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# The Case for SMRs in Australia

*June 2021*

## NuScale Power SMR

Image: NuScale Power

**12 x 77 MWe modules, 924 MWe on 18 hectare site**
**August 2020 US Nuclear Regulatory Commission (NRC) Final Safety Evaluation Report issued - first SMR to achieve NRC design approval.**

# The Case for SMRs in Australia

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**EXECUTIVE SUMMARY**


Nuclear power, particularly in the form of Small Modular Reactors (SMRs), provides diversity in electricity generation and long-term energy security. Here we outline the case for Australians to consider SMRs as part of the clean energy mix:

1. **Reaching Net Zero Emissions in Australia:** SMRs will make a valuable contribution to the reduction of greenhouse gas emissions from electricity generation, enabling Australia to reach net zero emissions economy-wide.
2. **Reliability:** SMRs will improve the reliability and resilience of Australia's electricity system by providing dispatchable generation, system inertia and frequency control.
3. **Affordability:** Modern SMRs are most likely to become the lowest cost clean generation in Australia because of their high capacity factor.
4. **Safety:** Modern SMRs are designed to be inherently safe.
5. **Radioactive Waste  and Used Fuel:** SMRs produce very little waste from day to day operations and the used fuel for the lifetime of the facility can be managed on site.
6. **Creating Jobs and Facilitating Economic Development:** SMRs will create many new jobs, help Australia become an innovative country and develop new industries.

***The development of nuclear power generation in Australia will lead to the establishment of an entire new industry with long-term environmental, technological, economic and social development benefits. These benefits will flow on progressively to other industries, all while bringing the economy closer to net zero emissions***.

## 1. Reaching Net Zero Emissions in Australia

***SMRs will make a valuable contribution to the reduction of greenhouse gas emissions from electricity generation and other sectors, enabling Australia to reach net zero emissions economy-wide.***

Australia's annual emissions from electricity generation for the year 2013 were 183 million tonnes CO2-equivalent (National Greenhouse Gas Inventory).

Six years later, and after billions of dollars spent on wind and solar, Australia's annual emissions from electricity generation for the year 2019 were 176 million tonnes CO2-e.

Australia has one of the world's highest emission intensities, typically 820 kg CO2-e/MWh (Finkel Review). Countries with low emissions intensities either have large hydro resources (e.g., Norway) or have nuclear as part of their energy mix (e.g., France, Belgium)[1].

***Nuclear power already makes a significant contribution to reducing emissions from electricity generation worldwide.***

In 2019, 2,657 TWh were generated by nuclear power reactors worldwide, saving over 2 billion tonnes CO2-e emissions (World Nuclear Association). In 2018, nuclear generated more electricity than solar and wind combined.

In 2019/20, Australia exported 7,195 tonnes of uranium oxide concentrate (ASNO Annual Report)[2] which would have generated ~243 TWh of clean electricity and saved the recipient countries around 200 million tonnes CO2-e, yet Australia does not take advantage of this valuable resource.

Australia must utilise every safe, low-emissions technology to reduce its emissions, including nuclear. Nuclear energy is already deployed in 31 other countries, with four new countries currently building nuclear power plants for the first time.

***Nuclear has zero operating emissions and low whole of life cycle emissions comparable with renewables.***

Nuclear power, like wind, solar and hydro, has zero operating emissions. The South Australia Nuclear Fuel Cycle Royal Commission examined in detail the whole of life cycle emissions for different electricity generation technologies. The median value for nuclear is 12 kg/MWh, the same as wind. Solar is slightly higher at 18-50 kg/MWh.

The Finkel Review reported a very large difference between low-emissions technologies (wind, solar, hydro, nuclear) that have zero operating emissions and the lowest intensity fossil technology, combined cycle gas turbine (CCGT), that has an operating emissions intensity of 370 kg/MWh. Firming renewables requires more open cycle gas turbine (OCGT) use as seen in South Australia. It is useful to examine the AEMO fuel mix record for South Australia[3]. The wind generation is seen to vary between <10% to 80%. To compensate, gas generation is 15% to >80%. This is not a long-term solution for low emissions.

[1] https://www.electricitymap.org/map
[2] https://www.dfat.gov.au/sites/default/files/asno_annual_report_2019-2020.pdf
[3] https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/data-nem/data-dashboard-nem#average-price-table

***Beyond electrical generation, emission reductions in other sectors, such as industry and transportation, are needed to achieve net zero economy-wide emissions.***

Emissions reductions are required in all areas of energy production and use. Industry commonly uses coal or gas for process heating. Modern nuclear reactors can produce process heat which can reduce emissions from industry. Wind and solar cannot provide process heat directly. Nuclear power not only reduces emissions from electricity generation, but also provides a pathway to emissions reductions in many other industries.

## 2. Reliability

***Small modular reactors (SMRs) will improve the reliability and resilience of Australia's electricity system by providing dispatchable generation with capacity factors in excess of 95%, along with***

SMRs have been deployed to power submarines and icebreakers for more than 60 years, in applications where reliability is essential.

SMRs with plant outputs of between 50 and 900 MW are particularly suitable for the Australian power system. SMRs have features that will enable them to work effectively in a power system that has intermittent renewables.

The leading US example is the NuScale SMR which has received design approval from the US Nuclear Regulatory Commission (NRC). Up to twelve 77 MW modules can be accommodated in one power plant to provide a gross output of 924 MW, with a capacity factor of greater than 95%.

Nuclear power plants operate regardless of the weather. They are designed to continue operating in extreme weather conditions. There are many examples in the US where nuclear power plants have continued to supply electricity in extreme weather conditions, when other electricity generators have failed. PV panels can easily be damaged by storms and particularly by hail.

***Modern SMRs are designed to "load follow" and can support weather-dependent renewables.***

SMRs are designed to load-follow and enable the further operation of intermittent renewables. For example, the NuScale SMR has a 100% turbine bypass to enable fast load changes and each module output can be changed at 200% per hour. With 12 modules, this provides a response that exceeds the US Utility Requirements for load following

SMRs do not rely on grid supplies for safety. On loss of grid, modern SMRs can remain in operation and are then ready to contribute to re-establishing the grid. If an SMR had been operating in South Australia at the time of the September 2016 State blackout, the grid could have been restored quicker than it was. However, if an SMR **had** been operating in South Australia at the time, it is unlikely that the State blackout would have occurred in the first place.

## 3. Affordability

***Modern SMRs are likely to become the lowest cost clean generation available in Australia because of their high capacity factor.***

The final cost of individual plants will depend on location-specific factors determined during feasibility studies. However, as with wind and solar energy, nuclear costs are coming down due to simpler and standardised design; factory-based manufacturing; modularisation; shorter construction time and enhanced financing techniques.

Nuclear power plants were traditionally very large in order to capture economies of scale. In some cases, this has caused construction delays and increased costs. Modern SMRs will be factory-built, and the complete reactor module is transported to site and installed with minimum on-site work. This reduces site construction time and the risk of expensive delays.

The 2017 report by the US Energy Innovation Reform Project found that the costs for the new generation of advanced reactors would be much lower than for conventional nuclear power plants. The US study found that the average levelised cost of electricity (LCOE) from advanced reactors was US $60/MWh. This would be $A78/MWh (0.77 exchange rate).

The 'whole of system' advantages of nuclear power have important strategic implications for the NEM and the entire economy. Electricity needs to be available on demand, 24 hours a day, 7 days a week and in all weather conditions.

In looking at the economics of different power generation options, it is essential to understand the distinction between generation costs and power system costs and to adjust for the low capacity factors, additional transmission costs and firming costs of intermittent renewable energy options.

Nuclear is available at full capacity 24 hours a day but solar, for example, starts with a low ouput at sunrise, rises to maximum output around midday and then drops to zero at sunset. You must therefore multiply the capital cost of solar by at least four times to get the same amount of electricity. Importantly, solar is not available at the time of the evening peak.

Although the operating costs of wind and solar are lower than nuclear, the real cost to the power system is higher. This is due to their low capacity factor, additional transmission costs and firming costs.

Modelling by the Australian consultancy Electric Power Consulting of Kiama in 2018 showed that the cost of a system with 100% renewables would be more than 4 times the cost of a system where coal was replaced by nuclear [4].

***With the repeal of Australia's legislative ban on nuclear power, it will be feasible to build an SMR by 2030 and several gigawatts of nuclear by 2040.***

The construction and operation of a nuclear power plant in Australia is presently prohibited by the Environment Protection and Biodiversity Conservation (EPBC) Act and the Australian Radiation Protection and Nuclear Safety (ARPANS) Act.

[4] Electric Power Consulting https://epc.com.au/index.php/nem-model/

The prohibition was put in place at a time when there was no real appreciation of the contribution that modern, safe nuclear power plants could make to energy security, affordability and emissions reduction.

In May 2016, the South Australia Nuclear Fuel Cycle Royal Commission recommended that prohibitions be removed:

> *Recommendation 8 - Pursue removal at the federal level of existing prohibitions on nuclear power generation to allow it to contribute to a low-carbon electricity system, if required.*

The House of Representatives Standing Committee on the Environment and Energy in its report on a federal inquiry into nuclear energy in Australia recommended: "lifting its moratorium on nuclear energy in relation to Generation III+ and Generation IV nuclear technology including small modular reactors, subject to the results of a technology assessment…and a commitment to community consent as a condition of approval."

The legislative prohibitions preclude any serious consideration of the merits of nuclear power generation in Australia. SMR vendors will not treat Australia as a potential market whilst the prohibitions remain.

Although government reports have repeatedly endorsed the merits of "technology neutrality" in power system planning, the legislative prohibitions have prevented its accomplishment.

System reliability, as well as affordability and lower emissions, beyond 2030 can only be underwritten by including load-following nuclear generation in the generation mix and allowing all technologies to compete with each other.

The actual time of construction of an SMR is planned to be around 36 months. This would be preceded by a period of around 4 years for community consultation, site selection, feasibility studies, environmental and development approvals and arranging financial facilities, making a total development period of around 7 years after the law is changed to lift the prohibition on nuclear power.

## 4. Safety

***Modern SMRs are designed to be inherently safe.***

Currently, nuclear power already has the lowest incidence of death and accidents amongst all energy production technologies, comparable to renewables, and many times lower than fossil fuels.

Following the accident at the Chernobyl nuclear power plant in the Ukraine in 1986, the nuclear power industry became one of the most highly regulated industries in the world. In this regard, the Convention on Nuclear Safety (CNS) came into force in 1994, laying down the fundamental principles for the protection of individuals, society and the environment from the harmful effects of ionising radiation. The CNS has 152 Member States, including Australia.

Australia's safety regulations are laid down by Commonwealth law and are enforced by the Australian Radiation and Nuclear Protection Agency (ARPANSA) for Commonwealth entities.

In 2013, the UK Tyndall Centre for Climate Change, in a report for Friends of the Earth, found that:

> *"… overall the safety risks associated with nuclear power appear to be more in line with lifecycle impacts from renewable energy technologies and significantly lower than for coal and natural gas per MWh of supplied energy".*

In 2016, the South Australia Nuclear Fuel Cycle Royal Commission concluded that safety was not a basis for ruling out nuclear power in Australia.

Learning from the past operations of nuclear power plants, modern SMRs are designed to be inherently safe, avoiding Chernobyl-type or Fukushima-type accidents.

Modern SMR designs have now become a game-changer for nuclear safety. Although traditional reactors are already safe, SMRs take safety to a new level of "walk-away safety". For example, the NuScale SMR does not require any operator action, backup electrical supplies or water supplies and would have survived even the Fukushima accident. The passive safety systems enable the reactor to be cooled indefinitely without attention.

The US NRC has confirmed that the NuScale plant does not require any emergency electrical generators to keep the plant safe. The NuScale SMR is the first nuclear reactor design to have achieved this accreditation in the US.

## 5. Radioactive Waste and Used Fuel

***Nuclear power produces very little waste and occupies less land than renewables because of its high energy density.***

The 924 MW 12 module NuScale SMR would produce each year only 120m$^3$ (two shipping containers) of low level waste that is packaged and stored in drums before being transported to a low level waste repository. The required repository is a simple, near-ground level engineered facility to hold the waste securely, usually in concrete cells, for around 300 years.

A NuScale module would also produce only ~1500 kg/year of used fuel which is initially stored in cooling pools in the reactor building and then stored in dry casks on site or reprocessed. The final disposal of the small amount of waste from reprocessing or complete used fuel assemblies will be in a deep geological repository. Construction of this type of facility is in progress in Finland. Sweden and France are in the final stages of licensing their geological repositories. Several countries, including Australia, are looking at borehole disposal.

Renewables like wind and solar are very low energy density technologies, that is, the physical quantity of materials and land required for a given output is very high. The amount of concrete and steel in a wind turbine is more than 10 times the quantity in a nuclear power plant for a given output. The NSW Nyngan solar plant has 1,350,000 PV panels on frames supported by 150,000 posts but produces only 102 MW peak output.

Wind and solar farms also require large areas of land. For example, the 150 MW Coleambally (NSW) solar plant occupies 550 hectares. This can be compared to a 924 MW NuScale plant that occupies only 18 hectares.

In addition, the turbine condensers for modern SMRs can be air cooled and do not require large quantities of water. They do not need to be located near a river or on the coast.

### 6. Creating Jobs and Facilitating Economic Development

***SMRs allow for local job creation and regional economic development, especially in communities with retiring coal plants.***

The first NuScale SMR is planned to be sited near Idaho Falls, USA. The Idaho Department of Labor has forecasted that the SMR will generate 12,800 local jobs during construction and 1,500 during operations.

The 1,000 direct construction jobs would create or support an additional 11,800 jobs through “inter-industry” trade and local services for the new workforce. NuScale expects direct construction jobs to peak at 1,100 employees and this would last for much of the three year site build.

The new plant will also support long term employment in Idaho Falls. NuScale expects the plant to directly employ 270 workers when it is online and the Department of Labor expects this will support 1,500 local jobs, equating to annual revenues of US $389 million for local industry in this regional area.

In Australia, SMRs would be ideal to re-power retiring coal-fired power station sites. Much of the supporting infrastructure – transmission connections, cooling water supplies, admin and maintenance buildings, etc. – could be reused. As in the UK and US, the existing staff can be retrained to operate and maintain the plant, saving jobs and the local economy.

NuScale has issued a report on repurposing US coal plants including the transition of workers to similar positions.[5]

## Conclusion: SMRs Enabling an Innovative, Net Zero Emissions Economy

***Reliable, clean energy from SMRs will reduce emissions from industry and open the door to innovation, such as producing and exporting cheap, clean hydrogen.***

Australia is looking at hydrogen as a key fuel for the future. This relies on the efficient and economic production of hydrogen. In his address to the Press Club on 12 February 2020, Chief Scientist Alan Finkel stated that “There’s a nearly A$2 trillion global market for hydrogen come 2050, assuming that we can drive the price of producing hydrogen to substantially lower than A$2/kg.” Process heat increases the efficiency of hydrogen production. Renewables cannot produce process heat, but nuclear reactors do, particularly the Gen IV types like the Terrestrial Molten Salt Reactor which supplies process heat at 600$^{o}$C for high temperature electrolysis. This enables hydrogen production at a cost comparable to steam methane reforming from gas, but with no emissions and a cost less than one third of renewable energy electrolysis (Terrestrial submission 260 to Federal Nuclear Inquiry).

[5] http://www.smrnuclear.com.au/wp-content/uploads/2021/04/nuscale-smr-technology-an-ideal-solution.pdf

In the modern era, the nuclear industry is transforming itself to meet contemporary community expectations and enable countries to transition to net zero emissions. Modern SMRs are designed to be inherently safe and will provide reliable, affordable and low-emissions power for 60-80 years.

When the legislative prohibitions on nuclear facilities are repealed, SMRs could be developed and become be a game-changer in Australia power system planning, progressively replacing obsolete power generators as they close down over the next 30 years.

***The development of nuclear power generation in Australia will lead to the establishment of an entire new industry with long-term environmental, technological, economic and social development benefits for the people of Australia. These benefits would flow on progressively to other industries, all while bringing the economy closer to net zero emissions.***

## GE Hitachi BWR-300 SMR
## 300 MWe
## December 2019 started regulatory licensing process with NRC

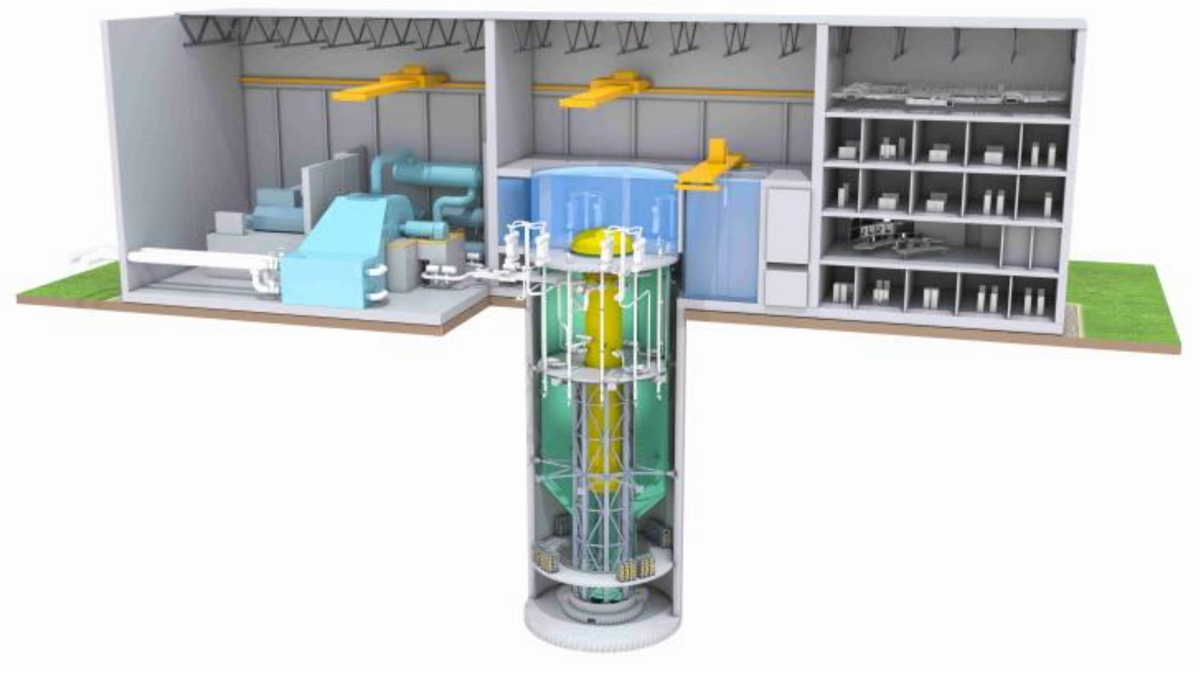

Image: GE Hitachi Nuclear Energy

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