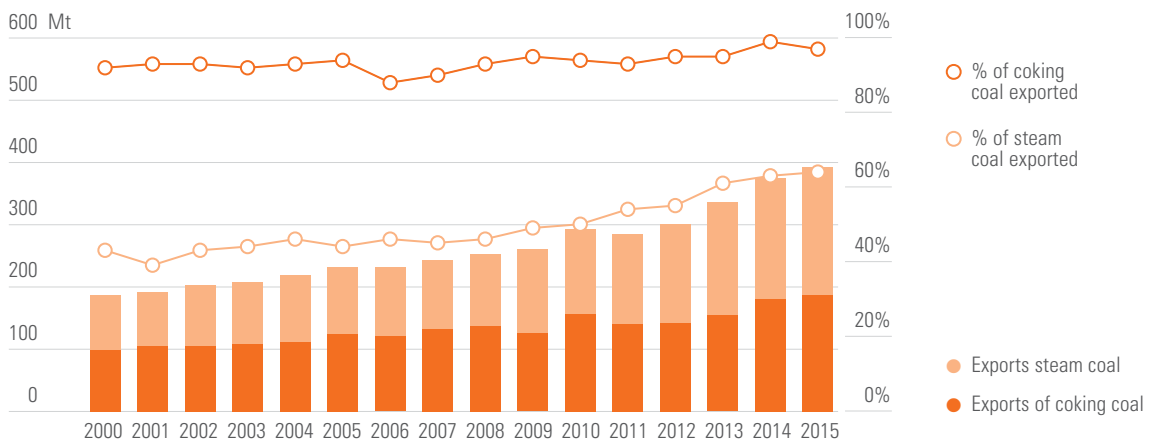
Source: IEA coal Statistics 2016.

Figure 2. Coal production in Australia, 2000 to 2015



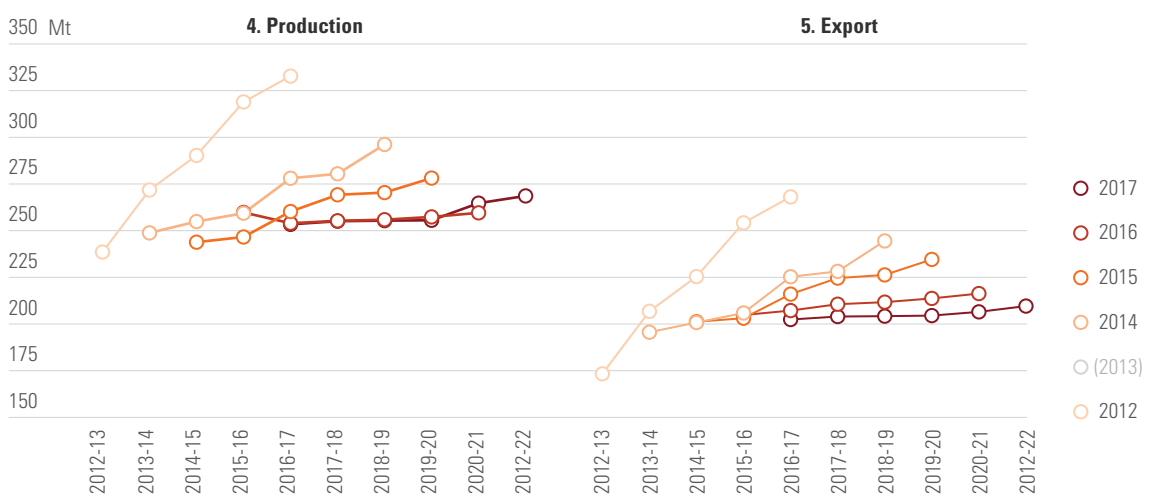
Source: OCE (2016).

Figure 3. Exports (Mt) and export share, steaming coal and coking coal, Australia 2000-2015



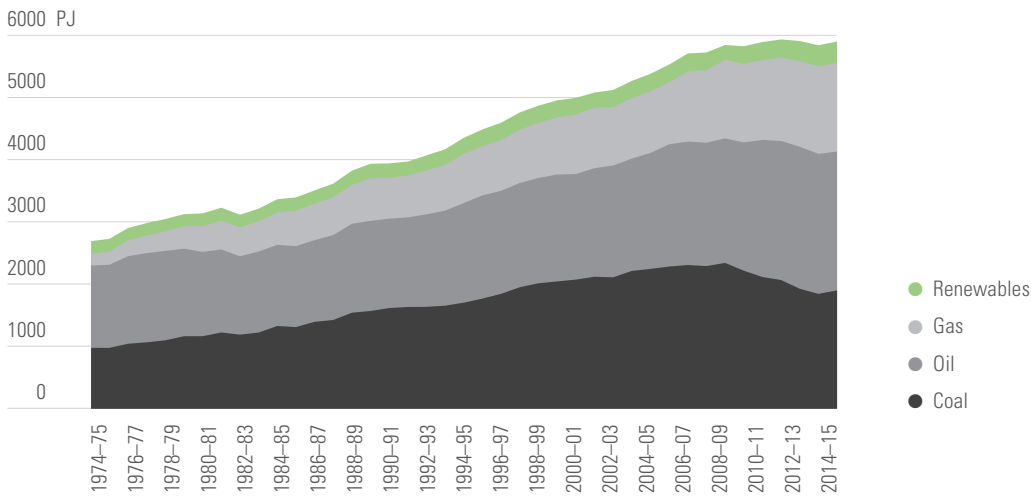
Source: OCE (2016).

Figure 4-5. OCE Australian Thermal Coal production outlooks, March quarters, 2012 to 2017



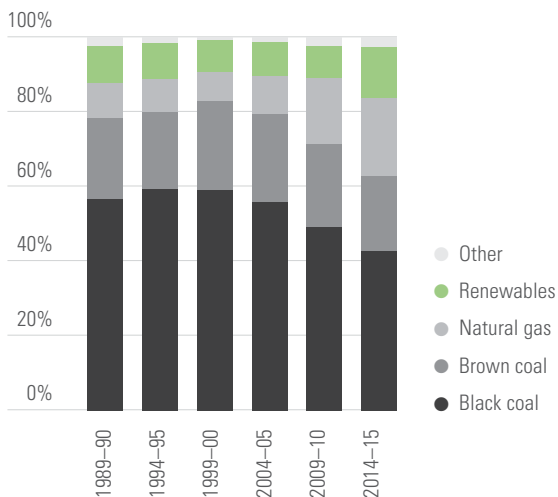
Source: Office of the Chief Economist, Resource and Energy Quarterly, March Quarter forecasts, 2012 to 2017.

Figure 6. Australian energy consumption by fuel type, FY ending 1975 to 2015



Source: OCE (2016).

Figure 7. Australian electricity generation fuel mix



Source: OCE (2016).

2.2. Role of coal in the national/sub-national economy

Coal accounted for about 15% of Australia's total export value in 2017 with thermal coal accounting for about between 4.6% and 5.7% of total export value over the past decade.

About 48,000 people were employed in coal mining in 2017, accounting for about 0.4% of Australia's direct workforce. Coal mining also accounted for a relatively stable share of about 20% of overall mining employment at since 2000. (Figure 9).

2.3. Policy aspects of the transition

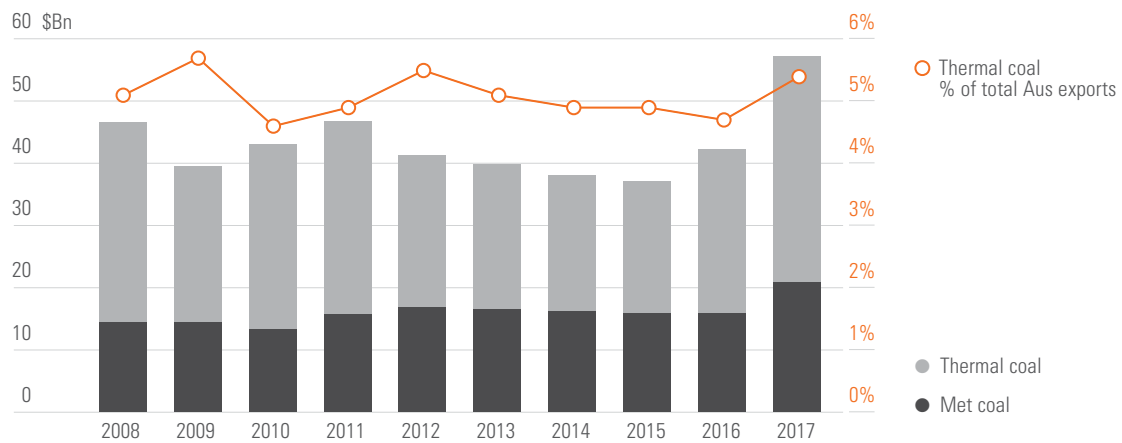
Coal exports and policy

The future of Australia's coal exports will be determined largely by international coal demand. Export demand will be determined by coal use trajectories in importing countries, which depend on a range of technological and economic factors and climate change policy implementation; on the balance between domestic production and imports in coal using countries; and in the relative position between different coal exporters. Australian policy settings have little impact on these developments. However, policy can affect the extent to which any new coal mines and transport infrastructure are opened up, and the speed of closure of existing coal mines.

The largest potential expansion of Australia's coal mining capacity for export are potential new mines in the Galilee Basin in Queensland, including the Carmichael coal mine proposed by Adani Mining, and Indian company (Queensland Government 2014). The project has achieved regulatory approval but appears not to have financial closure, with reports that financing was rejected by a large number of banks and financial institutions (Times of India 2015). The mine would have a peak capacity of 60 million tonnes of thermal coal per year, for export largely to India. Some of the coal would be relatively low in quality with a high ash content. The operation would require a new railway line of almost 200km length and expansion of port facilities.

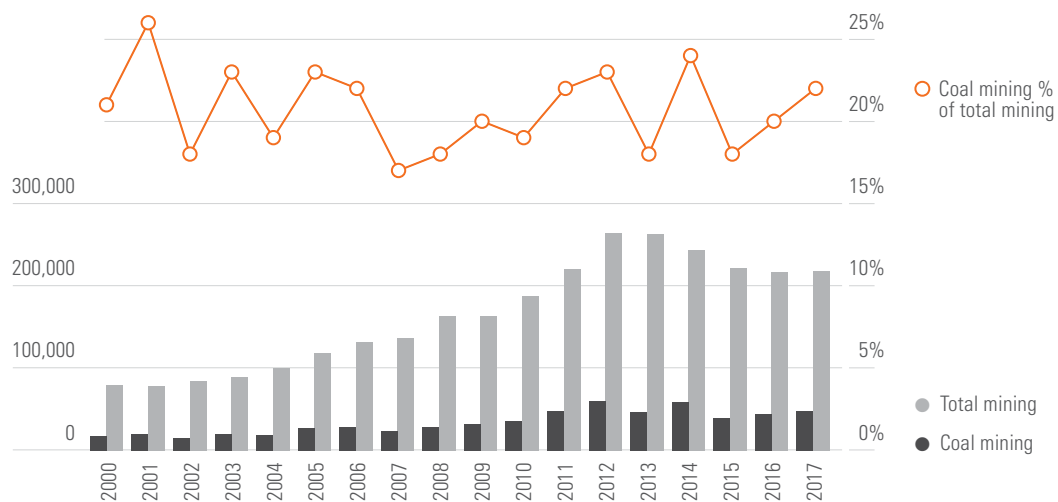
It is unclear what, if any, government support would be provided to the mine. However support in the form of

Figure 8. Coal exports and thermal coal as a percentage of all Australian export value (right axis)



Sources: ABS, *International Trade in Goods and Services*, cat. No. 5368.0 and Department of Industry Innovation and Science, *OCE (2017)*.

Figure 9. Annual coal mining employment as a share of total mining employment and overall employment (right axis)



Sources: ABS, *International Trade in Goods and Services*, cat. No. 5368.0 and Department of Industry Innovation and Science, *OCE (2017)*.

a royalty holiday by the Queensland State government and concessional loans by the Federal government for the construction of the rail line have been discussed (Cox 2015a/b).

The public debate on regulatory approval and potential subsidies for new coal projects is starkly bifurcated. The most prominent argument in favour is economic development in Australia's regional areas including jobs during the construction phase; the main arguments against are climate change mitigation and the risk of creating stranded assets. Much of the public discussion is conducted from entrenched positions that reflect opposing world views, rather than objective analysis of economic and environmental costs, benefits and risks.

Policy affecting domestic coal use

Australia's domestic coal use is on a trajectory of structural decline, as shown above. The potential roles that policy can take are to accelerate or delay the transition away from thermal coal. In the past, federal governments applied policy instruments with the goal to reduce carbon emissions. Chief among them were a carbon pricing mechanism in place from 2012 to 2014, which suppressed coal use in power generation during its operation (Jotzo 2012); and a renewable energy target mechanism which has paid a premium to renewable power, this began operation in 2001 and will be closed to new entrants from 2020.

Since the abolition of the carbon pricing mechanism,

different proposed schemes for establishing a carbon price signal in the electricity sector were proposed, including by official government sponsored reviews, but none ultimately achieved political traction with the federal government. The most recent of these proposals was in advanced stages of preparation for legislation, but was then discarded in a political shift associated with the installation of a new Prime Minister ahead of an election. Individual Parliamentarians have raised the prospect of government support for a new coal fired power station, however there has been no evident intent from industry to build a coal plant on commercial basis, and resistance from key constituencies including business associations. There is practically unanimous view among industry and experts that coal is no longer competitive with renewables for new installations. The vast majority of recent, currently planned and future anticipated power generation investments in Australia consist of wind and solar power, with only a very small amount of new gas generation and increasing investment in energy storage facilities (AEMO 2018). Meanwhile, the majority of State governments have their own sub-national targets for emissions and/or renewable energy, along with policy mechanisms such as power purchasing agreements, which have helped drive renewable energy investments.

The future of carbon related policies in Australia is highly uncertain. However, it appears likely that carbon reduction policy mechanisms that will affect coal use will remain on the political agenda, and may see a reprise under different future governments.

Policy for facilitating orderly transition of coal power plants

A number of coal fired power plants have closed in recent years in Australia, most recently the large Hazelwood brown coal (lignite) plant in Victoria, near Melbourne in 2017. This has given rise to initiatives to assist local communities and workers, and including funding commitments to help with local transition by the State government. This is discussed in the following section. It stands to reason that future coal plant closures will likewise attract an interest for mechanisms to ease the transition. A fundamental requirement for orderly transition is better predictability of coal plant closures (Jotzo and Mazouz 2015). This is likely to require future policy attention. The Finkel Review (Finkel 2017), an independent review of Australia's electricity sector for government, recommended a mandatory three-year notice period before closure of coal plants. This however seems impractical if, as in the case of Hazelwood, closure is precipitated by plant failure.

3. National coal transition scenarios

3.1. Outlook for Australia's coal fired power generation

Coal power station fleet and past closures

Australia has a large fleet of coal fired power plants generating about 60% of Australia's power, down from about 80% at the turn of the century (Australian Energy Update 2017). Ten coal fired generators have been retired in the National Electricity Market (NEM) since 2012 at an average age of 40 years (or 42 years in capacity weighted terms - see section 4 below).

The remaining fleet in the NEM consists of 18 stations:¹ 15 black coal power plants in New South Wales (NSW) and Queensland (QLD), and three brown coal (lignite) fired plants in Victoria (VIC). The fleet has an average age of just over 30 years, and a median age of 33 years. The combined nominal capacity of the fleet is 23.1 GW, of which 15.8 GW (68%) is older than 30 years.

Over the last 10 years, ten coal fired power stations were closed, with a combined capacity of 5.3 GW. The average age at closure was 40 years, and 42 years weighted by capacity.

No prospect for new coal fired power plants

Estimates of the levelized cost of electricity (LCOE) of any hypothetical newly built coal fired power stations are significantly higher than the LCOE of wind and solar PV power in Australia now, with that difference expected to widen over time (AEMO 2018, BNEF 2018). The difference in future LCOE is likely to exceed the costs of firming up intermittent renewables with energy storage even in a system with high renewables penetration.

As a result, it appears that there is no prospect for new coal fired power stations being built in Australia on a commercial basis. This is due to long lead times to build a coal plant, the lack of competitiveness in LCOE, shrinking

Table 1. Australia's remaining coal fired power station fleet in the National Electricity

Name	State	Fuel	Comissioned		Capacity MW (nameplate)	Age in 2018	
			from	to		from	to
Liddell	NSW	Black	1971	1973	2,000	45	47
Gladstone (QAL)	QLD	Black	1973	1973	25	45	45
Yabulu (Coal)	QLD	Black	1974	1974	37.5	44	44
Yallourn W	VIC	Brown	1975	1982	1,480	36	43
Gladstone	QLD	Black	1976	1982	1,680	36	42
Vales Point B	NSW	Black	1978	1978	1,320	40	40
Eraring	NSW	Black	1982	1984	2,880	34	36
Bayswater	NSW	Black	1982	1984	2,640	34	36
Tarong	QLD	Black	1984	1986	1,400	32	34
Loy Yang A	VIC	Brown	1984	1987	2,210	31	34
Callide B	QLD	Black	1989	1989	700	29	29
Mt Piper	NSW	Black	1993	1993	1,400	25	25
Stanwell	QLD	Black	1993	1996	1,460	22	25
Loy Yang B	VIC	Brown	1993	1996	1,026	22	25
Callide C	QLD	Black	2001	2001	810	17	17
Millmerran	QLD	Black	2002	2002	851	16	16
Tarong North	QLD	Black	2002	2002	443	16	16
Kogan Creek	QLD	Black	2007	2007	750	11	11

Source: Updated from Australian Energy Council (2016).

levels of baseload demand and also because of the large financial and regulatory risk on account of the carbon dioxide emissions from any new coal plant. While there has been support from some elements of the political spectrum for the idea of a government supported new coal fired power station, the prospect of such an investment seems unlikely.

Renewables investment and costs

Almost the entire investment pipeline in the Australian electricity sector is in renewables. According to the latest official statement by Australia's energy market operator, the Electricity Statement of Opportunities (AEMO 2018b), about 5.2 GW of committed new large scale renewable generation are expected to be available in the next few years, and a further 45 GW of proposed

¹ The National Electricity Market (NEM) comprises the States of Queensland, New South Wales, Victoria, South Australia and Tasmania, and the Australian Capital Territory, which are connected through a common grid. The NEM excludes Western Australia and the Northern Territory. All data in this section refers only to the NEM, thus excluding three operating black coal power stations in Western Australia. The scenarios in Section 3.2 by contrast also include Western Australia.

renewable generation projects are at various stages of development. The project pipeline is dominated by wind and solar PV, plus some energy storage facilities (batteries and pumped hydro) and a relatively small amount of potential new gas power plants. For context, the generation capacity from all large scale sources (excluding storage) currently stands at less than 50 GW, and total electricity demand is expected to be flat in the medium term.

Based on solar and wind farms already under construction or contracted and assuming that rooftop solar continues at current levels of annual installation, renewables are expected to provide around one third of Australia's power by 2020 (Green Energy Markets 2018). The costs of new renewable energy facilities, in particular solar PV, have fallen dramatically in recent years. Prices for purchasing power for large scale solar PV were around A\$135/MWh in 2015, and around A\$50-55 in the first half of 2018, based on information from the Australian Renewable Energy Agency. Wind power is thought to be contracted at prices just below solar PV. Costs are expected to fall further. The cost of balancing intermittent renewables in the 2040s, at high renewables shares, is expected to add another \$20-\$30/MWh to total system costs (Vorrath and Parkinson 2018). Expectations for future costs of energy from solar PV are as low as A\$20/MWh, and in the \$40-\$50/MWh range including firming, if the cost of financing could be contained to government bond rates, according to estimates by Sanjeev Gupta whose company is investing in solar PV and pumped hydro storage to help power the Whyalla steelworks (Parkinson 2018).

Renewables cost data observed all over the world also shows rapid cost reductions. Typical LCOE for solar PV fell by a factor of more than three between 2010 and 2017 (IRENA 2018). Solar PV costs are expected to continue falling, and on projections by IRENA (2018) would be below the current typical cost for onshore wind power by 2020. This is towards the bottom of the range of typical LCOE for fossil fuel generation. IRENA (2018, p.56) states that "by 2019, the best onshore wind and solar PV projects that will be commissioned will be delivering electricity for an LCOE equivalent of USD 0.03/kWh or less". Australia, with its very high insolation rates and low cost of land, though relatively high labour costs, may see costs near though not at the global frontier. Wind power also continues to see cost reductions, with the average levelized long-term

price from wind power sales agreements in the United States during 2017 reported at around US\$20/MWh (USDoE 2018). Offshore wind installations may also have potential for Australia.

If reductions in costs of renewables generation occur as seems likely, then a cross-over point may be reached where newly built renewable generators can provide energy (firmed up by storage, demand response and portfolio diversity), at costs lower than the operating costs of existing coal fired power stations. At that point, it will make commercial sense to replace coal plants with new renewables installations irrespective of their remaining technical lifetime, and even before taking into account carbon emissions and local air pollution. When this point will be reached is uncertain and depends on regional circumstances, however recent indications are that the crossover may occur much sooner than was thought previously.

Emissions reductions in the electricity sector and NDC compatibility

Recent official default scenarios in Australian modelling analyses assume a relatively slow exit of coal plants over the coming decades, consistent with the government's pro rata 26% to 28% emissions reduction target relative to 2005 levels by 2030 for the electricity sector (Finkel 2017, ESB 2018). This is not consistent with likely developments over the coming years and decades, even without climate policy in the electricity sector. As discussed below, technology cost advances in renewables generation technologies coupled with reductions in baseload demand are adversely affecting the economics of coal plants. Furthermore, the pro rata target for the electricity sector is unlikely to be consistent with Australia's NDC as it would require pro rata emissions reductions in non-electricity sectors of the economy where, overall, emissions reductions are expected to be harder to achieve and significantly more costly (Environment Victoria 2018).

A recent report analysing the emissions reductions required in the electricity sector to achieve the Australian 2030 NDC target, by Australia's CSIRO (Campey *et al.*, 2017), illustrates the point quantitatively. The analysis indicates that in order to achieve a 27% emissions reduction at 2030 compared to 2005 in the energy sector overall (that is emissions from electricity, direct combustion by industry and households, transport and fugitive emissions), electricity sector emissions would be reduced

Table 2. Australia's coal fired power station closures to 2017

Name	State	Fuel	Year commissioned		Year of closure	Capacity (MW)	Age at closure	
			from	to			from	to
Hazelwood	VIC	Brown	1964	1971	2017	1760	46	53
Northern	SA	Brown	1985		2016	546	31	31
Playford	SA	Brown	1960		2016	240	56	56
Anglesea	VIC	Brown	1969		2015	160	46	46
Redbank	NSW	Black	2001		2014	144	13	13
Wallerawang C	NSW	Black	1976	1980	2014	1000	34	38
Morwell	VIC	Brown	1958	1962	2014	189	52	56
Munmorah	NSW	Black	1969		2012	600	43	43
Collinsville	QLD	Black	1968	1998	2012	180	14	44
Swanbank B	QLD	Black	1970	1973	2012	500	39	42

Source: Updated from Australian Energy Council (2016).

by between 52% and 70%, depending on assumptions about energy efficiency improvements.

Coal use and resulting emissions in the “moderate” scenario are broadly compatible with the 2030 emissions target as per Australia's NDC to the Paris Agreement, in terms of emissions levels from electricity that would prevail at 2030.

The “faster” scenario goes further, and thereby illustrates a stronger 2030 target, in line with the global objective to ratchet up national contributions towards the global “two degrees or less” goal.

Deterioration of coal plants' profitability and expectations of accelerating coal plant closures

There are important factors that would suggest shorter remaining lifetimes and more rapid transition away from coal than in the analyses that have so far constituted the mainstream in Australia. This may explain why official forecasts and projections all missed the exit of the Hazelwood brown coal fired power-plant until it was announced by the plant owner. Previous closures occurred at an average age of 40 years, with only few plants (or units of plants) achieving an operational lifetime of 50 years or more (Table 2).

It is likely that the economics of coal based generation will deteriorate, as a result of less baseload demand and increasing renewables penetration. This deterioration has several components.

Firstly, intermittent renewables tend to get dispatched first on the grid as their marginal cost of producing power is zero, while fossil fuel plants have a short-term

operating cost in the form of fuel expenditure (although coal plants at times bid energy into the market at negative prices for lack of technical opportunity to curtail supply in the short run). This means that in a situation where addition of renewable power outstrips increases in electricity demand (as is the case in Australia), the fossil fuel fleet will supply less energy - that is, existing plants will run at lower capacity factors.

Secondly, the addition of renewables tends to result in lower average market prices, which further reduces revenue for fossil fuel plants (Seel *et al.*, 2018).

Thirdly, the higher the share of supply from intermittent renewables and changes to demand patterns (including higher penetration of air conditioning loads and distributed generation) lead to different residual load profiles, generally more “peaky” profiles with greater need for other generators to ramp their production up and down. The ramping can be provided by gas generators, hydropower and battery storage, but also by coal generators. Ramping coal generators up and down is now observed more frequently in Australia (with some coal plants significantly more flexible than others) and may be a strategy to shore up revenue. However the ramping puts additional stress on the equipment and will tend to shorten periods between major maintenance/refurbishment, as well as overall lifetimes of plants.

Finally, the risk of future climate policy related constraints - such as an explicit or implicit price on carbon emissions - increases the financing costs for coal fired power stations, and makes major refurbishment less attractive.

Taken together, these factors suggest that in future there will be a higher propensity for coal fired power stations to be closed before they reach the end of their originally assumed technical or economic lifetime. Such closures would then be likely to occur at a point in time when major repairs or refurbishment becomes necessary, unless policy or regulatory mechanisms are in place to for more predictable exit.

Taking a major plant off the grid increases prices in the wholesale market and thereby shores up the remaining coal plants; however it also attracts additional investment in renewables, which then puts further pressure on the remaining coal plants, until the next one exits, and so forth.

Coal plant closure scenarios

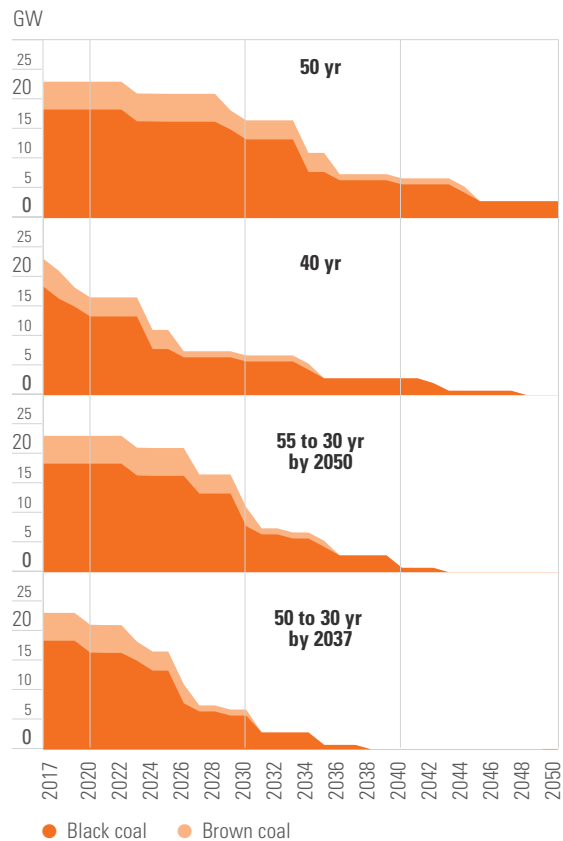
On the basis of these considerations we develop two scenarios for coal plant exit, which underlie the scenarios for coal use further below.

The top two panels in **Figure 10** illustrate the retirement pathways associated with a fixed 50 year and 40 year retirement age for the remaining coal fleet. The ten-year difference between the two scenarios makes a dramatic difference for future domestic coal use in Australia, especially in the 2020s. Note that the average age of the past ten coal plant retirements in the NEM was 40 years. The bottom two panels represent our coal plant closure scenarios, recognising the mounting economic pressure on coal plants, even without climate policy and based on higher levels of renewables penetration and changing load profiles in the NEM.

In the first scenario, the age at which remaining coal plants retire starts at 55 years in 2017 and falls gradually to 30 years by 2050. This scenario sees one major retirement (Liddell, approximately in line with the owner's announcement of intended closure) in the first half of the 2020s, and a rapid reduction in the second half of the 2020s, to less than half the existing capacity by 2030. All but one of the remaining plants would retire during the 2030s.

In the second scenario, the retirement age starts at 50 years in 2017 and falls to 30 years by 2037, proxying a situation where the deterioration of the economics of coal plants plays out more rapidly. Coal plant capacity is then reduced to less than one third of the present level before 2030, and by 2035 only one plant remains. Even more rapid closure scenarios are plausible if the cost of renewables including incremental cost for firming

Figure 10. Brown and black coal capacity remaining with different age based coal retirement trajectories



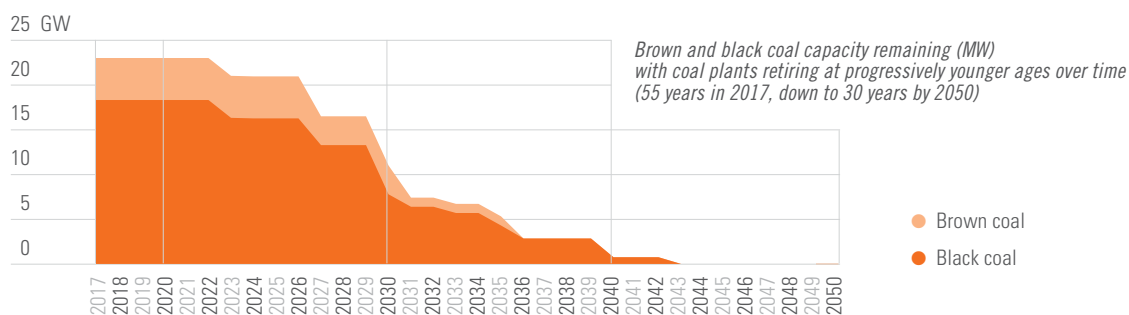
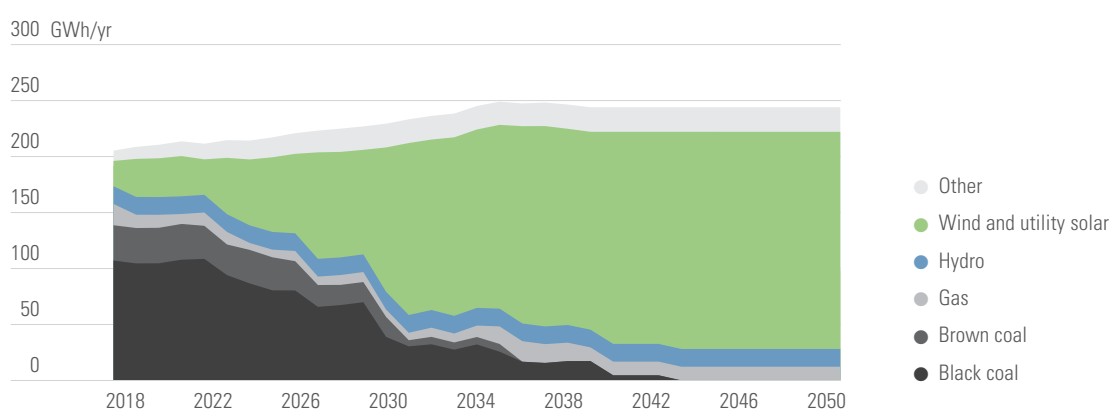
intermittent sources falls to levels that are consistently below the cost of operating coal power plants, including relatively young plants that are far from the end of their technical lifetimes. Such scenarios do not seem far fetched, however we do not present them here, instead opting for relatively conservative assumptions.

This section should present and describe national transition scenarios for coal developed by the individual country teams.

3.2. Quantitative Coal Scenarios

Moderate coal transition scenario (NDC compatible) and implications for coal

As a starting point for our moderate scenario we take a retirement age of 55 years. This is conservative and reflects current policy settings in the Australian electricity sector. It represents an assumed current retirement age that exceeds by 15 years the average historic retirement age of 40 years for the ten coal plants that exited the

Figure 11. Moderate scenario: Coal fired capacity in the Australian National Electricity Market**Figure 12. Electricity generation in the Moderate Scenario by generation type**

Note: We do not attempt to estimate the mix of wind and solar generation in this scenario which is focussed on coal transition. Renewables other than wind and solar may become commercial over the modelling horizon, and as such, the generation labelled wind and utility solar should be interpreted as a proxy for future renewables. "Other" includes rooftop solar PV.

Source: Crawford School of Public Policy, ANU.

NEM so far. It also exceeds by 5 years the retirement age for existing coal plants assumed by AEMO in its Integrated System Plan (AEMO 2018).

Recognising the mounting economic pressure on coal plants as described above, the retirement age is progressively brought forward such that it reaches 40 years by 2037 and 30 years by 2050 (Figure 11).

To approximate the expected electricity generation in the National Electricity Market for this retirement profile, we use published capacity and generation numbers from AEMO's ISP (AEMO 2018) and pro rate generation, assuming the same capacity factors for black and brown coal generation as in the ISP 'Fast Scenario' (which has the same retirement profile as AEMO's neutral scenario but the renewables generation figures are more aggressive and therefore closer to ours).

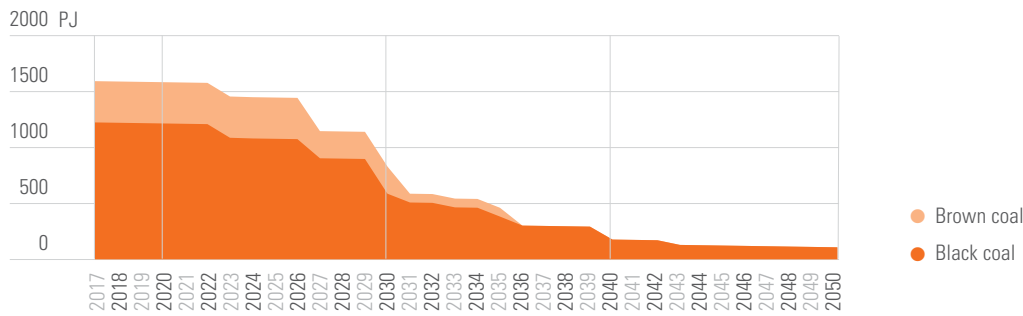
Our Moderate Scenario retirement profile lags the ISP scenarios by 5 years initially but then retires plants progressively earlier from 2024 onwards. This results in excess coal based generation in our Moderate Scenario

compared to the ISP scenario in the early years and an output shortfall in later years. The differences are made up entirely from solar and wind (we do not differentiate between different types of non-hydro renewable power in the scenarios).

For the period to 2050 following the end of the ISPs modelling horizon in 2040, we use flat demand and hold the relative output of different technologies constant as was done in the Jacobs modelling for the Finkel Review (Jacobs 2017).

To convert coal plant output, our estimations use heat rate data for the power stations in the NEM, average capacity factors across coal plants (distinguishing only black and brown coal) and simplified assumptions for coal use in power plants in Western Australia, and they also include coal burned in coke ovens.² This pro-

² Using the heat rates reported in the AEMO (2018) ISP for the remaining coal plants by year (with capacity factors implied by the ISP 2018-19 average) provides an estimate of coal use for power generation in the NEM. The retirement profile of the remaining

Figure 13. Australian thermal coal consumption, Moderate Scenario

vides a more reliable as a basis for comparing changes through time than it does an approximation for absolute numbers.

In our Moderate Scenario, overall thermal coal demand in Australia is projected to remain stable to 2023, after which it is projected to decline as the existing ageing coal fleet is progressively retired. Sharp falls in thermal coal demand are projected for the late 2020s and early 2030s, as a number of coal plants retire in quick succession with no coal plant remaining after 2042 (**Figure 13**).

Faster coal transition scenario (2 degree compatible) and implications for coal

We use the same methodology for the Faster Scenario as described above for the Moderate Scenario except that coal capacity is retired earlier (starting with a retirement age of 50 years in 2017) and the retirement age is shortened faster so that plants retire at 30 years of age by 2037.

At the start of the projection period, this exceeds by 10 years the average historic retirement age of 40 years for the ten coal plants that exited the NEM so far. The 50-year lifetime assumption is consistent with the retirement age for existing coal plants assumed by AEMO in its Integrated System Plan (AEMO 2018).

Such a scenario may eventuate if the economics of renewables continue to develop on existing trajectories, making it increasingly difficult for investors to justify

refurbishments and for inflexible coal plants to compete. Drastically shortened lifetimes for coal fired power stations could occur especially if and when firmed energy from newly built renewable sources becomes cheaper than the operating cost of coal based generation, as discussed above. Coal exit could then occur potentially more rapidly than in our Faster Scenario.

Possible future carbon policy implemented in the electricity sector could accelerate the transition in combination with underlying factors.

Figure 14 depicts the remaining coal capacity in the Australian National Energy Market under the Faster Scenario.

To approximate the expected electricity generation in the National Electricity Market for this retirement profile, we use published capacity and generation numbers from AEMO's ISP (AEMO 2018) and pro rate generation, assuming the same capacity factors for black and brown coal generation as in the ISP 'Fast Scenario' (which has the same retirement profile as AEMO's neutral scenario but the renewables generation figures are more aggressive and therefore closer to ours).³

Our Faster Scenario retires coal plants progressively faster than the ISP scenarios. The resulting output gap is

three coal plants in Western Australia has not been analysed separately and, for the thermal coal use estimates provided below, we assume they follow the same profile as those projected for the NEM. We also add coal burned in coke ovens and coal demand for final use in industry to our aggregate demand projection for thermal coal use in Australia to 2050. According the OCE 2017 (office of the Chief Economist, Australian Energy Outlook 2017) coal use in coke ovens amounted to 110.6 PJ in 2015-16 and 103.7 PJ for final use in industry. We have not undertaken a detailed analysis of expected future coal use in these sectors and have assumed a progressive halving of demand over the period to 2050.

³ Using the heat rates reported in EAMO 2018 (ISP) for the remaining coal plants by year (with capacity factors implied by the ISP 2018-19 average) provides an estimate of coal use for power generation in the NEM. The retirement profile of the remaining three coal plants in Western Australia has not been analysed separately and, for the thermal coal use estimates provided below, we assume they follow the same profile as those projected for the NEM. We also add coal burned in coke ovens and coal demand for final use in industry to our aggregate demand projection for thermal coal use in Australia to 2050. According the OCE 2017 (office of the Chief Economist, Australian Energy Outlook 2017) coal use in coke ovens amounted to 110.6 PJ in 2015-16 and 103.7 PJ for final use in industry. We have not undertaken a detailed analysis of expected future coal use in these sectors and have assumed a progressive decline to a quarter of the initial demand value over the period to 2050 (as distinct from halving under the Moderate Scenario).

Figure 14. Faster Scenario: Coal fired capacity in the Australian National Electricity Market

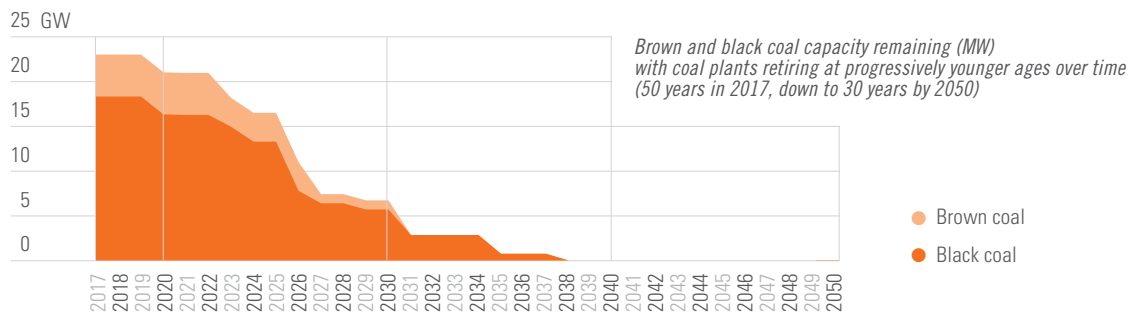
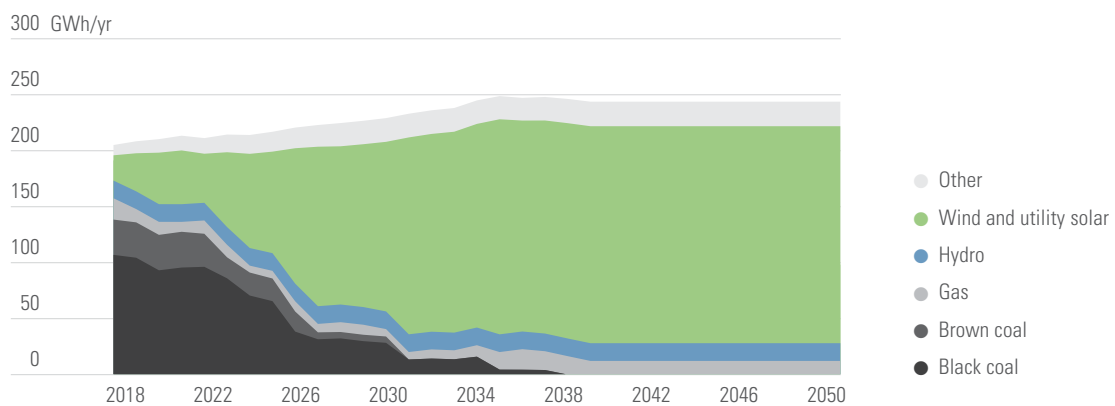


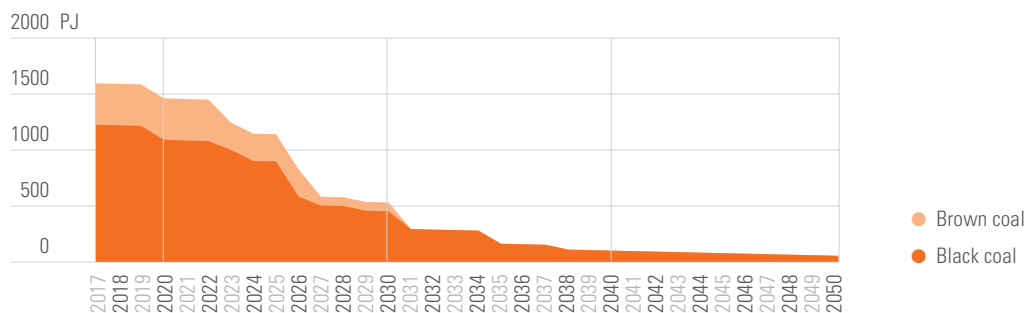
Figure 15. Electricity generation in the Fast Scenario by generation type



Note: We do not attempt to estimate the mix of wind and solar generation in this scenario which is focussed on coal transition. Renewables other than wind and solar may become commercial over the modelling horizon, and as such, the generation labelled wind and utility solar should be interpreted as a proxy for future renewables. "Other" includes rooftop solar PV.

Source: Crawford School of Public Policy, ANU.

Figure 16. Australian thermal coal consumption (PJ), Faster Scenario



assumed to be made up entirely from renewables. We use utility solar and wind as proxies for the renewables that are likely to replace coal based generation.⁴

⁴ Noting that even less than a decade ago, most electricity market models were still expecting that carbon capture and storage as well as geothermal were going to provide the bulk of emissions reduction opportunities in the Australian electricity sector. As such, it may well be the case that other technologies may emerge and turn out cheaper than utility solar and wind.

For the period to 2050 following the end of the ISPs modelling horizon in 2040, we use flat demand and hold the relative output of different technologies constant as was done in the Jacobs modelling for the Finkel Review (Jacobs 2017).

Thus, in our Fast Scenario, overall thermal coal demand in Australia declines from 2019 as the existing ageing coal fleet is progressively retired. Sharp falls in thermal

coal demand occur throughout the 2020s as coal plants retire in quick succession, with no coal plant remaining after 2037. Remaining coal use after 2037 in this scenarios is from coke ovens and some final use in industry.

Summary of results

In summary, the two scenarios for coal use in Australia show the following. The “moderate” scenario has coal power plant capacity and coal use declining rapidly through the 2020s and 2030s. Coal use would be less than half the present level by 2030, and decline by over 90% by 2040. This scenario is based on average plan lifetimes gradually declining as renewables become still cheaper than they already are.

The “faster” scenario has plant lifetimes diminishing more quickly, with coal use reduced by around 30% compared to today by 2025, reduced by two thirds by 2030, and falling to very low levels during the 2030s.

Table 3. Selected data from scenarios

Coal capacity remaining, GW					
	2020	2025	2030	2040	2050
Moderate	23113	21050	11050	750	0
Faster	21,113	16,570	6,740	0	0
Coal generation (NEM), % of total					
	2020	2025	2030	2040	2050
Moderate	65%	48%	15%	2%	0%
Faster	60%	26%	6%	0%	0%
Thermal coal demand, PJ					
	2020	2025	2030	2040	2050
Moderate	1659	1355	747	142	53
Faster	1,470	1,059	454	43	0
Emissions from coal use, MtCO ₂					
	2020	2025	2030	2040	2050
Moderate	176	162	95	18	10
Faster	163	128	59	10	5

Figure 17. Australian coal demand, Moderate Scenario and Faster Scenario

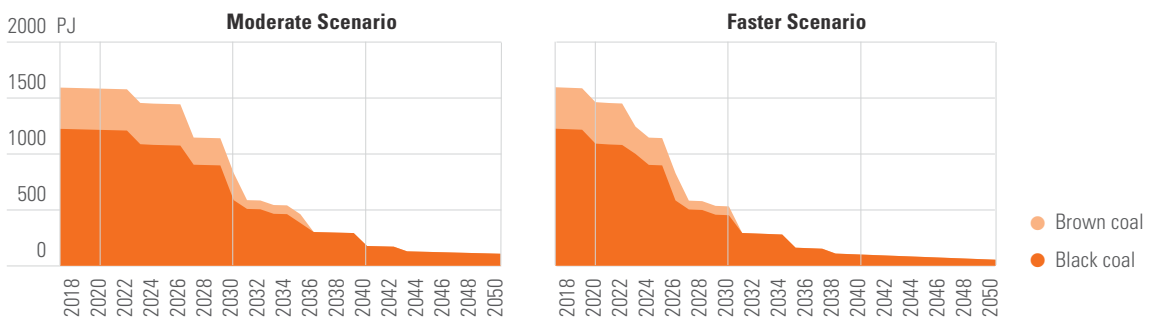
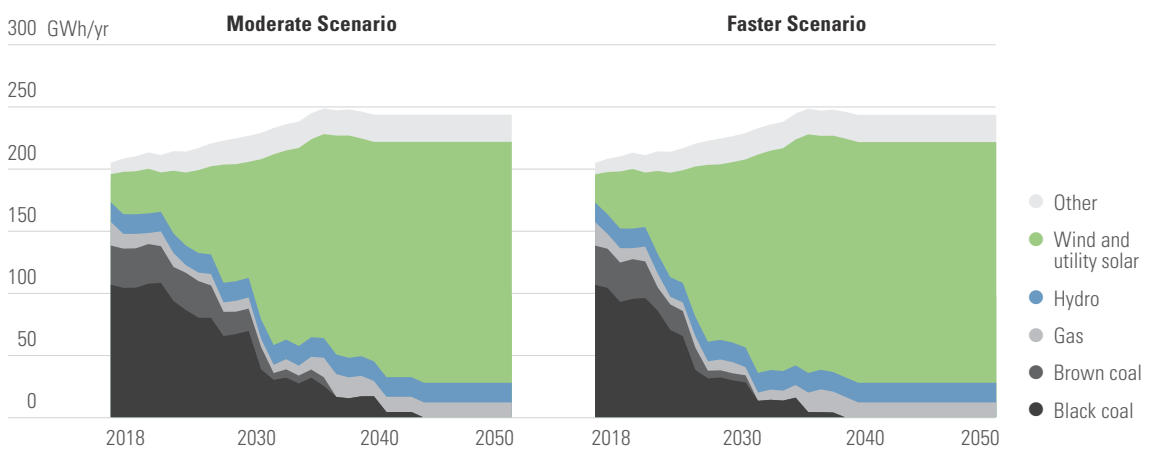


Figure 18. Generation (NEM), MWh, Moderate Scenario and Faster Scenario



These scenarios also allow an illustrative comparison of cumulative emissions outcomes. In the “moderate” scenario, cumulative emissions from coal use are around 2.6 GtCO₂ during 2020-2050, and in the “faster” scenario around 1.8 GtCO₂. This compares to cumulative emissions of around GtCO₂ from coal use in a hypothetical scenario where coal plants shut after 50 years of operation (with no reduction in capacity factors over time). As outlined earlier, the “moderate” scenario is broadly compatible with the 2030 emissions target as per Australia’s NDC to the Paris Agreement. The “faster” scenario would be compatible with a stronger national 2030 emissions target, in line with the global objective to ratchet up national contributions towards the global “two degrees or less” goal.

To what extent these cumulative emissions outcomes are compatible with long-term goals of climate policy such as the global “two degrees or less” goal depends on many factors, including judgements about what emissions budgets should be attributed to each country, and how much of the ‘allowable’ emissions will come from which sectors and sources. As a reference point, the “2 degree compatible” emissions budget for Australia proposed by Australia’s Climate Change Authority (2014) has a total national emissions budget of around 5.8 GtCO₂ from 2020-2050. The “moderate” scenario would have coal emissions take up around 44% of that cumulative emissions budget, while the “faster” scenario takes up around 32% of this 2020-2050 emissions budget. By comparison, coal currently makes up around 30% of Australia’s annual net emissions.

3.3. Policy dimensions of coal transition in Australia’s electricity sector

Achieving Australia’s NDC 2030 target and deeper reductions

Australia’s NDC target of a 26-28% reduction in national emissions will require large reductions in emissions from the power sector, if national emissions goals are to be achieved cost-effectively and without large scale use of international emissions units.

Our Moderate Scenario is broadly compatible with a 26-28% reduction in the energy sector overall, as discussed above. It in turn may be seen as compatible with the national emissions target, depending on assumptions about emissions trajectories in agriculture,

land-use change and forestry and industrial process emissions.

Sources other than electricity (where the majority of steam coal is used) account for two thirds of Australia’s greenhouse gas emissions, so the compatibility of a particular scenario for coal use with any given national emissions target depends heavily on developments in other sectors.

The Faster Scenario would achieve deeper reductions in electricity sector emissions earlier. Whether the Faster Scenario can be considered compatible with a two-degree scenario depends on assumptions about trajectories in other sectors, and on assumptions about national emissions budget for Australia is compatible with a global two degree scenario (eg Climate Change Authority 2014). The analysis provided here by contrast is only on coal use.

Roles for policy

A trajectory for coal fired power as in the Moderate Scenario may come about primarily as a result of commercially driven renewables investment, pushing coal fired power plants progressively from the system. Policies aimed at cutting emissions - whether at the federal or state level - may play an enhancing role. A trajectory such as in the Faster Scenario may also come about primarily as a result of market forces, however it would be more likely to occur with a sustained policy effort. A key task for future governments is to put in place stable policy settings. In a heavily partisan political environment on energy and climate policy, a carbon price was introduced and subsequently abolished, there were various failed attempts to introduce a carbon pricing signal into the electricity supply sector, the target for a renewable energy portfolio standard was changed along the way, and there is continued uncertainty over regulatory settings for the electricity market.

The resulting policy uncertainty has for a long time been suppressed investment in Australia’s energy sector. If a stable policy framework can be established for the energy sector, including for carbon dioxide emissions, then this in by itself should unlock investment and thereby accelerate the transition from coal.

A second potential role for policy is to provide greater predictability of the exit of coal fired power stations, and to ease the economic and social transition in affected communities (see following section). There currently are no provisions to encourage or mandate a

specific timetable for the closure of coal plants, leading to relatively sudden closures. As a result, replacement investments tend to come on stream only well after the closure of power plants, leading to higher prices and possible disruptions in electricity markets.

A third role for policy is to ensure that energy market settings and regulations are designed to facilitate investments in electricity generating assets and infrastructure that are necessary for the efficient and reliable operation of the system as it transitions from coal to renewable power. This includes investments in energy storage and equipment that provides grid services such as frequency control, as well as new transmission lines and infrastructure for effective integration of decentralized energy resources at the electricity distribution level (such as

business and household level solar PV, batteries and demand response). Some of these functions may require the establishment of new markets, or direct investments by governments.

Fundamentally, policy must not stand in the way of the transition that is underway. The coal industry represents large and concentrated economic interests, which when combined with the interests of local communities in coal regions can amount to a formidable force in favour of the status quo. There is a risk that policy designed to protect existing industrial structures could unnecessarily delay the transition and lock in high emitting installations for longer. In this light, the first prerequisite for effective coal transition is for policy not to get into the way of the transition that is already underway.

4. Case study: the closure of the Hazelwood power plant, employment impacts and policy responses

The single most consequential event pertaining to coal transition in Australia in recent years was the closure of the Hazelwood power station, Australia's largest power plant by capacity. It was a brown coal (lignite) fuelled plant in the Latrobe Valley, east of Melbourne. It closed in March 2017 after over 50 years of operation.

This section describes and analyses key aspects of that closure and policy responses to it, drawing directly on Wiseman *et al.*, (2017). It also summarizes findings from an econometric analysis about the regional employment effects of coal plant closures in Australia (Burke *et al.*, 2018). Implications for future coal transition policy in Australia are derived, including for closure of other major power stations that are to come.

4.1. The Hazelwood power plant closure⁵

The Hazelwood power station was one of Australia's largest at 1,600 MW capacity and supplied around 5% of Australia's electricity output before its closure in March 2017. It was Australia's most carbon intensive (and among the world's most carbon intensive) power station at typically over 1.5kgCO₂ per Kwh, and the oldest in operation at the time of closure. Its closure was feared to bring significant adverse social and economic effects in the local area, and was met with a large state government assistance program as well as efforts by the operators and communities to mitigate the impacts.

4.2. Coal fired power generation in the Latrobe Valley

The Latrobe Valley is in the state of Victoria, approximately 150 kilometres east of the state capital, Melbourne, in a region called Gippsland. The Latrobe Valley

is approximately 1,422 km² in size, and includes Latrobe City, one of the four major regional centres in Victoria with a population of approximately 74,000, and four major towns. The Latrobe Valley is situated on one of the world's largest brown coal reserves (Geoscience Australia, 2016). The Latrobe Valley coal reserves primarily consist of lignite, the most carbon intensive type of coal. The Valley's lignite reserves, which are mined from three open-cut mines (Yallourn, Hazelwood and Loy Yang), are used almost entirely for electricity generation for domestic use, with the Latrobe Valley supplying approximately 90% of Victoria's electricity needs.

Excavation of the Morwell Open Cut Mine (later Hazelwood mine) began in 1955. Coal from the mine was initially supplied to Yallourn power station, until Hazelwood power station was commissioned. Hazelwood's eight generating units became operational between 1964 and 1971. When it began operation, it was the SECV's intention that Hazelwood Power Station would operate for approximately 30 years.

4.3. Privatisation

During the 1980s and 1990s, Australia transitioned from a highly protected to a relatively open economy, with Coalition and Labour governments at both state and national levels committed to tariff reduction, corporatisation, privatisation and other microeconomic reforms. In 1996, the Victorian government sold Hazelwood Power Corporation for \$2.35 billion, to Hazelwood Power Partnership — a private consortium led by the British firm National Power — which took over the operations of the Morwell Open Cut mine and Hazelwood Power Station. Several changes in branding and share ownership of Hazelwood Power Partnership occurred since privatisation, with the majority owners since 2012 being French multinational Engie (formerly GDF Suez) holding a 72% share, and Japanese multinational Mitsui the remaining 28%.

⁵ Most of the text in this section is taken from Wiseman *et al.*, (2017). The original paper provides far more detail and full referencing. Information provided was current as of November 2017. All monetary amounts are in Australian dollars.

Privatisation led to a reduction in direct employment, and an increase in the proportion of contract work. Many younger workers left, leading to a sharp reduction in local house values. By the end of the privatisation process, approximately 8,000 workers had lost their jobs and the Valley had become the most disadvantaged region in Victoria, with full-time employment in the region falling by 9% between 1994 and 2001 and a large increase in outward migration from the region.

The privatisation process of the 1990s was followed by the development of an extensive series of government plans aiming to re-position the Valley and decrease regional dependence on the electricity and resources sectors. However, these initiatives have had limited success and the regional economy has remained dominated by the electricity generation sector.

4.4. Carbon pricing

The Latrobe Valley's economic dependence on emissions-intensive coal mining and power generation industries makes the region particularly vulnerable to the adoption of greenhouse gas emissions reduction policies. The Latrobe Valley was identified in the Garnaut (2008) National Climate Change Review as the region that would be most acutely affected by the adoption of a price on carbon.

A carbon price was in place during 2012-14. This resulted in short-run marginal costs of brown coal power plants to rise, in many cases above those of less emissions intensive black coal power plants and gas plants. As a result, capacity utilisation in the Latrobe stations including Hazelwood was reduced. However no plants were closed during that period, probably because of a widespread expectation that the carbon pricing scheme would not last (it was in fact repealed two years after it came into effect, following a change in federal government).

There were however expectations that the carbon price would result in plant closures, and community attitudes to this instrument of climate policy were generally negative in the Latrobe Valley. There were expectations that the local areas would benefit from part of a \$200 million "regional structural adjustment fund, raising hopes among the few groups in the Valley that remained committed to regional diversification away from coal and had sought government assistance for projects in that vein. However, only \$15 million was made available for regional diversification projects.

4.5. Events leading up to closure

In February 2014, the Hazelwood coal mine caught fire as a result of embers from nearby bushfires. The mine fire burnt for 45 days and covered the nearby town of Morwell with acrid smoke and ash before emergency services were able to extinguish it. Subsequent inquiries found that significant adverse health effects ensued. Inquiries also found that the operator of the mine was ill-prepared for the fire, had insufficiently identified risks to Morwell and the surrounding community and had failed to adopt adequate risk control measures.

In April 2016, the Victorian government announced an increase in coal royalties from 7.6 cents to 22.8 cents per gigajoule of energy. This brought the Victorian coal royalty rate (which had not been increased in ten years) into line with coal royalty rates in other Australian coal producing states.

In May 2016, the global CEO of Engie reported to a French Senate committee that it was assessing a number of possible actions regarding Hazelwood, including sale and closure of the mine. This statement increased speculation regarding an anticipated closure, but this was contradicted by the company and by the Australian government. However, on 3 November 2016, Engie announced that it had indeed decided to close the power station permanently on 31 March, 2017, leaving only 5 months to closure.

Engie consistently emphasised that the decision to close Hazelwood was made on a purely commercial basis noting, in particular, the increasingly large costs required to ensure continued safe and viable operation (Engie, 2016). Given the age of the Hazelwood power station, Victoria's work safety body required upgrades and repairs to 5 of its 8 boilers in order to meet health and safety standards, at a cost estimated by Engie of \$400 million. The response from Engie management included the view that "given current and forecast market conditions, that level of investment cannot be justified".

The Hazelwood power station stopped producing electricity on 29 March, 2017. Engie has estimated that the cost of rehabilitation of the site will be \$439 million for the mine site and \$304 million for the power station—and that it would take one year to decommission, three years to demolish, and 30 years until the site is returned to the Victorian government. Engie also announced that up to 250 workers would remain working at the power station and mine to rehabilitate the sites between 2017 and 2023, involving 130 Engie employees and 110-130 contractors in 2017-18.

4.6. Responses from state and federal governments

On the day of the closure announcement, the Federal Government announced it would provide a \$43 million package to assist workers affected by Hazelwood's closure. This included \$20 million to support local infrastructure, a \$3 million labour market structural adjustment package — including re-training, active job-seeking assistance and other support — and \$20 million as part of a *Regional Jobs and Investment Package*, focused on local job creation, diversifying the regional economy and building a highly-skilled workforce via projects determined by community input.

The Victorian Labor Government responded to the Hazelwood closure by announcing the largest regional assistance package in Victoria's history. The Victorian Government announced \$22 million in assistance for workers in the Latrobe Valley region and the establishment of the Latrobe Valley Authority to lead work on economic transition strategies. This was followed by the announcement of an additional \$224 million of funding aimed at promoting economic growth, business investment and job creation in the wider Valley community, bringing the Victorian Government's total support package to \$266 million.

Subsequently, the Victorian Government announced additional funding for a range of infrastructure-related projects in the region aimed at meeting sustainability, social equity and community well-being objectives, as well as two additional schemes to support coal/electricity sector workers in the Valley who had lost their jobs.

4.7. Impact on key actors and stakeholders

This section outlines the positions and actions of some of the key stakeholders impacted by the Hazelwood closure. Drawing on the conceptual framework developed by Green (2017), we consider the stakeholders most affected by a structural change and therefore most likely to make "transition claims"—claims on state and government resources to avoid or reduce losses associated with a structural change—and/or be implicated in transition policy.

Workers and unions

The direct impact on the lives and livelihood of power station employees and their families is a highly signif-

icant outcome of the closure of a major power station such as Hazelwood. At the time of the closure announcement, Hazelwood directly employed 750 workers — 450 employees and 300 contractors, and in the 2016 financial year, Engie reported payments to employees of approximately \$36 million. The average tenure of Hazelwood workers was 25 years, with an average age of 52. The characteristics of the Hazelwood workforce present significant challenges for transitioning to well-paying jobs with similar standing, quality and location, given the older demographic and specific (and sometimes informal) skill sets. In addition to the obvious consequences for employment and financial security, the experience of redundancy typically also involves significant psychological and social impacts for workers and their families (Brand, 2015).

Support for a proactive and planned approach to climate change mitigation has been a longstanding and shared view of the trade union movement. The Australian Council of Trade Unions (ACTU) adopted a *Policy on the Greenhouse Effect* in 1991. The union most engaged in the coal sector is the Construction, Forestry, Mining & Energy Union (CFMEU), whose Mining & Energy Division (M&E) represents members who are overwhelmingly employed in the coalmining and power generation sectors. M&E has actively engaged in climate change policy developments since the early 1990s.

The CFMEU has been a long-time supporter of market-based climate mitigation policies and worked to educate its members about the importance of carbon pricing. During the political struggles over carbon pricing during ca 2008-13, this position created tensions between the Union's executive and many of its members employed in the Latrobe Valley's power stations. During this period, M&E's main strategy for securing the continued viability of coalmining and coal-fired power generation, including through carbon capture and storage. CCS is no longer seen as a viable option in Australia, given its high costs and ever lower costs of renewable power. M&E's position has shifted toward a "just transition" narrative, with a focus on ensuring that plant and mine closures occur in a planned manner and that initiatives are in place to support the redeployment and retraining of workers, along with wider regional investment and employment initiatives. The union movement's focus on a "just transition" narrative has also facilitated a more cooperative relationship with the environment movement.

Local communities

The closure of Hazelwood has also had significant impacts on the broader Latrobe Valley community — including on local labour markets, businesses, government and other community service providers. Negative impacts from the closure, in addition to the job losses noted above, are likely to include reduced business income as well as increased pressure on community service and health providers. On the other hand, the closure of Hazelwood is likely to have had some positive health outcomes resulting from the reduction in pollutants and improved air quality.

Levels of disadvantage within the Latrobe Valley region are often highlighted by the relatively high proportion of people receiving income security benefits and Healthcare cards. However, the individuals and families whose income is slightly above the eligibility threshold for Healthcare cards are also a particularly vulnerable — and often over-looked — part of the community who face significant employment and income challenges.

Latrobe City Council, the local government, has been active in identifying and exploring economic transition policy options. It published several policy documents which outlined a proactive approach to creating economic growth and transition to a low carbon economy, and identified a number of State and Federal Government funding priorities.

A number of regional community groups have been exploring options for alternative employment generating initiatives.

4.8. Explaining the Hazelwood closure and government responses

“Best practice” concerning the closure of mines and electricity generation plant advises long-term planning, long closure notice periods, and close collaboration between the closing companies, workers/unions, government and community stakeholders on the socio-economic dimension of the transition process, so that the costs of closure can be reduced and equitably shared. None of these recommendations was heeded in the period preceding Hazelwood’s closure, despite widespread calls by numerous community, environment, union and even business groups for similar forms of proactive government stewardship of the phase-out of coal-fired power generation and regional renewal in the Valley.

After the closure decision was announced, the federal

and state governments came forward with transition policy packages totalling \$43 and \$266 million, respectively. In this section, we offer a brief preliminary explanation of these outcomes.

An institutional approach to understanding government responses

The lack of institutional capacity to engage in “best practice” mine/plant closure can be seen as a function of the political system and political economy interactions. It is also a product of Australia’s basic political institutions, of which three sets are most pertinent to the present analysis.

First, Australia’s electoral system is majoritarian. State and federal governments are formed by the party with a majority of seats in the lower house of the relevant parliament, and the composition of lower houses is determined by preferential voting in single-member districts. These electoral institutions favour the two major parties — Labor and the Liberal-National coalition, which dominate the control of executive government at both federal and state levels. They also incentivise parties to spend a disproportionate amount of their resources (including policy attention when in government) on marginal electorates.

Second, Australia has a federal system comprising three levels of government, with authority largely divided between state and federal level. This leads to “vertical” competition and blame-shifting between state and federal governments. The degree of opportunistic competition and blame-shifting (or their opposites, cooperation and credit-taking), between state and federal level political parties depends on the specific combinations of parties that are in power at a given time, and the particular issue in question. But the potential exists for “diagonal” party competition to occur, when opposing parties are simultaneously in power at state and federal level.

States are predominantly responsible for the regulation of the energy and resources sectors (though the federal government is also heavily involved in both sectors). Both federal and state governments effectively have significant powers over climate change and regional development. As such, there is always potential for not only horizontal, but also vertical and diagonal party competition and blame-shifting.

Third, federal elections occur triennially (with a degree of flexibility), and Victorian state elections occur quadrennially at fixed intervals. While there are no term limits

at either level, Australian governments experience a significant amount of turnover (which is partly explained by the relatively non-politicised, independent process by which electoral boundaries are set).

Overall, these three sets of political institutions make it especially electorally costly for governments to commit to long-term policies that impose perceived costs in the short term (for which they are likely to be blamed) but promise benefits in the longer term (for which an opposing party or a higher/lower level of government may be able to take credit at the time the benefits are realised) — especially where the costs are concentrated on electorally powerful groups and the future benefits are diffuse, poorly understood and perceived to be subject to uncertainty as to whether they will materialise. By contrast, spending initiatives (e.g. regional development and renewable energy subsidies) tend to have more salient, near-term “winners” and to impose less salient and more diffuse costs, making them more popular and less politically risky. Moreover, Australia’s political institutions make it difficult for governments to enter into the kinds of stable, cooperative arrangements with both unions and firms at the sectoral level that conduce to long-term sectoral transition planning and technology-intensive incremental innovation.

4.9. Lessons from the Hazelwood case study

Having privatised its power generation sector in the 1990s, private (mostly multinational and foreign-owned) corporations owned the Latrobe Valley’s generation assets, including Hazelwood. Unsurprisingly, these private companies made their own decision about how to maximise their profits within the bounds set by existing laws and regulations. What does this imply about the potential for future coal plant closures in Australia to be managed in a more consultative, planned and orderly fashion?

One implication is that, absent institutional reform (discussed below), the most likely means by which plant closure could move closer toward best practice is through the operation of market pressures. For example, there is increasing interest globally among major institutional investors in using their influence as shareholders to push the managers of carbon-intensive energy companies to adopt “just transition” strategies as they decarbonise their asset portfolios. Governments can also provide reg-

ulation, incentives or a combination of both to ensure that coal plant closures occur in a predictable manner that achieves acceptable social and regional outcomes. A second implication of the analysis summarized here (and laid out in much greater detail in Wiseman *et al.*, 2017) is that institutional reforms will be necessary to alter the incentives companies face, unless and until private energy companies are pushed by their shareholders to adopt such “best practice” with regard to mine/plant closure and just transition strategies. Two broad institutional reform strategies appear to be theoretically possible: one focusing on background political-economic institutions; another on specific regulatory changes relevant to plant closure/transition.

Under the first of these approaches, governments could try to create new or alter existing institutions so as to increase the level of strategic coordination between energy firms, governments, unions and affected community stakeholders, effectively making governance in Australia’s energy sector more “corporatist”. The idea would be to facilitate better transition planning indirectly, by engineering deeper forms of interaction between stakeholders so as to improve information flows and build trust and cooperation over time. However, the prospect of a near-term corporatist turn in Australian energy/climate governance seems dim. Nevertheless, the history of structural renewal of old industrial regions elsewhere in the world, for example in Europe (Campbell and Coenen 2017) can provide valuable insights for Australian coal transition policy.

The second approach, involving the direct regulation of companies’ transition obligations, is more concordant with Australia’s political-economic institutions. Under this approach, state or (ideally) federal governments to strengthen existing laws/regulations governing the closure obligations of energy companies, or enact new laws to regulate closure. Companies already face legal obligations with respect to plant closure, decommissioning and rehabilitation. These could be strengthened, for example, with respect to closure notice periods, workforce transition planning, and stakeholder consultation processes. Alternatively, entirely new mechanisms could be introduced to provide incentives for an orderly phase out of emissions-intensive facilities such as coal-fired power generators. One possibility among many would be a market-based closure arrangement that leverages financial payments from plant owners that remain operational, as proposed by Jotzo and Mazouz (2015).

An overall observation is that in this difficult policy-making environment, an important variable is likely to be the agency of civil society actors in making the *politics* of energy/climate policymaking more conducive to just transition-oriented regulatory reforms. Our case study has demonstrated that the positions of key civil society stakeholders in Australia's energy debate, including unions, environment groups and to some extent business groups have been converging toward a just or at least orderly transition as a rhetorical heuristic for substantive policies to improve the transition arrangements in the Australian energy sector. As we have argued with respect to Victoria, this civil society action provided a rationale for, at least, some significant *ex-post* transition policy when political and electoral conditions were ripe, as they were following the Hazelwood closure announcement.

4.10. Do power station closures result in higher local unemployment rates? ⁶

At the centre of social and regional economic concerns about energy transition is the question whether and to what extent the closure of large plants results in lasting employment effects. Closures of coal-fired power stations are of particular interest because these stations are in some cases among the largest regional employers, with local economies tending to be centred on the activities of the station. All of Australia's coal-fired power stations are located in regional areas. Adaptive capacities tend to be more limited in these areas than in capital cities. In this section we summarize the findings from an econometric study that investigates regional employment effects of coal plant closures over the period 2010-2017 (Burke *et al.*, 2018).

Employment structures and change

Around 64,300 people were employed in Australia's electricity supply industry as of November 2017, according to official statistics. This was down from more than 80,000 in the mid-1980s. Most are employed at the transmission, distribution, and retail levels rather than in electricity generation. Around 94% have full-time jobs. Almost three-quarters are male. From a macro perspec-

tive, the number of people working in electricity supply is relatively small, accounting for only 0.5% of the total number of employed people nationwide. The number of people working in electricity supply is less than the annual flow of involuntary retrenchments across the national economy (around 355,000 in the year to February 2013) or the annual total flow from employment to unemployment. Across Australia, another 51,500 people were employed in coal mining as of November 2017. Many of these work in supplying coal for export.

Australia's seasonally-adjusted unemployment rate was 5.5% in December 2017. Australia's labour force participation rate was 65.7%. National unemployment figures hide substantial variation among SA4 regions. The average unemployment rate during the year to December 2017 ranged from 2.2% in Sydney's Eastern Suburbs to 12.2% in the Queensland Outback. There are sizeable fluctuations in regional unemployment rates over time.

Structural change is a persistent feature of Australia's economy. Services now account for around 88% of employment (based on individuals' main job), up from less than 55% in 1900. Manufacturing now employs 17% fewer people than in the mid-1980s. To date, job losses in sunset occupations have been more than offset by new jobs.

Coal power plant employment

From a national perspective, a transition from coal-fired electricity generation does not necessarily involve fewer jobs in electricity generation, in the short run at least. This is because installation of solar and wind generation capacity is a relatively labour-intensive process, with more people now working in installing and maintaining solar panels than in coal-fired power stations. While relatively few people are employed by operating solar and wind farms, it is also important to note that new coal-fired generators would also not be large employers (on account of increasing automation).

In addition to direct job losses from the closure of a coal-fired power station, indirect job losses might also be expected. These are particularly likely for jobs located earlier in the supply chain, such as at local coal mines. There might also be job losses in industries supplying other locally-consumed goods and services. The local construction industry may face reduced demand, for example, which would flow through to fewer construction jobs.

⁶ This section uses selected text from Burke *et al.*, 2018. The original paper provides much more detail and full referencing.

While workers in coal-fired power stations and local suppliers have skills that are transferable, new jobs are not always located near newly-closed coal-fired power stations. If there are limitations to geographical mobility, and if alternative employment is slow to eventuate, local unemployment might rise. Australia's best sites for solar power are not in the Latrobe Valley, for example, but in sunnier locations. On the other hand, new power-sector investments in the Latrobe Valley have the advantage of ready access to electricity transmission lines.

In addition to influencing the local unemployment rate, the closure of a large facility such as a coal-fired power station might have other local labour market implications. The participation rate might fall if those who lose their jobs opt for early retirement. It is possible, however, that spouses and other family members might be more likely to join the labour force after the retrenchment of a breadwinner, which would place upward pressure on the participation rate. The magnitudes of such effects are not well known.

Data and method

Burke *et al.*, (2018) use monthly panel data at the regional level to examine the local labour market implications of closures of Australia's coal-fired power stations. Focusing on the period 2010–2017, the paper tests if higher local unemployment has been observable subsequent to the closures. The analysis controls for time-varying and time-invariant factors that might affect unemployment rates, including region fixed effects, state-specific month dummies, closures of plants in other key industries (vehicle manufacturing, nickel, aluminum, and steel), and the coal export price (for major coal-exporting regions).

The analysis uses Australian Bureau of Statistics monthly estimates of labour force status by labour market region. These are available for 87 Statistical Area Level 4 (SA4) regions. The labour force data are based on where people live, not where they work, with the regions being defined so that a high proportion of people live and work in the same region. This is easier to achieve outside capital cities. In regional areas, each SA4 region typically has a population of 100,000–300,000 people. In metropolitan areas, the typical population is 300,000–500,000. The ABS data come from a monthly survey of around 26,000 dwellings, stratified by region. The study uses a sample that commences in January 2010 and extends to December 2017, the dataset con-

sists of 8,352 observations (87 regions * 96 months). The econometric model estimated includes variables to control for key structural and time-specific factors affecting the unemployment rate in each region. This includes sets of region fixed effects and state-specific month dummies. Region fixed effects are included to control for unobserved factors that may cause persistent differences in regional unemployment rates across Australia. These may be correlated with the likelihood of having a coal-fired power station closure. Similar results are obtained using random effects. The vector of state-specific month dummies includes a separate dummy for each month of the estimation period, for each state. This is a powerful control set, allowing to net out effects of shocks to unemployment that are common across regions in any state in any month. The state-specific month dummies also serve to de-seasonalise the data. The estimation also controls for closures of other key employers: vehicle manufacturers, and nickel, aluminium, and steel processors. In coal-exporting regions the estimation controls for the coal export price, using the two-month lag. Detail about the data, estimation procedures, limitations and interpretations is provided in Burke *et al.*, (2018).

Average employment estimates

The analysis finds that regions with one or more recently-closed coal-fired power stations have on average seen an increase in their unemployment rate of around 0.7 percentage points, other factors held constant. This is predominantly due to increased unemployment among males. The analysis splits out unemployment effects for the first six months after closure; for the next six months; and for thereafter. Unemployment is higher in each period, with the largest effect in the second six-month period. The effect is unlikely to be permanent, but our study does not have an adequate time-series of post-closure data to explore long-run effects.

It is important to note that the finding of higher unemployment is for the average of all closures observed in Australia over the period 2010–17, and controlling for other factors. It does not hold for each individual case and region.

Latrobe Valley employment

Latrobe-Gippsland saw two coal-fired power station closures during our study period: Morwell power station (Energy Brix) in August 2014 and Hazelwood power

station in March 2017. Figure x shows that there was an uptick in the region's twelve-month average unemployment rate from 2015, and that it exceeded the state average by more than 2 percentage points in the second half of 2016. The Latrobe-Gippsland unemployment rate has been falling since the closure of the Hazelwood power station, although it remained above the state average as of the end of 2017.

There are a number of possible explanations for why the Latrobe-Gippsland unemployment rate did not rise further in the months after the Hazelwood closure. One is that some workers were retained for site decommissioning, as mentioned. Some others received transfers to nearby coal-fired power stations under a worker transfer scheme formed under cooperation between the state government, unions, and the companies involved, and which received a financial subsidy from the state government. Concern about the fate of Hazelwood workers also saw the state and federal governments commit a substantial sum of money for infrastructure and other local initiatives (see above). Former employees also

reportedly received an average separation payment of \$330,000 (including leave payouts), which may have resulted in increased local spending.

4.11. Implications for coal transition policy

Australia's coal fired power plant sector will see a number of large plants decommissioned over coming decades, and the capacity replaced with alternative technologies. This spells a need for a strategy and policy mechanisms to help with orderly transition and to achieve better outcomes for local communities.

As the Hazelwood closure case shows, recent practice has seen sudden and poorly anticipated closures, with government support coming in relatively late and in the form of substantial on-budget financial commitments. This has obvious drawbacks for the likely effectiveness of the measures, cost-effectiveness of public support, and ultimately the societal acceptance of assistance provided by the nation or States for transition in one particular sector for closures in specific localities.

5. Conclusion

Australia's coal sector faces major change over coming decades. Preparations should be made to enable an economically successful and socially acceptable transition away from coal.

Future export demand for thermal coal, which presently underpins a large industry in Australia, is highly uncertain. While export volumes have grown, the future holds rising cost competitiveness of renewables compared to coal, efforts to limit and reduce greenhouse gas emissions in most countries, and rising concern about local air pollution especially in the fast-growing regions of the industrializing and developing countries. All of these factors work against the expansion of coal use. Coal trade tends to be more volatile than consumption and production in importing countries, with coal trade a residual in countries including China and India; much depends on whether importing countries scale down or maintain domestic production if total coal demand reduces. For exporters, there is a clear prospect of falling coal export demand over time, and a risk of relatively sudden reductions in coal demand.

The outlook for Australia's domestic coal use is clearly for a phase-out of steaming coal from the electricity sector, where most of the domestic coal is used. Australia is blessed with a practically unlimited supply of renewable energy opportunities. Renewables are already cheaper than any coal power plant would be, and the economics of existing coal plants are under increasing pressure in an electricity market where renewables play a larger and larger role. Australia's coal fired power fleet is relatively old, and our analysis suggests that coal plant closures will occur rapidly through the 2020s and 2030s. Coal plant closures to date, including the closure of the large Hazelwood power plant in 2017, came suddenly and ahead of expected closure dates. There was very little preparation for communities where coal plants were located, and insufficient lead time for timely investment in new capacity.

Implications for policy can be derived. For exports, Australian governments should refrain from providing subsidies or other preferential treatment for coal mines and coal transport infrastructure. There is no strategic case

for investing public resources in the coal industry; to the contrary, there would be significant risks of wasting public funding and encouraging private sector investments in assets that could turn out to be less productive than anticipated or stranded altogether. Governments need to recognize the prospect that international coal demand will fall, and the risk that coal export demand could drop off rapidly, as a result of alternatives becoming cheaper and more desirable and of climate change policy in other countries. Roles for policy in this regard may include for support economic diversification in regions where coal is economically important.

For domestic coal use, mostly in electricity, governments should strive to put in place stable policy frameworks to help guide and facilitate the transition – and to avoid the pitfalls of policy designed to protect existing industrial structures that retain high emitting installations for longer than necessary.

Such a framework would include, firstly, a predictable policy treatment of carbon dioxide emissions that can link in with a possible future economy-wide emissions price signal. This has been a political stumbling block for over a decade but should remain on the medium to longer term policy agenda. An emissions price signal would enhance investment conditions in the electricity sector by reducing carbon policy uncertainty. Secondly, there is an important role for mechanisms to encourage predictable and orderly closure of coal fired power stations, to avoid the scenarios of sudden exit experienced to date. Part of coal exit policies should be provisions to help with regional economic transformation and diversification, and measures to achieve socially acceptable transition outcomes for local communities. Thirdly, the far-reaching technological shifts underway in the energy sector call for continued adjustments in the market and regulatory frameworks which in the electricity sector were built for a centralized, coal-dominated system. Evolution of regulation and market design will help facilitate the necessary investments – such as for energy storage, transmission and integration of decentralized energy resources – to achieve an efficient and reliable energy system in the transition from coal to renewables.

References

- Australian Energy Council (2016). Submission to the Parliamentary enquiry on Retirement of coal fired power stations, submission 44.
- AEMO (2018a), Integrated System Plan 2018, Australian Energy Market Operator.
- AEMO (2018b), Electricity Statement of Opportunities 2018, Australian Energy Market Operator.
- BNEF (2018), New Energy Outlook 2018, Bloomberg New Energy Finance.
- Burke, P., Best, R. and Jotzo, F. (2018), Closures of coal-fired power stations in Australia: Local unemployment effects, CCEP Working Paper 1809, September 2018. Crawford School of Public Policy, Australian National University.
- Campbell, S., Coenen, L. (2017), Transitioning beyond coal: Lessons from the structural renewal of Europe's old industrial regions, CCEP Working Paper 1709, November 2017. Crawford School of Public Policy, Australian National University.
- Campey, T., Bruce, S., Yankos, T., Hayward, J., Graham, P., Reedman, L., Brinsmead, T., Deverell, J. (2017) Low Emissions Technology Roadmap. CSIRO, Australia. Report No. EP167885
- Climate Change Authority (2014), Reducing Australia's greenhouse gas emissions - targets and progress review. Final report.
- Cox, L. (2015a), Abbott government hints Adani could be considered for rail funding, Sydney Morning Herald.
- Cox, L. (2015b), Queensland Labor backs Adani's Carmichael coal project, Sydney Morning Herald.
- Energy Security Board (ESB) 2018, Final Detailed Design of the National Energy Guarantee, August 2018.
- Engie (2016), Hazelwood to close in March 2017 – Media Release. 3 November.
- Environment Victoria (2018), Ensuring the National Energy Guarantee can unlock renewable energy ambition, June.
- Finkel, A. (2017), Independent Review into the Future Security of the National Electricity Market, final report, June.
- Garnaut, R. (2008), Garnaut Climate Change Review, Cambridge University Press.
- Geosciences Australia (2016), Australia's Identified Mineral Resources.
- Green, F. (2018), Transition policy for climate change mitigation: who, what, why and how, CCEP Working Paper 1807, July 2018. Crawford School of Public Policy, The Australian National University.
- Green Energy Markets (2018), Renewable Energy Index May 2018.
- IEA (2016), Coal Statistics, International Energy Agency.
- IRENA (2018), Renewable Power Generation Costs in 2017, International Renewable Energy Agency, Abu Dhabi.
- Jacobs (2017), Emissions mitigation policies and security of electricity supply: Report to the Independent Review into the Future Security of the National Electricity Market.
- Jotzo, Frank (2012), Australia's carbon price. Nature Climate Change.
- Jotzo, F. and Mazouz, S. (2015), Brown coal exit: a market mechanism for regulated closure of highly emissions intensive power stations. *Economic Analysis and Policy* 48: 71-81.
- OCE (2016), Australian Energy Update 2016. Office of the Chief Economist, Department of Environment and Energy, Canberra.
- OCE (2017), Resource and Energy Quarterly, various issues. Office of the Chief Economist, Department of Environment and Energy, Canberra.
- OCE (2018), Resource and Energy Quarterly, June 2018. Office of the Chief Economist, Department of Environment and Energy, Canberra
- Parkinson, G. (2018), upta: ACCC underwriting idea may help slash solar costs to \$20s/MWh, RenewEconomy 16 August 2018.
- Queensland Government (2014), Carmichael Coal Mine and Rail Project, Department of State Development, Manufacturing, Infrastructure and Planning.
- Seel, J., Mills, A.D. and Wiser, R.H (2018), Impacts of High Variable Renewable Energy Futures on Wholesale Electricity Prices, and on Electric-Sector Decision Making. LNBL, Berkeley.
- Times of India (2015), Three French banks refuse to fund Adani project in Australia.
- USDoE (2018), 2017 Wind Technologies Market Report, US Department of Energy.
- Vorrath, S. and Parkinson, G. (2018), Australia solar costs hit "extraordinary" new lows – \$50s/MWh, RenewEconomy, 27 June 2018.
- Wiseman, J., Campbell, S. & Green, F. (2017), Prospects for a "just transition" away from coal-fired power generation in Australia: Learning from the closure of the Hazelwood Power Station, CCEP Working Paper 1708, November 2017. Crawford School of Public Policy, Australian National University.

COAL TRANSITIONS: RESEARCH AND DIALOGUE ON THE FUTURE OF COAL

COAL TRANSITIONS is a large-scale research project led by Climate Strategies and The Institute for Sustainable Development and International Relations (IDDRI) and funded by the KR Foundation.

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