Australia’s Energy Future: Nuclear power is a bet on unproven technologies with no track record of success

Submission from John Quiggin, Professor of Economics, University of Queensland to House Select Committee on Nuclear Energy

At the beginning of the 21st century, nuclear power appeared as an established technology. New “third generation” (Gen III and III+) designs promised to reduce construction costs while overcoming the safety risks that had led to the general abandonment of new nuclear projects following the Three Mile Island and Chernobyl catastrophes. By contrast, as recently as 2010, solar photovoltaics (PV) was a nascent technology, confined to niche applications, and requiring substantial subsidies.

In the last decade and a half this situation has completely reversed. The failure of the “nuclear renaissance” in the US and other Western countries means that we have virtually no operating experience of Gen III reactor designs, while the handful of completed projects have experienced cost overruns and delays similar to those that end the first wave of nuclear projects in the 20th century.

Although some proposals for large reactors remain current, most attention has shifted to small ‘modular’ designs which have not been built even in prototype form. The costs and operating performance of these designs remains purely speculative.

By contrast, solar PV has expanded massively and is now a well-established technology, which could be classed as “mature” except for the fact that it is still experiencing rapid technological progress. Even disregarding future possibilities for progress, solar PV is the already the cheapest source of new electricity generation in most places, and cheaper than existing coal and gas in sunny locations such as Australia.

Furthermore, the relatively recent development of battery technology, which provides a solution to the fact that solar PV is not available at night, is now well-established, on a scale larger than Gen III nuclear. Utility scale battery storage in the United States is expected to reach 30 Gigawatts by 2025.

Perceptions formed in the first decade of the century continue to influence the thinking of many commentators, leading them to think of nuclear power as well-understood and reliable, unlike ‘new-fangled” solar. The reality is the opposite. For Australia in the 2020s and 2030s, nuclear power represents a leap into the unknown. Nuclear advocates are betting on technologies which have no track record of success and, in many cases, no track record at all.

Large scale nuclear

Much of the discussion of nuclear power in Australia focuses on the experience of the 20th century and, in particular, the relatively successful French nuclear program of the 1970s. However, the French case was exceptional, reflecting low construction costs and the availability of subsidised capital from the French state. In most other countries, including Canada and the United States, nuclear power projects experienced delays and cost overruns. By the 1980s, France was experiencing similar cost increases.

The ‘Generation II’ designs used in the 20th century are no longer relevant for two main reasons

(i) Catastrophic failures including Three Mile Island, Chernobyl and Fukushima, which have led to requirements for additional and expensive safety features. Even if Australia were to set lower standards, no company now supplies Gen II reactors

(ii) Increased on-site construction costs, which resulted in the abandonment of most projects in the late 20th century, including the end of the French program.

The large reactors currently available are classed as Generation III or III+. These designs incorporate a more modular approach to construction with major elements being produced offsite. However, they are not “modular” in the sense associated with (so far non-existent) small modular reactors, where the entire reactor would be factory-built.

In the early 21st century, there were high hopes for a “nuclear renaissance’ particularly in the United States. However, only two reactors were ultimately completed, at Vogtle in Georgia. Other projects were abandoned after the expenditure of billions of dollars. Similarly, only two new reactors were completed in Europe. More recently, Korean company KEPCO has delivered eight reactors in Korea and the United Arab Emirates.

	Abandoned/ cancelled	Operational	Ex China	Under construction	Reactor years	Ex China
AP1000	4	6	2	0	27	1
EPR	1	4	2	3	12	1
APR1400	0	8	8	4	24	24
Candu ACR1000	0	0	0	0	0	0
ESWBR	4	0	0	0	0	0
Toshiba AWBR	4	0	0	0	0	0
Total	13	18	12	7	63	26

New plans

There are a number of proposals for the construction of large nuclear plants. However, none will be completed in time to provide useful information for Australia's energy policy. The list below covers the most advanced proposes.

* South Korea has started construction on two plants due to become operational in the early 2030s

* Poland agreed with Westinghouse for construction of nuclear plants to be operational by 2032 or 2033. Following a change of government, the estimated starting date was revised to 2040. No financing model has been agreed and construction has not commenced.

* EDF proposed Sizewell C in 2012. On current estimates, allowing for construction start in 2026, commission between 2035 and 2040. No financing model agreed and construction not yet started

* Czechia began a process for new nuclear power in 2019. Current agreement with KNHP for an APR1000 (modified APR1400). Target date 2038.

* France has announced plans for six new reactors, with a planned commencement of construction by 2027

* There are no proposals for new large reactors in the US or Canada

A policy aimed at delivering large scale nuclear power in Australia before 2050 would require a design to be selected and contracts to be signed by 2035 at the latest. None of these proposed plants will be operational by then.

Small and medium reactors

The term “small modular reactor” is used to refer to two radically different reactor design classes.

First, there are reactors small enough (typically generating less than 100MW) to be assembled in a factory and shipped to a location where they can be installed in a modular fashion, with as many reactors as needed to meet demand.Second there are reactors which are similar to existing Gen III/III+ designs (in fact, often modified versions of these designs) but with power output around 300MW. These reactors are described as modular in the sense that, like all modern reactor designs, significant parts of the reactor are built off-site before being shipped to the site for assembly. I will refer to these as ‘medium sized reactors”.

Small Modular Reactors

I will use the term Small Modular Reactor (SMR) to refer to reactors small enough to permit factory production (typically less than 100 MW) and intended to be combined in a modular fashion to deliver the electricity required at a given site. The central idea is that the economices of factory production with large runs will offset the loss of scale economies associated with a small reactor.

The history of SMRs has been one of unfulfilled promise. In 2012, SMRs were seen as a likely option for large-scale deployment in the early 2020s. Three US companies, Babcock and Wilcox, Nuscale and Westinghouse received US government grants to develop SMRs with the aim of commercial deployment by 2022. None of these ultimately proceeded to construct even prototypes.

At the time of my 2015 submission to the SA Royal Commission only the Nuscale project remained, with a target date of initial commercial deployment by 2024. Uniquely among SMR designs, Nuscale reached the point of an actual contract with a commercial buyer Utah Associated Municipal Power Systems (UAMPS). However, repeated delays and cost blowouts led UAMPS to terminate the project in late 2023.

This record of failure might have been expected to result in reduced interest in SMRs. In reality, however, there has been a profusion of designs. Wikipedia lists no fewer than 60 designs. With the exception of two projects in Russia and China, none has yet reached the prototype stage, though initial work has been done on some projects.

At present, the leading contenders, apart from NuScale, include X-energy, Oklo, Kairos and Terrapower among others. Most are proposing ambitious schedules for prototype construction, despite previous delays and failures. For example, Terrapower, backed by Bill Gates is currently developing a molten salt reactor with a proposed completion date of 2030. The same company spent more than a decade developing a radically different design, the travelling wave reactor, which was proposed for operation by 2024. This project has now apparently been abandoned.

It will be unclear for some years which, if any, of these designs are technically feasible. But the very profusion of designs creates an almost insoluble problem. The economic operation of SMRs depends on the efficiencies available from factories with long production runs. But this in turn requires that only one, or at most a handful of designs should capture the entire market. Even if prototype designs are produced in the early 2030s, the determination of which will make it to market, will take many more years. Since the Australian market is too small to make a design economic, any choice of SMRs must wait until this process is complete, probably in the 2040s.

Medium sized reactors

The earliest nuclear reactors, built in the 1950s and 1960s were small by today's standards. However, manufacturers rapidly realised that economies of scale could be achieved with larger reactors. The main constraint was that a reactor should not be so large that an unplanned outage would disrupt the entire grid. The "sweet spot" turned out to be around 1000MW, and most reactors constructed after 1970 were close to this size.

The logic underlying this process has not changed. Rather, the popular appeal of the term "small modular reactor" has led manufacturers of traditional large reactors to meet the apparent market demand with scaled down models. Notable examples include the Westinghouse AP300 and the GE Hitachi BWRX-300, based on the (licensed but never constructed) Economic Simplified Boiling Water Reactor (ESWBR) and ultimately derived from 20th century Boiling Water Reactor design. Rolls-Royce offers a 470 MW design, also referred to as an SMR, and originally proposed around 2017.

The Westinghouse AP300 may be taken as the archetypal example of a medium size reactor, based on an actually existing large reactor. As noted by its proponent,

> The 300-MWe/900-MWth AP300, launched on May 4, is a compact single-loop version of Westinghouse's 1,100-MWe AP1000 reactor. "We're talking about the same technology, the same equipment, the same safety basis—there's no new technology here," David Durham, president of Westinghouse Electric Co. Energy Systems,

https://arc.net/l/quote/ubntvoos

On an optimistic view, replacement of two reactor loops by one might reduce some cost components by 50 per cent. Others, such as control systems would more likely remain unchanged. And the basic engineering physics of thermal boilers implies that halving the capacity of a boiler will not reduce the costs by 50 per cent.

It follows that in terms of capital cost per MW, a scaled down design like the AP300 cannot be cheaper than the larger original. And, indeed, Westinghouse has not claimed this explicity. Rather, the company has offered optimistic assessments of the cost of the AP300, which compare favorably with the very high realised costs of the Vogtle and (abandoned) VC Summer projects. Other commentators have joined the dots to conclude, incorrectly, that the AP300 is more cost effective than the AP1000.

The main advantage of medium-sized reactors are that they can be deployed in grids where a full-sized reactor would be too large, and that financing is likely to be more straightforward. On some estimates, this enough to reduce or eliminate the inherent cost differential associated with a smaller reactors. However, it is unlikely that medium-sized reactors will be cheaper.

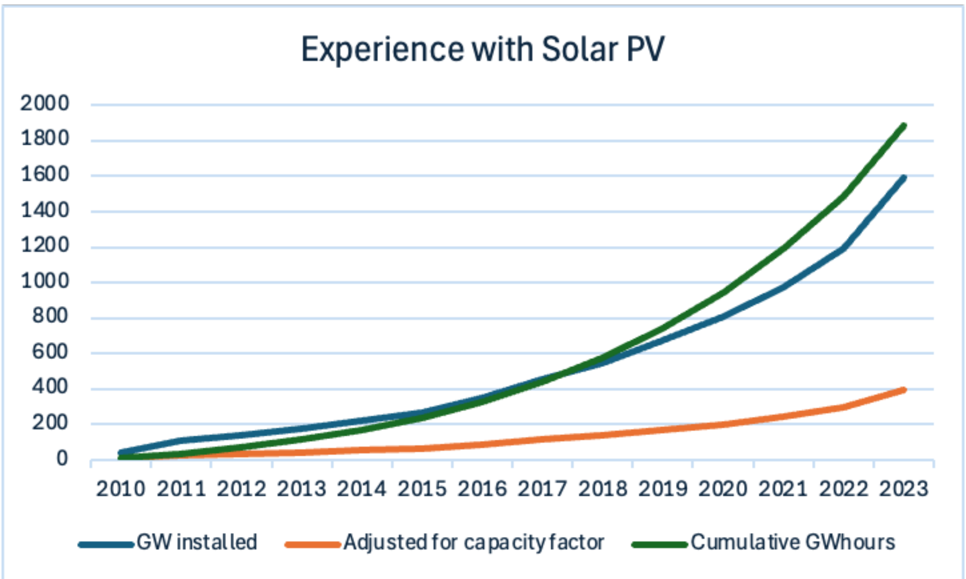
Unlike the more innovative designs that may genuinely be classed as "small modular reactors", we can at least have reasonable confidence that medium-sized reactors like the AP300 are technically feasible since they are based on existing operational designs.

Comparison with solar photovoltaics and wind

As recently as 2010, solar PV was a marginal technology in electricity generation. Since then, installations of solar PV have totalled 1590 GW. Allowing for a 25 per cent capacity factor, the equivalent in full-time generating capacity now totals nearly 400 GW. This is comparable to the entire installed base of nuclear power and far greater than the base of Gen III nuclear reactors installed since 2000. As a result, we now have nearly 1900 GW-years of generating experience with solar PV, compared to less than 100 GW years of experience with Gen III reactors. These points are illustrated in Figure 1.

This experience has shown that failure rates and maintenance costs are minimal (mainly cleaning) , and that degradation of performance is modest enough to satisfy the requirements of a typical 25-year warranty.

As with nuclear power, it seems likely that solar panels can continue working well beyond their official service life. However, the massive improvements in efficiency observed over a 25-year period suggests that, in most cases, it will be more cost effective to upgrade to new panela.



The same points can be made with respect to wind power. Wind power is now a well-established technology with a track record of reliable generation and a steadily declining cost trajectory.

Conclusion

The adoption of nuclear power in Australia would represent a leap in the dark. None of the technologies currently under consideration (Gen III large nuclear,. Small Modular Reactors and medium-sized reactors) has any significant track record of reliably delivering electricity at an economically reasonable cost. The handful of large Gen III reactors that have been delivered in the past 25 years have, like the Gen II reactors that preceded them, been characterised by massive delays and cost-overruns. No SMRs or medium-sized reactors have been constructed (with the exception of one reactor each in China and Russia) and none is likely to be operational in time to be relevant to Australia's energy transition.

By contrast, solar PV and wind are well-established technologies with a track record of reliable generation and history of declining costs (steady in the case of wind, spectacular in the case of solar). The advent of battery and other storage technologies is already resolving the problem of intermittency.

The appeal of nuclear power may be described as 'retrofuturistic'. That is, it rests on nostalgia for an optimistic vision of the technological future that prevailed in the 1950s and 1960s, but was not borne out in reality.

In the 21st century, 'renewables' such as solar PV and wind are reliable and well-established technologies with almost unlimited scope for expansion. Australia should take this path into the future.