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Submission to Commonwealth of Australia, Senate Environment and Communications References Committee inquiry:

Retirement of coal fired power stations

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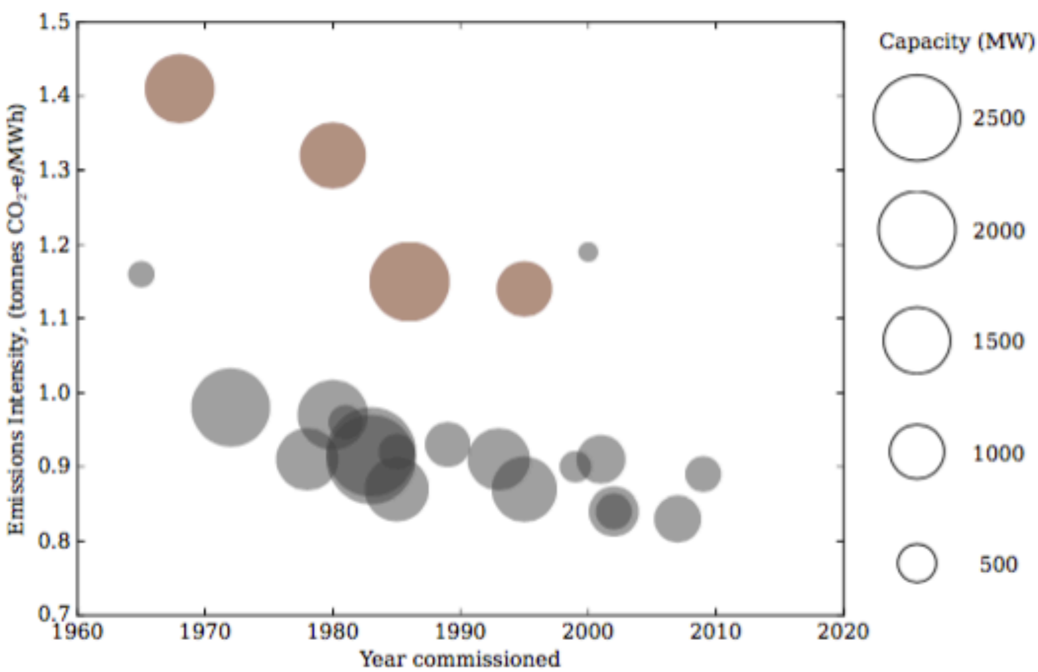

Submission to:
Commonwealth of Australia, Senate Environment and Communications References Committee inquiry on:

Retirement of coal fired power stations

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1 Introduction

I welcome the opportunity to provide a submission to Senate inquiry into the *Retirement of coal fired power stations*. This submission draws on analysis and research into the evolution of the Australian National Electricity market and the nascent transition to a de-carbonised electricity sector.

This submission focuses on elements from Section C of the terms of reference. In particular, this includes comment on:

- the 'Paris Agreement' to keep global warming below 2 degrees Celsius, and ideally below 1.5 degrees Celsius,
- the state and expected life span of Australia's coal fired power power plants
- the increasing amount of electricity generated by renewable energy and likely future electricity demand,
- maintenance of electricity supply, affordability and security

This submission also draws on a recent report I co-authored, *'Winds of change: An analysis of recent changes in the South Australian electricity market'*[1]. This report analysed some of the dynamics in the South Australian region of the National Electricity Market (NEM) following the withdrawal of the states two coal fired power stations, and contains insights and lessons that can be learnt by other jurisdictions other Australian jurisdictions on their pathway to decarbonisation. This report is included with the submission.

I would be more than happy to give any further details or evidence at a public hearing, should that be of interest to the Committee.

[1]McConnell and Sandiford, *Winds of change: An analysis of recent changes in the South Australian electricity market*.

2 De-carbonisation commitments

In December 2015, a historic global climate agreement was agreed under the United Nations Framework Convention on Climate Change at the 21st Conference of the Parties in Paris. This agreement included a global goal to hold average temperature increase to well below 2°C and pursue efforts to keep warming below 1.5°C above pre-industrial levels. This 'Paris Agreement' entered into force on the 4th November 2016, after the required ratification conditions were met. On November the 10th, the Federal Government reaffirmed Australia's strong commitment to effective global action on climate change with the ratification of the Paris Agreement[2].

In order to meet the objectives of Paris Agreement, analysis from the International Panel on Climate Change (IPCC) illustrate *'large-scale global changes in the energy supply sector (robust evidence, high agreement)'*[3]. In scenarios where the 2°C objective is achieved, emissions from the energy supply sector are projected to decline by 90% or more below 2010 levels between 2040 and 2070 on global level. Emissions in many of these scenarios are projected to decline to below zero from them onwards.

Figure 1 illustrates the direct emissions of CO_2 by sector in mitigation scenarios that maintain emissions consistent with a 2°C pathway. In both scenarios that include Carbon Capture and Storage (CCS) and scenarios that don't, direct emissions from the electricity sector fall to practically zero by 2050. According to the International Energy Agency (IEA), the average CO_2 intensity of electricity in OECD countries to meet this needs to fall from 0.411 t/MWh in 2015 to 0.015 t/MWh by 2050 to achieve the goal[4].

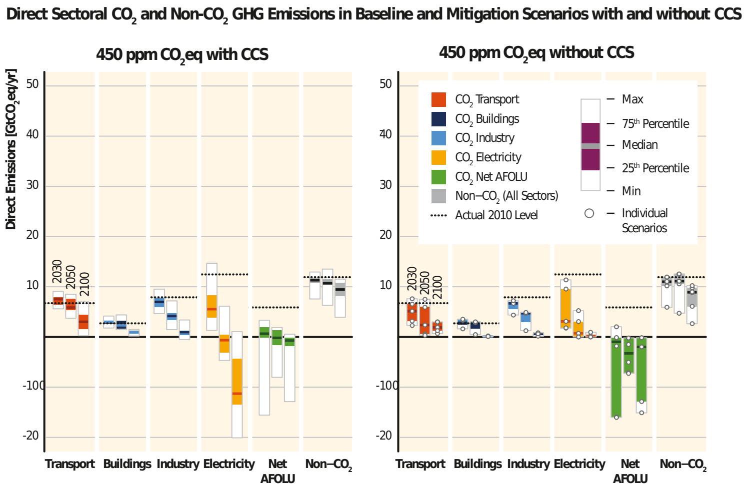

Figure 1: Direct emissions of CO_2 by sector in mitigation scenarios that maintain emissions consistent with a 2°C pathway. The left panel shows scenarios that include Carbon Capture and Storage (CCS) and the right panel shows scenarios that do not. The bars show the distribution of mitigation scenarios that reach around 450 ppm CO_2–eq, with each bar representing the 2030, 2050 and 2100 emissions respectively. As can be seen, the 2050 emissions in both the CCS and non-CCS scenarios require virtually zero emissions from the electricity sector [source: IPCC[5]]

[2] Prime Minister, Minister for Foreign Affairs, and Minister for the Environment and Energy, *Ratification of the Paris Agreement on climate change and the DOHA amendment to the Kyoto Protocol — Prime Minister of Australia*.

[3] IPCC Climate Change, "Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change", page 20.

[4] IEA, *Re-powering Markets*.

2.1 Australian Context

As part of this Paris Agreement, Australia has committed reduce emissions to 26–28% of 2005 levels by 2030[6]. These targets have been described as *'substantially weaker'* than those recommended by the Climate Change Authority in 2015[7]. To meet the commitments of the Paris Agreement and maintain temperature increases below 2°C will require a strengthening of the 2030 targets, rapid reductions in emission between 2030 and 2050, or both.

This de-carbonisation objectives will necessarily have dramatic impacts on the electricity sector. Both Australia's energy use and emissions intensity are high by international standards[8]. This is largely due a reliance on coal fired power. Figure 2 shows the monthly generation mix for the National Electricity Market (NEM) states since 2011[9]. Coal generation counted for 77% of energy generated in the NEM since 2011. While a price on carbon was in effect coal generation dropped to a low of 74% of energy supplied. It has since increased, with coal generation returning to approximately 78% in FY16. Consequently, Australia's electricity sector has generally had a high emission intensity (0.8 t/MWh)[10], and is responsible for approximately a third of Australia's emissions. This intensity is both higher than the current OECD average, and substantially higher than the 2°comparable intensity of 0.015 t/MWh by 2050, as suggested by the IEA.

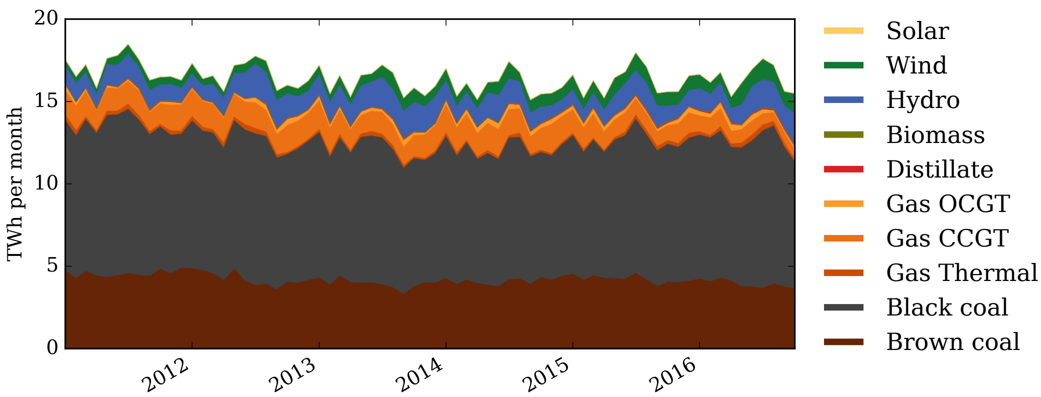

Figure 2: Monthly generation in terawatt hours (TWh) by fuel type in the National Electricity Market (NEM) since the beginning of 2011. Coal generation accounts for approximately 77% of all energy supplied in the NEM.

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[5]IPCC Climate Change, "Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change", page 18, Figure SPM.7.

[6]Australian Government, *Fact sheet: Australia's 2030 climate change target*.

[7]Bernie Fraser, *Some observations on Autsralia's post 2020 emissions reduction target, statement by the chair*.

[8]Climate Change Authority, *Towards a climate policy toolkit*, page 86.

[9]The NEM states include NSW, QLD, SA, Tas and Victoria. The NEM supplies approximately 90% of grid-based electricity in Australia

[10]Vivid Economics, *Analysis of electricity consumption, electricity generation emissions intensity and economy-wide emissions: Report prepared for the Climate Change Authority*.

3 State & expected lifespan of Australia's coal fired power power plants

Figure 3 illustrates the commissioning date and 'technical lifetime' of coal fired generators in Australia. This data was sourced from the Australian Energy Market Operators (AEMO) National Transmission Development Plan (NTNDP) from 2010[11]. This figure includes all currently operating[12], but does not include all coal fired facilities[13].

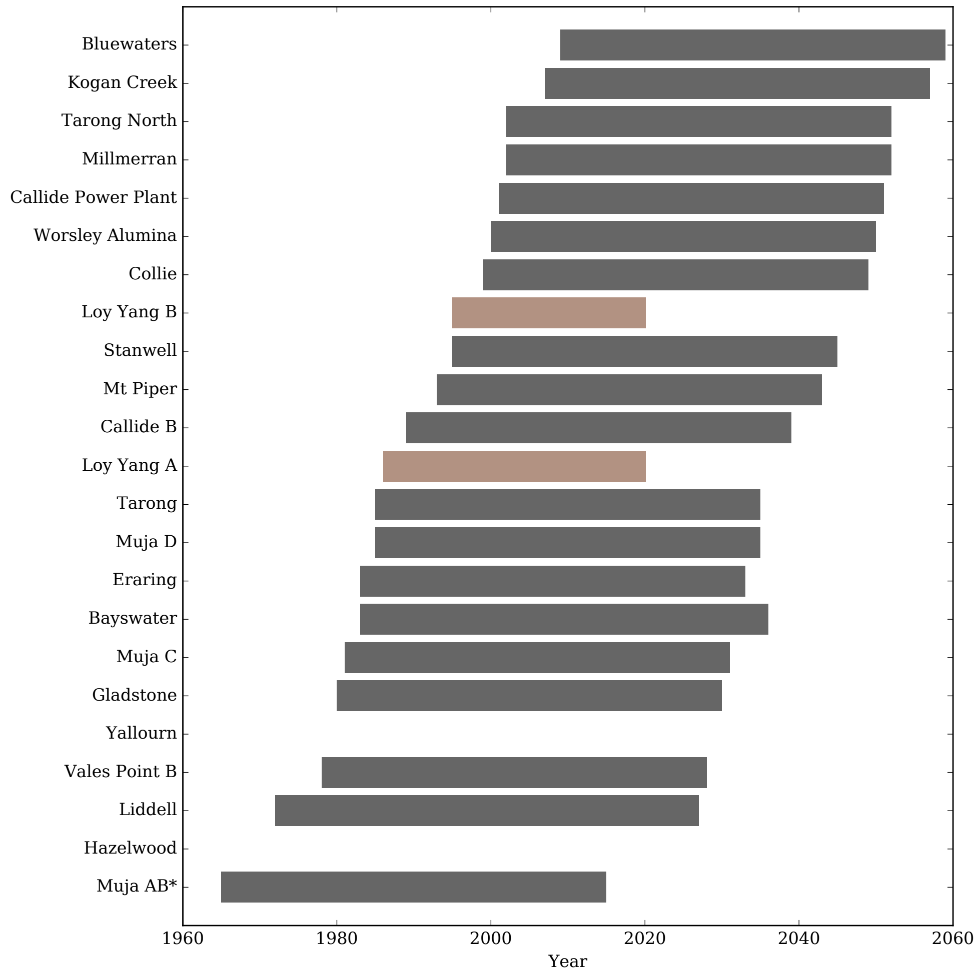

Figure 3: Commissioning date and technical lifespan for coal generators in Australia. Black coal generation is represented by black bars and brown coal generation is represented by brown bars.
***The Muja AB (in WA) is technically the "oldest" and was actually retired in April 2007. However, it was recently refurbished and returned to service in 2014.**

[11] AEMO, *2010 NTNDP*, See 'Input Assumption' tables'.

[12] This includes Hazelwood, which recently announced closure. It doesn't include the 13 power stations that have closed in past 6 years

[13] There are other coal fired industrial facilities, that may produce power but may be co-generations and are also associated with smelters. This includes but is not limited to the 25 MW Gladstone QAL power station and the 38MW Yabulu Nickel refinery in QLD

The AEMO data suggests there are 23 currently operating coal fired power stations, with an aggregate capacity of 26.6 GW (data can be found as an appendix, see page 9). The current median age of existing plants is 30 years, while the mean is 27. By 2030, the median age will be 44, and by 2040 the median age would be 54.

Figure 4 below illustrates the age, emissions intensity and capacity of the existing coal fired power stations. As can be seen, emissions intensity of power stations have generally improved with time, reflecting increases in thermal efficiency with new plants.

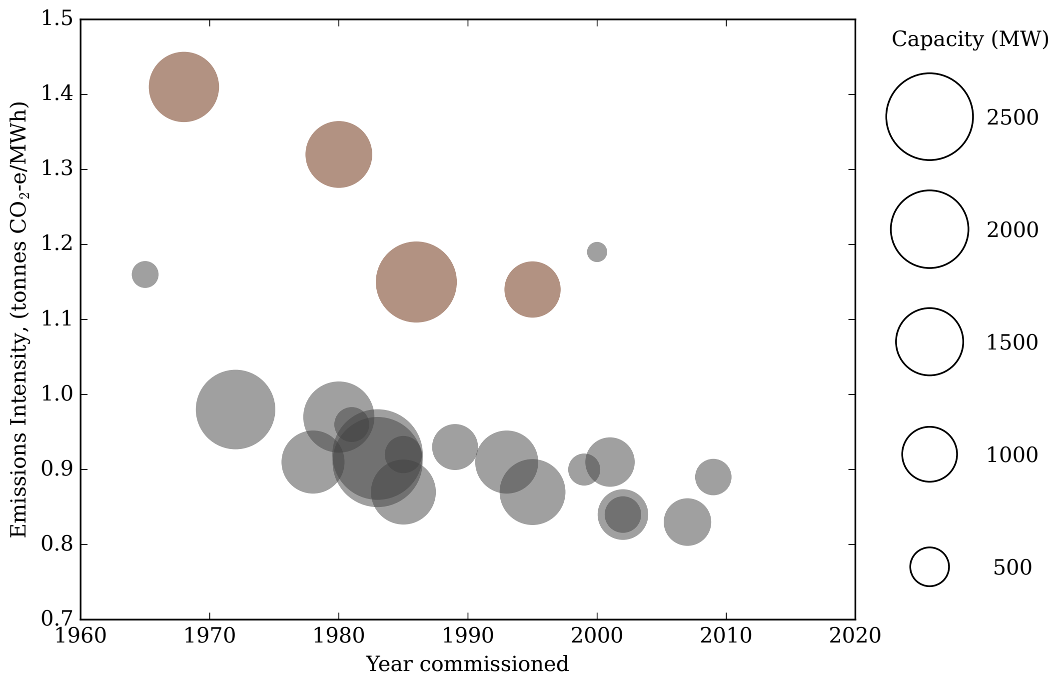

Figure 4: The figure illustrates the emissions intensity, capacity and age of coal generation in Australia. Generators capacity is illustrated by the size of bubbles, while age is represented on the horizontal axis and emissions intensity on the vertical axis. Black coal generation is represented by black bubbles and brown coal generation is represented by brown bubbles.

4 Retiring Coal

Independent of climate commitments, virtually all of these coal fired power stations will have reached the end of their 'technical lives' by 2050. While power stations can continue to operate beyond their technical lifetimes, this would be inconsistent with commitments under the 'Paris Agreement' and climate objectives.

Should all these plants close by 2050, it would require the equivalent of the two South Australian plants (Northern and Playford) to be retired every year for the next 34 years. Alternatively, this roughly equates to closing a Hazelwood sized power station equivalent every 2 years between now and 2050.

4.1 New Coal?

While CCS technologies have been and still are expected to play a role in de-carbonisation, the technology is not yet available at commercial scale, unlike other low-carbon technologies[14]. In addition to this, it is not clear that CCS will can be economically retrofitted to old (and low efficiency) coal plants, nor is it certain that it is sufficiently flexible to sit alongside renewables in an electricity system[15].

As can be seen in Figure 5, technologies with CCS are expensive relative to other low cost energy sources. Indeed with out CCS, wind power is competitive with new coal and new combined cycle gas turbines (CCGT).

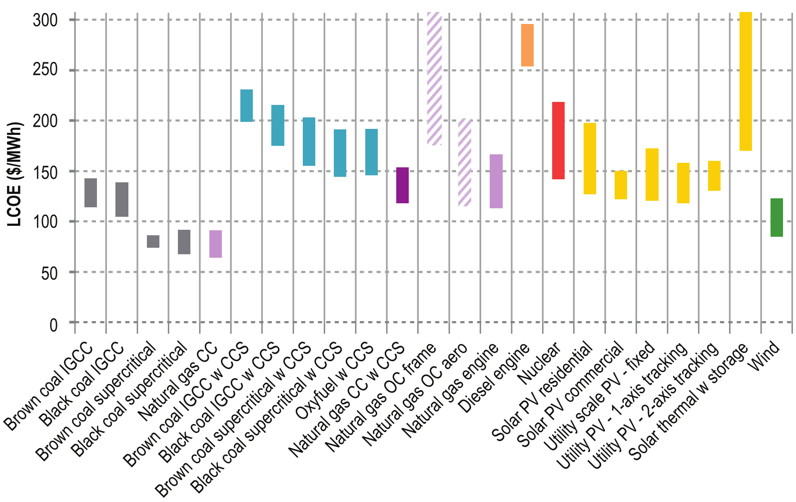

Figure 5: Levelised cost of new entry, adapted from Bongers (2015)[16]. As highlighted, the cost of wind power is completive with both new build black coal and combined cycle gas turbines, with out Carbon Capture and Storage (CCS). A like-for-like comparison (with equivalent emissions outcomes) shows both wind and solar to be significantly cheaper than the alternative options involving coal fired CCS.

[14]IEA, *Re-powering Markets*, page 28.
[15]Ibid., page 28.
[16]Bongers, *Australian Power Generation Technology Report*, Figure 1, *Figure E2: 2015 Levelised cost of electricity ($/MWh)*, page iii.

Regardless of whether coal closure results from pursing climate objectives or simply age and economic factors, technologies that replace the output are not likely to be developed in the same location. With or without CCS - coal is no longer the 'cheapest' form of bulk energy. Renewable energy technology is currently one of the cheapest form of new entry energy generation, and this cost advantage is likely to increase over time.

This has a significant implications for coal closure. The resulting relocation of energy production from concentrated coal resources to distributed renewable resources has obvious social implications for communities affected and currently centred around coal generation.

4.2 A note on gas

While this inquiry is focused on closing coal, it is also worth commenting on the role and future of gas fired power. In the absence of CCS, the deep emissions reductions required will also necessitate closure of existing gas fired generation capacity.

At present, there is over 12GW of gas capacity in Australia. To maintain emissions intensity below the threshold of 0.015 t/MWh suggested by the IEA will require over 90% of this to close. With the most thermally efficient combined cycle gas turbines (CCGT), much more than 1GW with high capacity factor will push emission intensity above this mark[17].

4.3 Reliability and Planning

Many studies have conclude that such a de-carbonisation is both technically and economically feasible. However reaching this goal calls for careful consideration of market design[18]. Electricity market design has a significant impact on the efficient scheduling and operation of power systems. The future of coal generation raises several issues for the functioning of power markets. Uncertainty over the timing of coal plant retirement adds to the uncertainty surrounding levels of demand in the quest to define future investment needs.

This uncertainty points to a need for coordinated system planning of transitional arrangements, and is supported by recent price spikes and market dynamics in the South Australian market. In this case, a disorderly sequence of station withdrawals, mothballing and interconnector upgrades in South Australia has clearly impacted the way the prices have unfolded. In particular, the closure of Northern, in May, *prior* to completion of interconnector upgrades has severely accentuated the price impacts, and enhanced the conditions for the exercise of market power[19].

Market power issues might be expected to emerge in other states as the exit of large power stations accordingly increase market concentration and market power of remaining generators. This phenomenon remains to be seen in Victoria and the Latrobe Valley, where the exit of not only a large power station, but also a major market participant will substantially concentrate the Victorian electricity market.

[17]In a high penetration renewable energy system, open cycle gas turbines which provide peak capacity are likely to be more valuable. These have relatively lower thermal efficiencies (and consequently higher emissions intensities), but have very low capacity factors and typically used infrequently)

[18]IEA, *Re-powering Markets*.

[19]McConnell and Sandiford, *Winds of change: An analysis of recent changes in the South Australian electricity market*.

5 Summary

- In order to meet the objectives of 'Paris Agreement' and keep global warming below 2°C, requires emission from the electricity sector to dramatically reduce, to practically zero, by 2050.
- The majority of existing coal fired power stations in Australia will have reach the end of their technical lives by 2050.
- Renewable energy is competitive with new entry fossil generation. This is particularly true when comparing equitable emissions outcomes.
- Plant ages, the 'Paris Agreement' and renewable energy costs suggest significant retirements of coal, with concurrent replacement with renewable energy between now and 2050.
- Evidence from South Australia points to a need for coordinated system planning of transitional arrangements maintenance of electricity supply, affordability and security

Appendix: Australian Coal Plants: Data

The table below includes data on existing coal fired power stations in Australia. This data was used to create Figure 3 and 4. Technical life and commission date are from AEMO's 2010 NTNDP[20] while the emissions intensity data is from the ACIL Allens's, *'2016 Emissions Factor Assumptions Update'*[21].

Table 1: Coal fired power stations in Australia

Station Name	Commissioned	Capacity	Emissions Intensity	
			Scope 1	Scope 3
Bayswater	1983	2720	0.87	0.05
Bluewaters	2009	441	0.87	0.02
Callide B	1989	700	0.92	0.01
Callide Power Plant	2001	810	0.9	0.01
Collie	1999	342	0.88	0.02
Eraring	1983	2693	0.86	0.05
Gladstone	1980	1680	0.96	0.01
Hazelwood	1968	1640	1.4	0.01
Kogan Creek	2007	750	0.82	0.01
Liddell	1972	2100	0.93	0.05
Loy Yang A	1986	2180	1.15	0
Loy Yang B	1995	1050	1.14	0
Millmerran	2002	850	0.83	0.01
Mt Piper	1993	1320	0.86	0.05
Muja AB*	1965	240	1.13	0.03
Muja C	1981	404	0.93	0.03
Muja D	1985	461	0.9	0.02
Stanwell	1995	1440	0.86	0.01
Tarong	1985	1400	0.86	0.01
Tarong North	2002	443	0.83	0.01
Vales Point B	1978	1320	0.86	0.05
Worsley Alumina	2000	135	1.16	0.03
Yallourn	1980	1480	1.31	0.01

[20] AEMO, *2010 NTNDP*, see 'Input Assumption' tables.

[21] see https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan/NTNDP-database