Executive summary

Technological change in electricity generation is a global effort that is strongly linked to global climate change policy ambitions. While the rate of change remains uncertain and the level of commitment of each country varies over time, in broad terms, there is continued support for collective action limiting global average temperature increases. At a domestic level, the Commonwealth government, together with all Australian states and territories aspire to or have legislated net zero emissions (NZE) by 2050 targets.

Globally, renewables (led by wind and solar PV) are the fastest growing energy source, and the role of electricity is expected to increase materially over the next 30 years with electricity technologies presenting some of the lowest cost abatement opportunities.

Purpose and scope

GenCost is a collaboration between CSIRO and AEMO to deliver an annual process of updating the costs of electricity generation, energy storage and hydrogen production technologies with a strong emphasis on stakeholder engagement. GenCost represents Australia's most comprehensive electricity generation cost projection report. It uses the best available information each cycle to provide an objective annual benchmark on cost projections and updates forecasts accordingly to guide decision making, given technology costs change each year. This is the seventh update following the inaugural report in 2018.

Technology costs are one piece of the puzzle. They are an important input to electricity sector analysis which is why we have made consultation an important part of the process of updating data and projections.

The report encompasses updated current capital cost estimates commissioned by AEMO and delivered by Aurecon. Based on these updated current capital costs, the report provides projections of future changes in costs consistent with updated global electricity scenarios which incorporate different levels of achievement of global climate policy ambition. Levelised costs of electricity (LCOEs) are also included and provide a summary of the relative competitiveness of generation technologies.

'Firming' or integration costs of variable renewables

In this report, where we make a comparison between the costs of variable renewables such as solar PV and wind and the costs of other technologies we include the cost of firming those renewables which we call integration costs. These are the additional costs of ensuring supply is reliable when using intermittent energy sources. These integration costs are itemised in the report and include storage, transmission, system security and spilled energy.

Additional analysis on three key nuclear generation topics

Based on public discussion of GenCost's approach to nuclear generation since the 2023-24 final report release, the three most common areas of contention are:

- The capital recovery period should be calculated over the entire operational life (e.g. 60 years), and not the industry standard of 30 years used in GenCost
- Due to US experience, capacity factors of below 93% should not be considered (GenCost uses the range 53% to 89%)
- The nuclear development lead time should be 10 to 15 years, not 15 years or greater as proposed by GenCost.

Additional evidence and analysis of these topics has been provided in this consultation draft.

Nuclear technology's long operational life

Nuclear advocates have asked for greater recognition of the potential cost advantages of nuclear technology's long operational life and CSIRO has calculated those cost advantages for the first time. Our finding is that there are no unique cost advantages arising from nuclear technology's long operational life. Similar cost savings are achievable from shorter lived technologies, even accounting for the fact that shorter lived technologies need to be built twice to achieve the same life.

There are several reasons for the lack of an economic advantage from longer operational life. Substantial refurbishment costs are required, and without this new investment nuclear cannot achieve safe long operational life. When renewables are completely rebuilt to achieve a similar project life to nuclear, they are rebuilt at significantly lower cost due to ongoing technological improvements whereas large-scale nuclear technology costs are not improving to any significant extent owing to their maturity. Also, due to the long lead time in nuclear deployment, the limited cost reductions achieved in the second half of nuclear technology's operational life, when the original capital investment is no longer being repaid, are not available until around 45 years from now, significantly reducing their value to consumers compared to other options which can be deployed now.

Nuclear generation capacity factors

GenCost has always provided a capacity factor range for every generation technology rather than a single point estimate. However, nuclear advocates would prefer GenCost only consider a single value of 93% which is the average capacity factor achieved in the United States. To be clear GenCost agrees that high capacity factors of around 90% are achievable for nuclear generation. However, a prudent investor (government or private) must prepare for all plausible eventualities. The fact is that the global average capacity factor for nuclear generation is 80% and 10% of nuclear generation is operating at below 60%. This is because circumstances vary widely between countries and even within a country there is a merit order for generation dispatch. On international data alone, the proposition of only considering a 93% capacity factor is not supported by the evidence.

However, our preference is to always use Australian data where it is available. In Australia we have more than 100 years of experience with operating baseload generation, not nuclear but coal. Some black coal plants operate at close to 90% capacity factor but the average for black coal in the past decade is 59%. On this basis a single point estimate of 93% does not adequately capture the plausible range achievable in Australia. GenCost bases its capacity factor assumptions for all baseload technologies – coal, gas, and nuclear – on the Australian evidence, applying a maximum of 89% and minimum of 53%. The minimum is based on the same formula that we apply to renewables (the minimum capacity factor for new build generation is assumed to be 10% below the average capacity factor of existing equivalent generation).

Nuclear development lead time

The development lead time includes the construction period plus all of the preconstruction activities such as planning, permitting and financing. Many stakeholders have agreed with the GenCost estimate of *at least* 15 years lead time for nuclear generation. Those stakeholders that are more optimistic cite two alternative sources, the International Atomic Energy Agency (IAEA) who have an estimate of 10 to 15 years and the recent completion of a nuclear project in the United Arab Emirates (UAE) had a 12 year lead time. Both estimates are in relation to building nuclear for the first time. This consultation draft provides additional analysis of nuclear lead times to examine this issue more closely. We examine recent construction times and their relationship with the level of democracy in that country.

In the last 5 years, median construction time has increased to 8.2 years compared to 6 years when the IAEA made their estimate in 2015. This increase in construction time cannot be explained by the pandemic because median construction times were longer in the two years preceding the pandemic (8.6 and 9.8 years). Note that most of the historical construction time data is dominated by countries with established nuclear industries and so may be optimistic for a first-time country.

There is some statistical evidence for the impact of the degree of democracy on nuclear lead times. Pakistan, China and the UAE have had the fastest construction times in the last decade with average construction times of 6 to 8 years, but their democracy index scores are low. Finland, South Korea, the United States (US) and India all had construction times 10 years or longer with high democracy scores. The two Western democracies in this list, Finland and the US had construction times of 17 and 21 years respectively which is significantly longer than the Asian democracies.

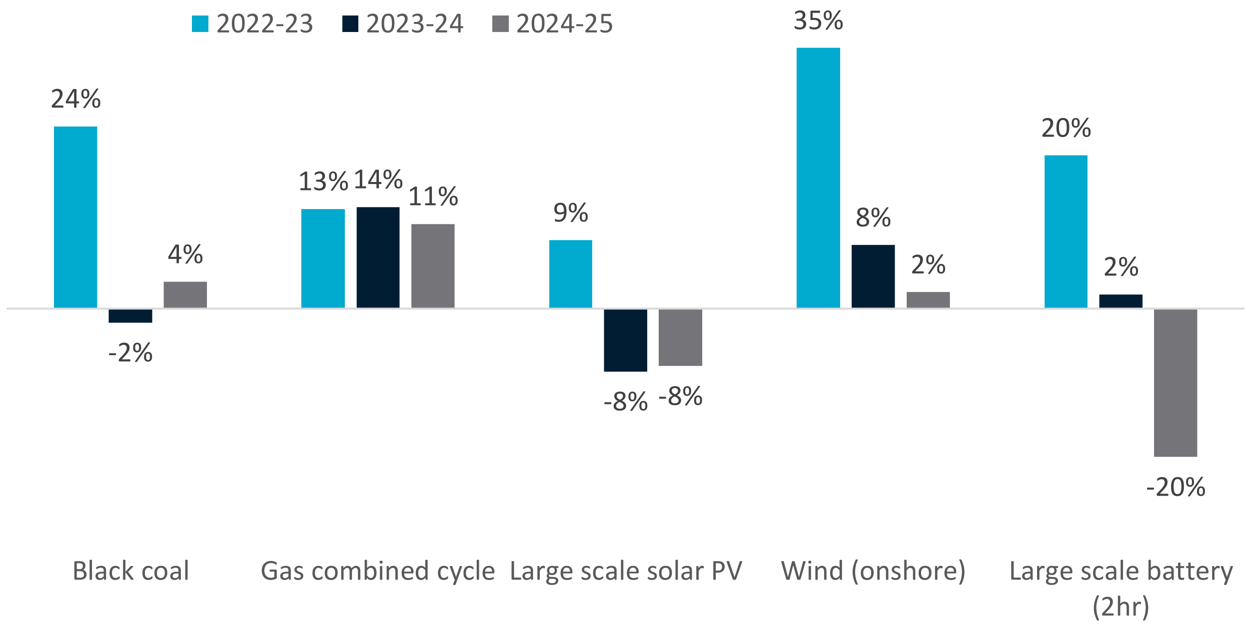
Another factor which is correlated with shorter construction times is the existence of an ongoing building program rather than long intervals between projects.

Given the direction of construction data available after the report's release, the IAEA range of 10-15 years should likely be reinterpreted as 12 to 17 years to allow for the extra 2 years median construction time which now prevails. The lower part of this new range, 12 years, would be consistent with the UAE experience. Australia is not likely to be able to repeat the UAE experience because our level of consultation will be consistent with our higher level of democracy and the experience of other Western democracies. As such, *at least* 15 years remains the most plausible lead time.

Key changes in capital costs in the past year

The COVID-19 pandemic led to global supply chain constraints which impacted the prices of raw materials needed in technology manufacturing and in freight costs. Consequently the 2022-23 GenCost report observed an average 20% increase in technology costs. For each of the two years following that observation, the inflationary pressures have progressively eased but the results remain mixed. Technologies have been affected differently because they each have a unique set of material inputs and supply chains.

The capital costs of onshore wind generation technology increased by a further 8% in 2023-24 and another 2% in 2024-25 while large-scale solar PV has fallen by 8% in consecutive years (ES Figure 0-1). Large-scale battery costs improved the most in 2024-25 falling by 20% in 2024-25. Gas turbine technologies are still increasing but this is because GenCost is now including hydrogen fuel readiness as a standard feature. This has increased gas technology capital costs but recognises the reality that gas generation is more likely to be deployed with multiple fuel options.



ES Figure 0-1 Year on year change in current capital costs of selected technologies in the past 3 years (in real terms)

The cost of electricity technologies compared

LCOE is the total unit costs a generator must recover over its economic life to meet all its costs including a return on investment. Each input to the LCOE calculation has a high and low assumption to create an LCOE range for each technology (ES Figure 0-2).

The LCOE cost range for variable renewables (solar PV and wind) with integration costs is the lowest of all new-build technologies in 2024 and 2030. The cost range overlaps with the lower end of the cost range for coal and gas generation. These are high emission technologies which, if used to deliver the majority of Australia's power supply, are not consistent with Australia's current climate change policies[1].

If we exclude high emission generation options, the next most competitive generation technologies are solar thermal, gas with carbon capture and storage, large-scale nuclear and coal with carbon capture and storage.

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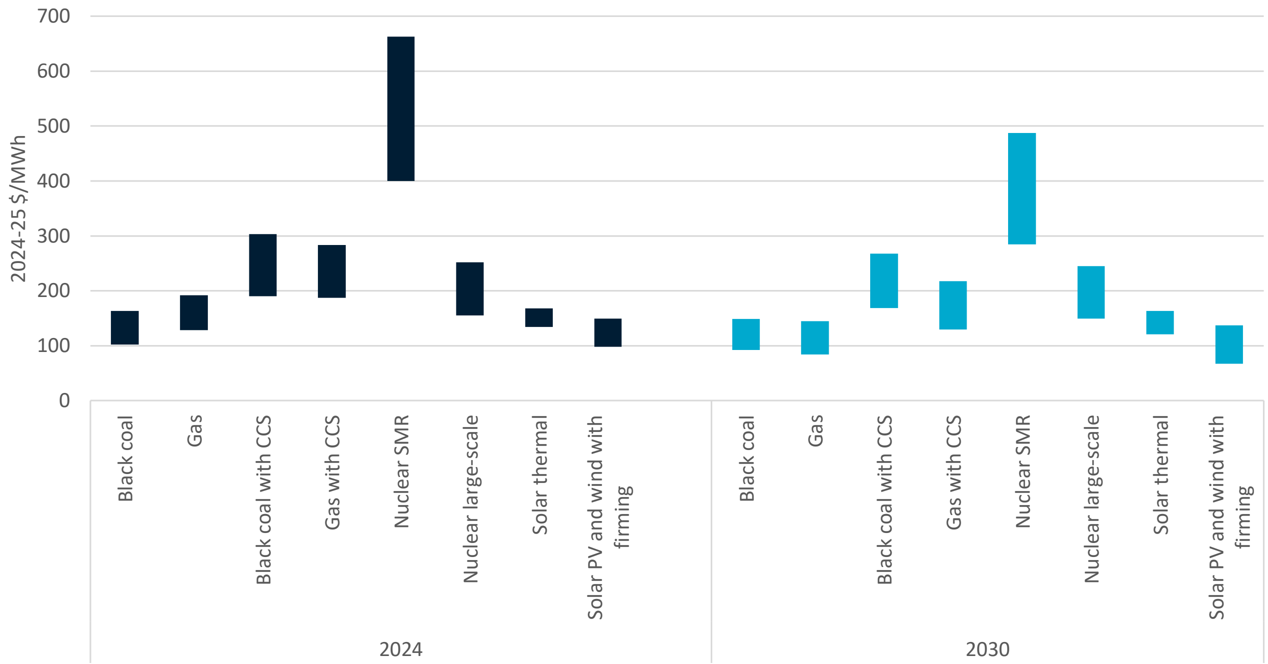
[1] Although most modelling indicates that gas is likely to continue to be utilised and constructed for some time yet as a peaking technology which supports the grid but with low contribution to total electricity produced. AEMO analysis of electricity systems consistent with net zero by 2050 can be accessed at: https://aemo.com.au/consultations/current-and-closed-consultations/draft-2024-isp-consultation



ES Figure 0-2 Calculated LCOE by technology and category for 2024 and 2030

While solar thermal costs are low, given the need to access better solar resources further from load centres, they will face additional transmission costs compared to coal, gas and nuclear. Directly calculating these costs was not in scope but could add around $14/MWh to solar thermal costs based on transmission costs that were calculated for solar PV and wind.

Nuclear SMR costs improve significantly by 2030 but remain significantly higher cost than these other alternatives (ES Figure 0-2). For clarity, neither type of nuclear generation can be operational by 2030. Developers will need to purchase the technology in the 2030s sometime after pre-construction tasks are completed. At least 8 years of construction would then follow before full operation can be achieved. As such, the inclusion of large-scale and SMR nuclear in the cost comparisons is only as a point where investment could be considered. A practical operation date would be the 2040s by which time the costs of other technologies will have fallen further. Renewable and storage technologies also have development lead times, but their deep development pipeline of projects means that there are new projects reaching the point of financial close each year.