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PICKING WINNERS: UNDERSTANDING THE FUTURE COST OF ELECTRICITY GENERATION IN AUSTRALIA

With liberalised electricity markets, investment in Australia's future energy mix will be greatly dependent on the expected generation cost of alternative energy sources. Based on analysis using a levelised cost of energy approach to directly compare alternative technologies, fossil fuels continue to remain competitive relative to nuclear, hydro and wind generation sources over the long term.

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The expected cost of alternative energy sources will be critical to the development of Australia's future energy mix. There is a great deal of criticism regarding the slow response by Australian generators and policy makers to changing the energy mix away from fossil fuels. However, as this analysis shows, such responses must be carefully planned to ensure that the true cost of long-term sustainable energy supply is not skewed towards less efficient energy sources. Excessive energy costs relative to regional benchmarks will undoubtedly translate into competitive disadvantages. Importantly, the magnitude of the investment and social costs for any given energy source prevents dramatic changes occurring to the energy mix midway through a development cycle. Often there is no turning back once the development pipeline is under way. For example, generators in the United States and Europe are experiencing difficulties in decommissioning baseload power plants that have an effective remaining life of 30 years, particularly in cases where most of the capital costs have yet to be recovered.

The composition of electricity supply in Australia in the period to 2030 will be influenced by a number of factors in the energy policy arena, most notably:

- policy settings for renewable energy, in particular, the 2020 mandatory renewable energy target (currently 20 per cent);
- the cost and availability of different fuel sources (the costs of fuel will partly depend on the price signal for carbon dioxide);
- the cost of competing generation technologies;
- the extent to which alternative technologies are commercialised;
- societal attitudes towards alternative generation technologies, especially nuclear; and
- the capacity of transmission and interconnection infrastructure as well as the regulatory framework.

The following analysis compares the costs of competing generation technologies including carbon costs over the long term, using the levelised cost of energy as a benchmarking tool. We deploy the levelised cost of energy approach because it is a relatively simple analytical tool to compare alternative technologies where different scales of operation, investment or operating time periods exist. The levelised cost can therefore be used to compare the cost of energy generated by a renewable power plant with that of a fossil fuel generating unit or other technology, despite significant differences in construction times, plant life and capital outlay. The calculation for the levelised cost is generally the net present value of total life cycle costs of the project divided by the quantity of energy produced over the system life.

Energy investments

Regardless of the motivation behind investing in alternative energy sources, a clear appraisal of the relative costs and benefits that arise from competing sources is required to inform decision makers. The major energy generators and private equity investors are likely to dominate investment in Australia's evolving energy mix, as long as they provide returns on investment commensurate with risk over the long term. Understanding the cost drivers of electricity generation is critical to assessing the investment options for alternative energy sources.

The liberalisation of the Australian electricity markets has removed part of the regulatory risk shield under which integrated monopolies can transfer costs and risks from investors to consumers and taxpayers. Investors now have additional risks to consider and manage. For example, generators are no longer guaranteed the ability to recover all costs from power consumers, nor is the future power price level guaranteed. Investors must internalise these risks, which adds to the required rates of return. It also diminishes the time horizon for financiers seeking to fund investment and for investors seeking to recover capital. Private investors' required real rates of return are likely to be similar to the discount rate used in this study, however, the time required to recover invested capital is generally much shorter than the average life of a generating unit. While the levelised cost is not the only metric available for framing investment decisions, it is an important consideration in estimating operating margins and capital costs.

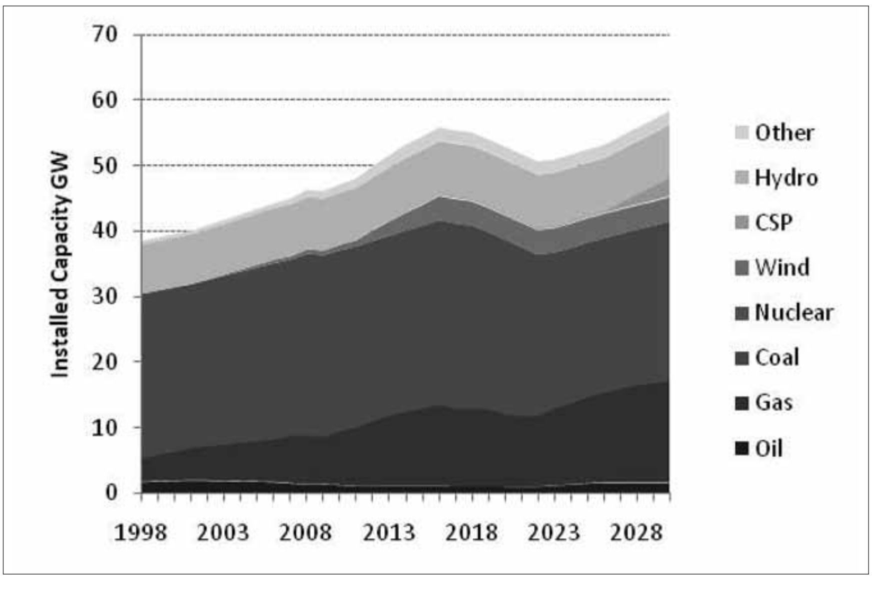
There are a number of general features of electricity generation in Australia. The demands on Australia's electricity supply infrastructure are growing, with increasingly distributed and variable sources of generation, including wind and solar power adding to the complexity of distribution. Like most countries, electricity demand does not respond quickly to price changes when supply conditions change and there appears to be a lack of timely and diverse electricity-generation investment, as well as a lack of significant investment in transmission interconnection. There is often public opposition to the location of new generation and transmission infrastructure, which causes delays and increases risks and costs for investors. Finally, regulatory complexity and uncertainty, especially as Australia's market has been integrated over a large geographic area, further inhibit diversity in energy investments. These issues complicate the investment decision.

Australia's energy mix

Australia's energy mix is dominated by fossil fuels. Figure 1 provides a history and forecast of installed generation capacity by plant type. Coal and gas make up around 77 per cent of installed capacity and almost 89 per cent of annual production. Figure 1 illustrates a significant decline in capacity from 2018, which coincides with the expected phased decommissioning of several coal and gas generation units. However, since Australia's power demand is expected to increase rather than decline over this period, the gap in generation capacity raises questions about which energy alternatives will be cost effective over this period. A gap of at least 10 gigawatts (GW) of generating capacity by 2020 represents a significant investment opportunity for energy generators.

In 2010, Australia's installed energy capacity was approximately 47 GW, which produced around 207 terawatt hours (TWh) of electricity. Australia's energy intensity, which is a measure of energy efficiency, has historically been in line with most Western countries and this is projected to continue out to 2030, as illustrated in Figure 2. Energy demand is expected to continue to

FIGURE 1: Installed electricity generation capacity (GW) in Australia 1998–2010 and forecast 2011–2030 by fuel type



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grow at a rate consistent with GDP growth, moderated by the efficiencies implied by improved energy intensity. So what alternative energy technologies are available and what does their cost structure look like over the long term?

Levelised costs of electricity generation

Cost data were obtained for more than 50 power plants in Australia and cross-referenced against data from the International Energy Agency (IEA), the Australian Bureau of Agricultural and Research Economics and Sciences (ABARES) and the Australian Nuclear Science and Technology Organisation (ANSTO). These power plants comprise 20 coal-fired power plants, 12 gas-fired power plants, five wind power plants, four oil plants and six hydro plants, as well as 10 plants based on other fuels or technologies. Nuclear, solar and other renewable energy plant data were obtained from European and US operators and regulators. Broad comparisons of energy efficiency, carbon intensity and construction costs are provided in Table 1 for both existing plants and the expected values of newer technologies.

The technologies and plant types covered by the present study include several units under construction or planned for commissioning between 2010 and 2015, and for which cost estimates have been developed. The calculations are based on the levelised lifetime cost approach. An average of energy commodity price forecasts from UBS, ANZ Bank, Macquarie Bank and BHP Billiton were used in the analysis.

FIGURE 2: The energy intensity of Australian electricity industry relative to the energy intensity levels of the US, France and Germany, 1998 base year

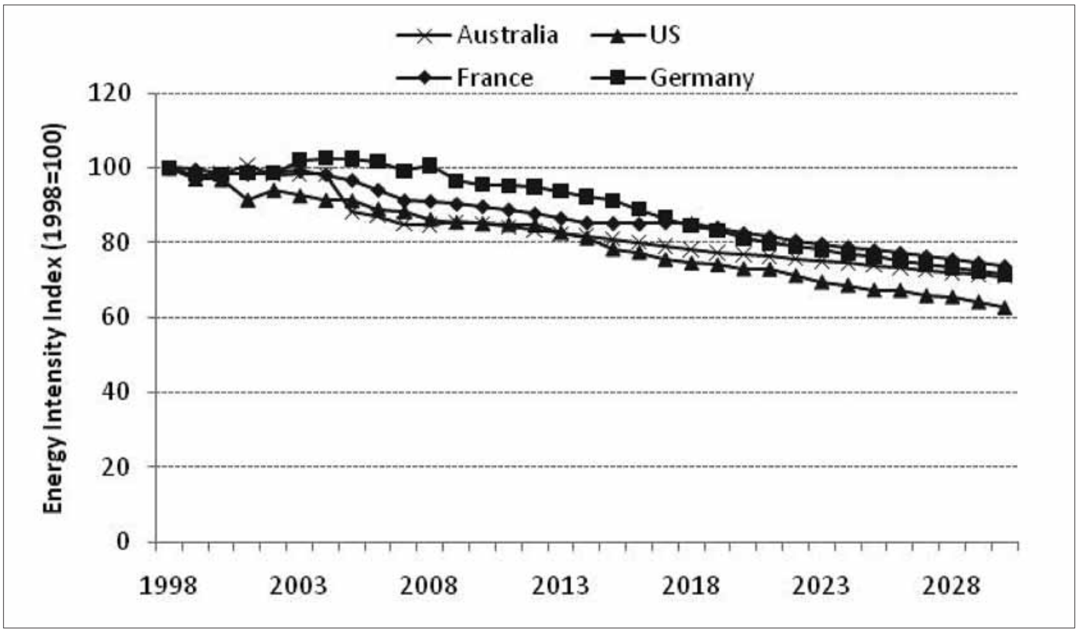


TABLE 1: Peak plant availability, average plant availability, average plant efficiency and carbon intensity assumptions by generation type

Generation Type	Peak plant availability	Average plant availability	Average plant efficiency (MWht/MWh)	Carbon intensity (tCO2/MWht)	Australian power production average 1998-2010 (TWh pa)
Oil	96%	92%	35%	0.28	0.053
OCGT & GST	95%	90%	35%	0.20	24.301
CCGT	94%	88%	56%	0.20	7.185
Coal (USC)	94%	88%	47%	0.34	9.355
Coal (SC-large)	94%	82%	37%	0.34	97.341
Coal (SC-small)	94%	82%	34%	0.34	4.247
Lignite	92%	85%	32%	0.40	40.912
Nuclear	96%	81%	34%	0.00	-
Wind	25%	25%	100%	0.00	1.008
CSP	20%	20%	100%	0.00	0.019
Hydro	60%	20%	100%	0.00	12.087

To estimate the levelised cost of production, we must assess the relationship between actual power prices and actual short-run and long-run costs, and then forecast how this relationship is likely to develop over the forecast period to determine a corresponding power price forecast.

Levelised power production prices are derived in this analysis using the following process:

1. The short-run marginal cost (SRMC) of electricity is calculated from fuel prices, CO2 (carbon emissions) costs and variable operating and maintenance (O&M) costs by plant type.
2. The long-run average cost (LRAC) of electricity to 2030 by plant type is calculated from the SRMC, fixed O&M costs and capital costs.
3. New-build plant capacity is then calculated by estimating planned additions and retirements, as well as any forced new builds, with the balance of any power deficit based on a ranking of allowed new-build technologies.
4. The average SRMC is then calculated from the load duration curve and the proportion of time for which each generation type is marginal.
5. The same process is then repeated for average LRAC.
6. The expected power price is then forecast based on a combination of SRMC and LRAC.

The calculations use generic assumptions for the main technical and economic parameters such as the economic lifetime of different plants, the average load factor for baseload plants and an appropriate discount rate. A selection of some main assumptions used in the analysis is provided in Table 2.

Assuming a typical debt to total capital ratio of 60 per cent and a credit rating of BBB+, advice from the banking community indicates that an appropriate average cost of capital on the above investments, without a technology risk premium, would be in the range of 9.8 per cent to 10.6 per cent. Hence, a discount rate of 10 per cent was chosen to estimate the levelised costs of energy for this analysis.

Electricity generation costs calculated are busbar costs (costs of producing one megawatt hour of electricity) at the station and do not include transmission and distribution costs, which can substantially affect consumer prices, particularly in Australia. The costs associated with residual emissions, including greenhouse gases, are included as part of the estimated generation costs. A constant CO2 price of A$32 per tonne is assumed for this analysis.

The levelised cost of energy by generating type is illustrated in Figure 3.

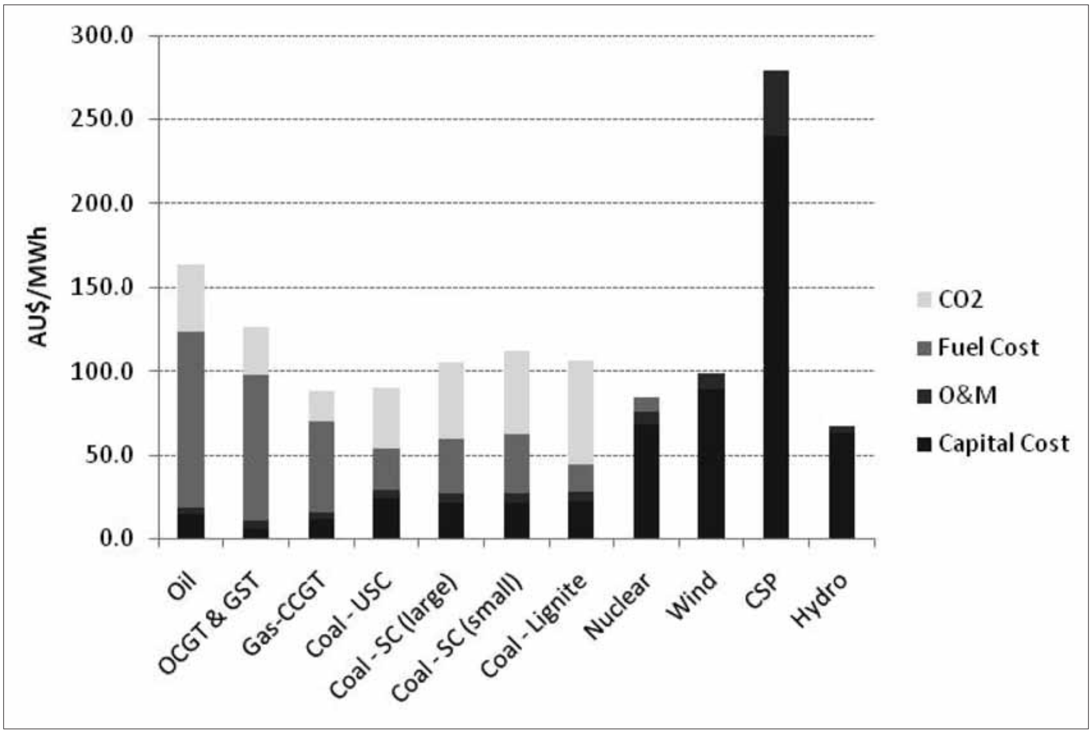
Coal-fired generating technologies

Most coal-fired power plants have construction costs of around A$1.5 million to A$2 million per MWh. Construction times are around four years for most plants. In Australia, fuel prices (coal, brown coal or lignite) are relatively inexpensive as most generators use run of mine coal (unprocessed) at delivered costs of around A$32 per tonne with a high expectation of long-term price stability. Levelised generation costs are around A$40 to A$60 per MWh for most coal-fired power plants. Generally, investment costs represent around one-half of the total costs, while operating and maintenance costs account for 15 per cent and fuel accounts for around 35 per cent. Emissions costs push the levelised cost to around US$90 per MWh for the more efficient coal-fired power plants.

TABLE 2: Construction cost and cost growth rates, plant life, existing asset age and number of employees required per MWh assumptions by plant type

Generation Type	Construction cost (US$/ MWh)	Average construction cost growth (2010-20)	Average plant life (yrs)	Average age of existing assets	Employees per MW
Oil	983,400	-2.28%	40	23	0.10
OCGT & GST	376,200	-2.74%	40	18	0.14
CCGT	756,860	-2.74%	40	10	0.10
Coal (USC)	1,533,700	-2.32%	50	7	0.15
Coal (SC-large)	1,280,400	-2.32%	50	27	0.15
Coal (SC-small)	1,280,400	-2.32%	50	33	0.15
Lignite	1,405,800	-2.33%	50	30	0.15
Nuclear	4,020,000	-5.64%	50	-	0.20
Wind	1,635,020	-5.69%	100	3	0.00
CSP	3,502,640	-6.72%	100	-	0.00
Hydro	1,410,000	-2.03%	100	40	0.15

FIGURE 3: The cost breakdown of the levelised long-run marginal cost of electricity generation in Australia 2011–2030, A$ per MWh



Note: Nuclear Operating and Maintenance (O&M) cost includes a decommissioning expense of A$3.8 per MWh included in O&M. OCGT – Open Cycle Gas Turbine; GST – Gas Steam Turbine; CCGT – Combined Cycle Gas Turbine; USC – Ultra Super Critical; SC –Super Critical; CSP – Concentrated Solar Power].

Carbon capture and storage technology has the potential to change the nature of the energy mix to favour coal-fired generation. From the modelling conducted under the levelised cost model, the inducement cost for emissions would have to be around A$50 per tonne for carbon capture and storage (CCS) to become economical over the longer term. Unless significant government subsidies can be deployed to bridge the cost gap, a long-term emissions price of A$50 per tonne does not appear likely given the cost of alternative generation sources available.

Gas-fired generating technologies

In most cases, construction costs for gas-fired power plants range from A$0.4 million to A$0.8 million per MWh. The construction costs of gas-fired plants are considerably less than those of coal-fired and nuclear power plants. Gas-fired plants are built rapidly with expenditures spread over two to three years. The operating and maintenance costs of gas-fired plants are also significantly less than coal or nuclear plants. However, the low gas price in 2010 of US$3.5 to US$ 4.5 per gigajoule (GJ) must be adjusted to cater for expectations of significant escalations in the longer-term gas price.

The levelised costs of gas-fired plants range from A$70 to 90 per MWh. Fuel cost is the major contributor representing 73 per cent of total generation cost, while investment and operating/maintenance shares are around 20 per cent and 7 per cent, respectively. Emissions costs push the levelised cost to around US$88 per MWh, which makes gas very competitive against coal-fired generation.

Nuclear generating technologies

For nuclear power plants investment costs, not including refurbishment or decommissioning, vary from A$2 million to A$4 million per MWh for most plant types. It is generally expected that 90 per cent or more of total expenses are incurred within five years or less. The levelised costs of nuclear electricity generation are expected to be A$80 to A$90 per MWh. The share of investment in total levelised generation cost is around 70 per cent while the other cost elements, operating and maintenance and the fuel cycle, are estimated to average 20 per cent and 10 per cent of total costs, respectively. Investment costs include estimates for refurbishment and decommissioning as well as interest costs during construction.

Caution is required since the limited availability of capital cost data for nuclear new builds makes it difficult to calibrate the long-term costs accurately, and nuclear power plant construction expenditures are known to exceed budgets. However, zero emission costs allow nuclear to be very competitive against coal and gas generation levelised prices.

The project-based WACC of nuclear projects tends to be lower due to typically high debt capital structures and the provision of loan collateral. Historically, utility companies in Western countries do not generally proceed with a nuclear new build without government loan guarantees. Public opposition to nuclear power generation is another serious obstacle.

Wind generating technologies

Wind power plant construction costs range from A$1 million to A$ 2 million per MWh depending on location (onshore or offshore). Existing build schedules indicate a construction period of between one and two years. The costs calculated for wind power plants are based on the levelised lifetime methodology used for other technologies to maintain consistency. For intermittent renewable sources such as wind, the availability/capacity of the plant is a key factor driving the need to determine the levelised cost of electricity generation. The observed availability and capacity of wind power plants ranges from 17 per cent to 38 per cent for onshore plants and 40 per cent to 45 per cent for offshore plants. The levelised costs for wind power plants are estimated to range from A$45 to A$145 per MWh, however, for many plants, the costs are around A$95 per MWh. Operating and maintenance costs comprise around 15 per cent to 40 per cent of total costs, depending on location.

The levelised cost does not reflect ancillary costs associated with the need for backup power to compensate for the low average availability factor for wind relative to existing baseload plants. Furthermore, wind is limited not only as an intermittent source, but it also has an associated high probability that on peak energy use days (when it is very hot or very cold) wind speeds tend to be lower than usual. Transmission investment would also be required since wind resources tend to be far from where the electricity is consumed. Distribution costs are not considered in this analysis, however, as an indication, a $1 billion investment for an 800km transmission line could add up to A$20 per MWh to the levelised cost of electricity.

Hydro generating technologies

The hydro power plants considered in the study ranged from very large to very small units. The levelised costs for hydroelectricity generation range from A$65 to A$100 per MWh for most plants. This technology remains competitive but it has limited capacity for baseload generation.

Solar generating technologies

For large-scale concentrated solar plants, the availability/capacity factors reported vary from 9 per cent to 24 per cent. At a higher capacity/availability factor, the levelised costs of solar-generated electricity are around A$200 per MWh while lower availability/capacity factors translate into a levelised cost above A$300 per MWh. The analysis includes a 'learning rate discount' to allow for technology improvements through time by indexing a capital cost decrease of 25 per cent as a function of the increased volume of solar power plants built over time.

Small-scale solar units in the form of photovoltaic cells can avoid grid-related capital expenditures which can make solar power cost competitive, however, only large scale project-specific investments are considered in this analysis.

Other generating technologies

Fringe energy sources such as geothermal, combined heat and power systems, tidal and biomass also need to be considered. Geothermal energy appears to be an attractive energy source because it is 'always on' and independent of the weather. The difficulty with sustainable geothermal power is that the speed at which heat travels through the solid hot rocks in the earth's interior limits the rate at which heat can be sustainably extracted. Time delays occurring between the injection of cold water pumped into the earth's interior and the extraction of steam to run a turbine mean that, on average, geothermal energy is probably unsustainable as a long-term energy source in Australia. Geothermal energy is also highly dependent on the location of suitable sites.

The total levelised costs of generating electricity for combined heat and power plants are highly dependent on the use and value of the combined product. Heat and power plants are also very site specific and levelised costs are expected to range from A$90 to A$120 per MWh. Reliable information on the construction costs and capacity/availability of large-scale tidal and biomass plants are not available and have not been explicitly considered for this analysis. It is unlikely that either technology will be commercially viable on a large scale in Australia in the next 10 to 20 years.

Conclusions

To help eliminate some of the emotion in the energy debate in Australia, the above analysis outlines the relative levelised costs of alternative electricity generation to 2030. It is clear that with the inclusion of a price on carbon dioxide emissions, coal, gas, nuclear, hydro and wind remain competitive over the long term. Without an emissions price, fossil fuel technologies are clearly dominant. Large-scale solar power remains very expensive even when high rates of technology advancement in the field are assumed. Other potential sources such as geothermal and tidal power are decades from commercial-scale development and are unlikely to feature prominently in Australia's energy mix by 2030.

The levelised costs and the ranking of technologies are naturally sensitive to the discount rate and the projected prices of energy commodities. However, the analysis shows that the relative costs of electricity output by generation type can be measured using reasonable projections of capital costs, fuel costs and a price on carbon-dioxide emissions.

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