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, in broad terms, world leaders continue to provide their support for collective action limiting global average temperatures. 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 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 electricity costs change significantly each year. This is the sixth 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.

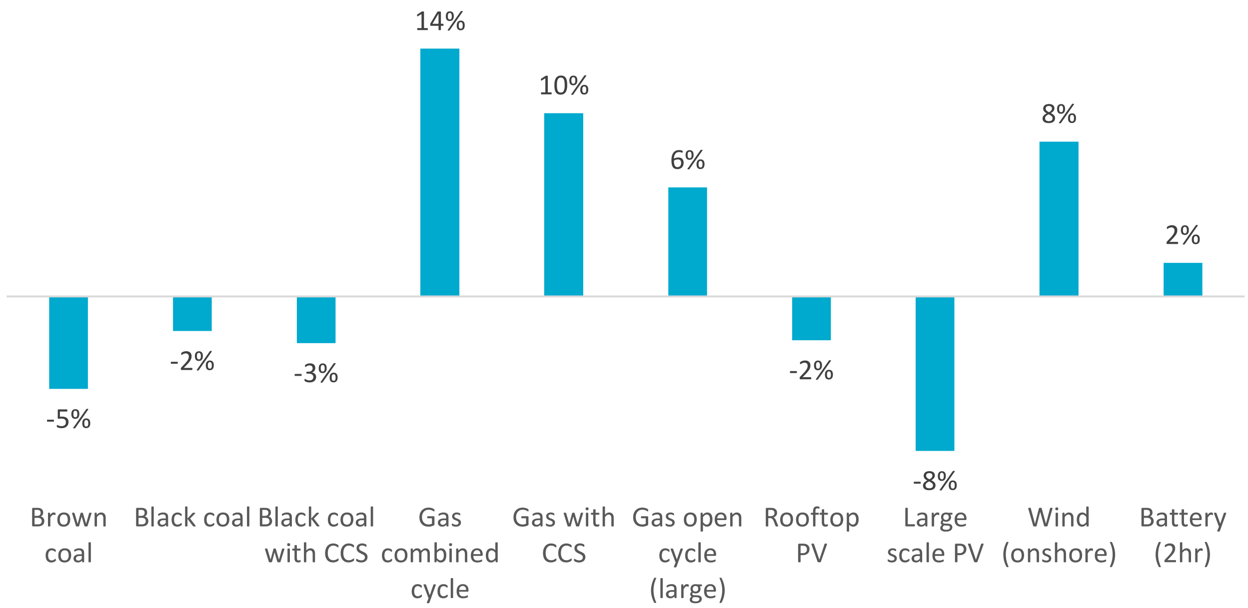
Outcomes of 2023-24 consultation

GenCost received the highest volume of feedback to the consultation draft in its history with 45 written submissions and many participating for the first time. This input has led to several changes, the most significant of which being the inclusion of large-scale nuclear in the report for the first time. GenCost has also increased wind generation costs and developed a revised approach for including solar thermal generation costs on a common basis with other bulk supply technologies.

Consultation continues to be a valuable way of improving the quality of the report given that no single organisation can cover the breadth of technologies explored. Feedback can take the form of suggestions and questions. Given the volume of feedback it has not been possible to individually address every question raised in the body of this report. However, we have now added Appendix D which addresses the major common questions and answers.

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. One year on, the inflationary pressures have considerably eased but the results are mixed. The capital costs of onshore wind generation technology increased by a further 8% while large-scale solar PV has fallen by the same proportion. Gas turbine technologies were the other main group to experience cost increases of up to 14% (ES Figure 0-1). The capital costs of other technologies were relatively steady. Technologies are affected differently because they each have a unique set of material inputs and supply chains.



ES Figure 0-1 Change in current capital costs of selected technologies relative to GenCost 2022-23 (in real terms)

Addition of integration costs for variable renewables in 2023

Solar PV and wind are called variable renewables due to their weather dependency. The 2023-24 GenCost report includes integration costs for variable renewables in 2023 for the first time and incorporates it in the LCOE. Most new-build technologies can enter an electricity system and provide reliable power by relying on existing capacity. Existing capacity can provide generation at times when the new plant is not available or when demand is rising but the new-build technology is already at full production. This includes new-build variable renewables when they are in the minority. However, as their share increases, forcing the retirement of existing flexible capacity, the system will find it increasingly difficult to provide reliable supply without additional investment.

To address this issue, GenCost calculates the additional cost of making variable renewables reliable at shares of 60%, 70%, 80% and 90%[1]. We call these additional costs the integration costs of variable renewables and they consist mainly of additional storage and transmission costs.

[1] 90% is about as high as variable renewable deployment is likely to need to go as increasing it further would result in the undesirable outcome of shutting down existing non-variable renewable generation from biomass and hydroelectric sources.

Feedback from the 2022-23 GenCost report requested that integration costs be presented that account for storage and transmission projects that will be delivered before 2030 since they have been sponsored by government or approved by the relevant regulator on the basis that they will be needed to support variable renewables. To accommodate that request, we present variable renewable integration costs for 2023 which include committed and under construction pre-2030 storage and transmission projects. 2030 LCOE results are also included but continue to exclude these pre-2030 costs since by 2030 they will represent existing capacity.

The results indicate that the cost of deploying high VRE shares is 12% to 36% higher in 2023 than in 2030. Around two thirds of the higher costs are due to investors having to pay 2023 instead of 2030 technology costs. Technology costs are falling over time. The remainder of the difference is due to the cost of the pre-2030 committed and under construction storage and transmission projects. Total integration costs to make high shares of variable renewables reliable are estimated at $41/MWh to $49/MWh in 2023 and $28 to $53/MWh in 2030 depending on the VRE share.

Addition of large-scale nuclear to GenCost

A majority of submissions to the 2023-24 consultation process requested the inclusion of large-scale nuclear in addition to nuclear small modular reactors (SMR) that had been included in GenCost since its inception in 2018. In response GenCost re-examined the appropriateness of large-scale nuclear and concluded that, although the deployment of large-scale nuclear would require a significant increase in the reserve margin relative to SMR and existing Australian generation plants, there was no known technical constraint to deploying generation units of this size. It was also concluded, due to the current state of the development pipeline in Australia, that the earliest deployment would be from 2040.

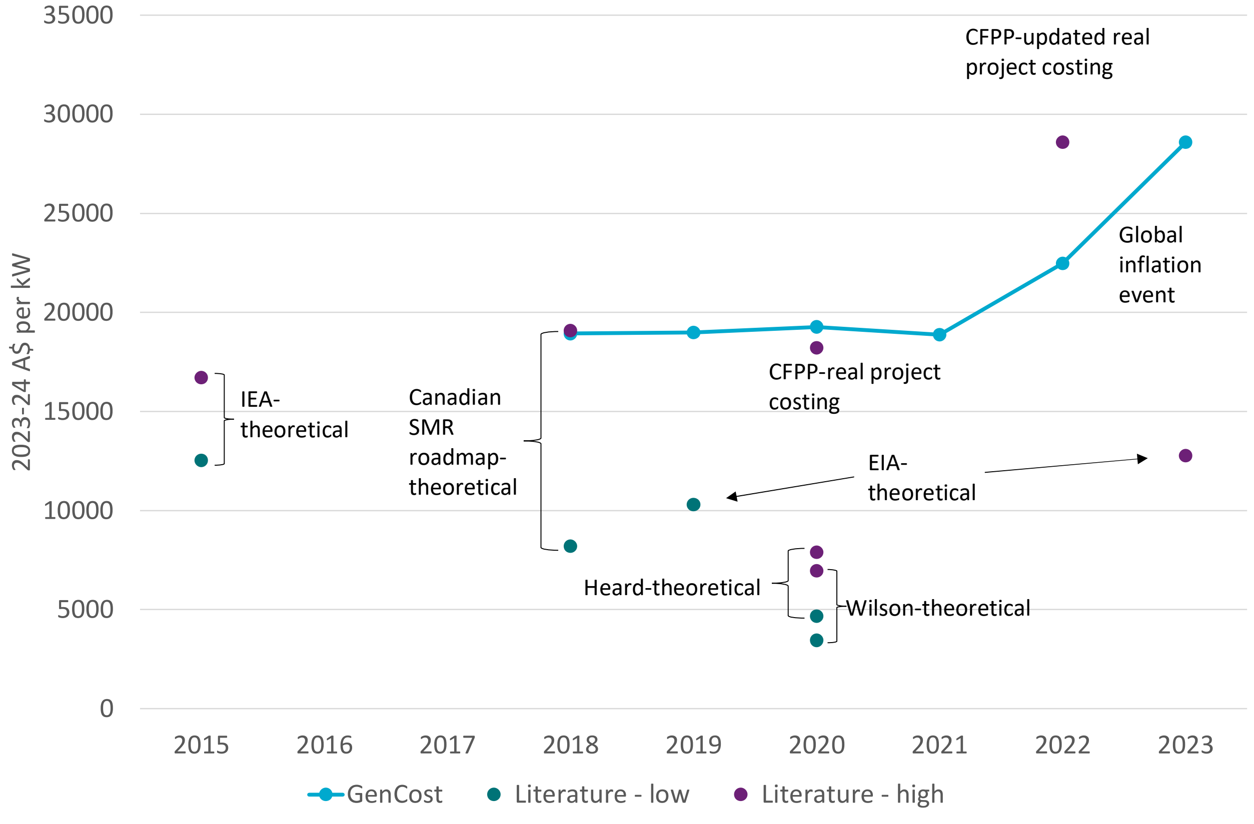
To source appropriate large-scale nuclear costs for Australia, it is necessary to rely on costs of large-scale nuclear deployed in other countries. Such costs are not directly transferable to Australia due to differences in a multitude of factors including labour costs, workforce skills, governance and standards. The source country for large-scale nuclear cost data also has to be carefully selected because there are large differences in costs between countries. The lowest costs occur in countries such as South Korea which has delivered a continuous building program for many years and costs are generally higher in western countries which have tended to have more sporadic building programs.

GenCost based its large-scale nuclear cost on South Korean costs as the best representation of a continuous building program consistent with other technologies in the report. GenCost then adjusted for differences in Australian and South Korean deployment costs by studying the ratio of new coal generation costs in each country. That ratio is used to scale the South Korean large-scale nuclear costs to Australian deployment costs. Based on this approach the expected capital cost of a large-scale nuclear plant in 2023 is $9,217/kW. This capital cost can only be achieved if Australia commits to a continuous building program and only after an initial higher cost unit is constructed. The first unit of all first-of-a-kind (FOAK) for Australia technologies are expected to be impacted by higher costs. This applies as much to nuclear as it does to other technologies such as offshore wind, solar thermal and carbon capture and storage. FOAK premiums of up to 100% cannot be ruled out.

The estimated electricity cost range for large-scale nuclear under current capital costs and a continuous building program is $163/MWh to $264/MWh. This is expected to fall by 2040, after current inflationary pressures resolve, to $141/MWh to $232/MWh.

Significant increase in nuclear small modular reactor costs

The cost of nuclear SMR has been a contentious issue in GenCost for many years with conflicting data published by other groups proposing lower costs than those assumed in GenCost (ES Figure 0-2). UAMPS (Utah Associated Municipal Power Systems) is a US regional coalition that develops local government owned electricity generation projects. Up until the project's cancellation in November 2023, UAMPS was the developer of a nuclear SMR project called the Carbon Free Power Project (CFPP) with a gross capacity of 462MW. It was planned to be fully operational by 2030. After conversion to 2023 Australian dollars, project costs were estimated in 2020 to be $18,200/kW which is only slightly below the level that GenCost had been applying ($19,000kW). This validated CSIRO's use of the higher end of the range presented in theoretical studies available at the time.



ES Figure 0-2 Timeline of nuclear SMR cost estimates (calendar year) and current costs included in each GenCost report (financial year beginning)

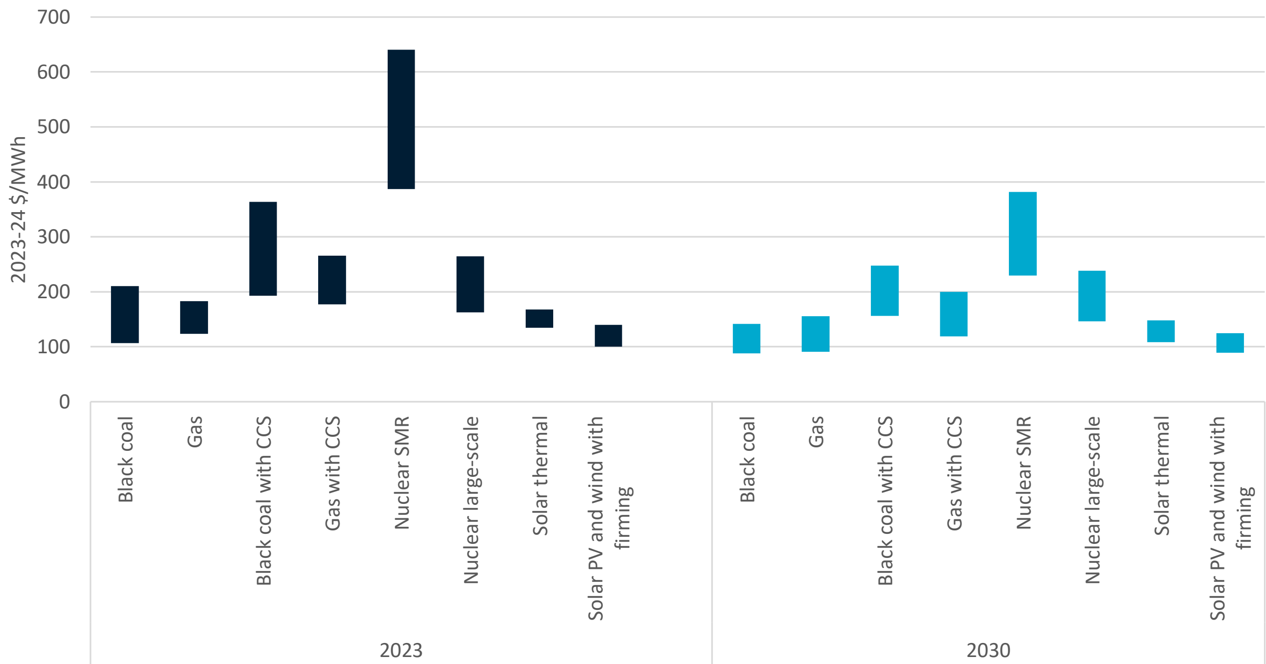
In late 2022 UAMPS updated their capital cost to $28,580/kW citing the global inflationary pressures that have increased the cost of all electricity generation technologies. The UAMPS estimate implies nuclear SMR has been hit by a 57% cost increase which is much larger than the average 20% observed in other technologies. This data was not previously incorporated in GenCost. Consequently, current capital costs for nuclear SMR in this report have been significantly increased to bring them into line with this more recent estimate. This new data is considered more reliable because all previous data was theoretical whereas the UAMPS project was the first to provide transparent data for a real project.

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 0-3).

The LCOE cost range for variable renewables (solar PV and wind) with integration costs is the lowest of all new-build technologies in 2023 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[2].

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.



ES Figure 0-3 Calculated LCOE by technology and category for 2023 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 0-3). For clarity, neither type of nuclear generation can be operational

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[2] 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

by 2030. Developers will need to purchase the technology in the 2030s sometime after an expected 11 years of pre-construction tasks are completed. 4 to 6 years of construction would then follow before full operation can be achieved. As such, the inclusion of large-scale and SMR nuclear in the 2030 cost comparison is only as a point of interest rather than practicality. 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.