



**SMR Nuclear Technology Pty Ltd**

Governor Macquarie Tower

Level 23, 1 Farrer Place

Sydney NSW 2000

ABN: 88 160 242 428

[www.smrnuclear.com.au](http://www.smrnuclear.com.au)

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## **The Advantages of Safe Nuclear Power for a Reliable, Dispatchable and Low-Emissions Power System in Australia**

*A Submission by SMR Nuclear Technology Pty Ltd to the House of Representatives Standing Committee on the Environment and Energy*

*May 2021*

### **INTRODUCTION AND EXECUTIVE SUMMARY**

Nuclear power, particularly in the form of Small Modular Reactors (SMRs) provides diversity in electricity generation and long-term energy security.

SMRs would improve the resilience of Australia's electricity system providing dispatchable generation, system inertia and frequency control.

SMRs would make a useful contribution to the reduction of green house gas emissions from electricity generation and other sectors.

SMRs would help Australia become an innovative country and develop new industries.

There are only four practical technologies available for low-emissions power systems: hydro, solar PV, wind and nuclear power.

Nuclear power and hydro are the only technologies that are dispatchable  
Nuclear power is the only one of these that is not weather-dependent.

Nuclear power is already making a vital contribution to reliable, affordable and low-emissions power systems in 30 other countries.

SMRs are designed to be inherently safe.

SMRs are likely to be a game-changer for the Australian power system planning, replacing obsolete power generators that may be closed down over the next 30 years.

Australia will have the opportunity of establishing a completely new industry, bringing highly-skilled job opportunities and long-term environmental, technological, economic and social development benefits that will flow to its entire population.

## 1. Reliability

*Modern nuclear power plants are reliable, dispatchable and safe, with capacity factors in excess of 90%.*

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 would be particularly suitable for the Australian power system. SMRs have features that will enable them to work effectively in a power system that has variable renewables.

The leading US example is the NuScale SMR which has received design approval from the US Nuclear Regulatory Commission. Up to twelve 77 MW modules can be accommodated in one power plant to provide a gross output of 924 MW. The NuScale plant is specifically designed to automatically adjust its output to compensate for the variable generation from wind turbines (see Section 9).

The NuScale plant has a capacity factor of 95%. Data from the US EIA shows that nuclear power plants in the USA routinely operate with a capacity factor of > 90%.

The safety features of modern SMRs are elaborated further in section 5 below.

## 2. Affordability

*Modern SMRs are likely to become the lowest cost generation available in Australia because of their contribution to power system reliability.*

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.

The 'whole of system' advantages of nuclear power has important strategic implications for the NEM and the entire economy. (see section 7 for further details).

## 3. Lower Emissions

*Nuclear power will contribute to Australia overcoming its lack of success to date in significantly reducing emissions from electricity generation.*

Australia's annual emissions from electricity generation for the year December 2012 were 191 million tonnes CO<sub>2</sub>-e (National Greenhouse Gas Inventory).

Five years later, and after billions of dollars spent on wind and solar, Australia's annual emissions from electricity generation for the year March 2017 were 188 million tonnes CO<sub>2</sub>-e.

Australia has one of the world's highest emission intensities, typically 820 kg CO<sub>2</sub>-e /MWh (Finkel Review). Countries with low emissions intensities either have large hydro resources (Norway) or have nuclear as part of their energy mix (France, Belgium)<sup>1</sup>.

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

In 2018, 2,563 TWh was generated by nuclear power reactors worldwide, saving over 2 billion tonnes CO<sub>2</sub>-e emissions (World Nuclear Association). Also in 2018, nuclear generated more electricity than solar and wind combined.

In 2015/16, Australia exported 8,417 tonnes of uranium oxide concentrate (ASNO Annual Report) which would have generated ~280 TWh and saved the recipient countries more than 250 million tonnes CO<sub>2</sub>-e, yet Australia does not take advantage of this valuable resource.

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

Nuclear power, like wind and solar, 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 12kg/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, CCGT, that has an operating emissions intensity of 370 kg/MWh.

## 4. System Planning

***With the repeal of the legislative ban, it should be feasible to develop an initial MW SMR nuclear generation plant by 2030 and several GWs by 2040.***

The construction and operation of a nuclear power plant in Australia is presently prohibited by the EPBC Act and the ARPANS Act.

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.*

<sup>1</sup> <https://www.electricitymap.org/map>

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 be underwritten by including load-following nuclear generation in the generation mix and allowing all technologies to compete with each other.

***Modern SMRs could make a vital contribution to Australia’s needs for reliable, low-emissions, affordable energy.***

Without repeal of the legislative ban, Australia’s power system will continue to be constrained at great cost to the economy.

## 5. Safety

Nuclear energy has the lowest incidence of death and accidents amongst all energy production technologies, comparable to renewables. It is 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 what we believe from a safety point of view to be the most highly regulated industry 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. Under the CNS, each country must establish safety regulations for nuclear power.

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.

Modern SMRs are designed to be inherently safe, avoiding Chernobyl-type or Fukushima-type accidents.

SMRs can be installed below ground level. This protects them from external hazards and unauthorised access. The reactor building is able to withstand aircraft impact.

The NuScale module sits in a large “swimming pool” enabling the reactor to be cooled indefinitely without attention.

Modern SMR designs have now become a game-changer for nuclear safety. Although traditional reactors are 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 - “indefinite cooling time”.

The US Nuclear Regulatory Commission (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.

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.

Australia has a world-class nuclear regulator, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

## 6. Environmental Issues

### *i) Emissions*

Energy production not only has short-term health impacts relating to accidents and air pollution; there are also the long-term, environmental impacts relating to climate change. Signs of this are already starting to show, with extreme weather events, reduced rainfall, sea level rise, etc.

Australia must utilise every safe, low-emissions technology to reduce its emissions. Nuclear is a safe, low-emissions technology that should be included in the energy mix in Australia, as it is already in 31 other countries, with four new countries with nuclear power reactors presently under construction.

No country has achieved a low level of emissions without nuclear and/or hydro<sup>2</sup>.

### *ii) Process Heat*

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. Nuclear power not only reduces emissions from electricity generation, but also provides a pathway to emissions reductions in many other industries.

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<sup>2</sup> <https://www.electricitymap.org/map>

### iii) *Energy Density*

Renewables, for example wind and solar, are very low energy density technologies, that is, the physical quantity of plant 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.

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°C for high temperature electrolysis. This enables hydrogen production at a cost comparable to steam methane reforming, but with low emissions and a cost less than one third of renewable energy electrolysis (Terrestrial submission 260 to Federal Nuclear Inquiry).

### iv) *Land Area*

Wind and solar require large areas. For example, the 150 MW Coleambally (NSW) solar plant occupies 550 hectares. This can be compared to a 720 MW NuScale plant that occupies only 18 hectares.

### v) *Waste*

The lifetime of a solar plant is around 25 years. By 2016, it had been estimated that 23 million solar panels had been installed in Australia. Reclaim PV (SA) has estimated that 100,000 - 150,000 PV panels every year are faulty and need replacing. The International Renewable Energy Agency (IRENA) has projected that by 2050 there will be up to 78 million tons of PV waste. Parts of PV panels can be recycled, but this requires the panels to be dismantled and the materials separated - an energy intensive process.

By comparison, a 720 MW 12 module NuScale SMR would produce each year only 120m<sup>3</sup> (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 ~1500kg/year of used fuel which is initially stored in cooling ponds 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. Several countries, including Australia, are looking at borehole disposal.

#### **vi) Noise**

Nuclear and PV produce very little noise during operation. Wind turbines produce significant noise which has an environmental impact and limits their siting.

#### **vii) Weather-dependency**

Nuclear power plants operate regardless of the weather. They are designed to continue operating in extreme weather conditions. There are many examples in the USA 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.

Winds and solar, by contrast, are totally weather-dependent. The output from a wind turbine rapidly decreases as the wind drops. Although this can be forecast to some extent, the drop can sometimes be quicker than expected. For example the AEMO report into conditions on 10 February 2017 (the very hot day in NSW) identified that the wind dropped faster than forecast, leading to a shortage of supply. According to AEMO, of more concern is the total cut-off of supply from a wind turbine when the high wind protection operates. In windy conditions, the turbine can suddenly de-load without warning. South Australia has over 1,600 MW of wind turbines, but the total output can be <10% for several days during calm conditions. The total output of **all** the wind farms in the NEM was less than 20% of their installed capacity for 2,760 hours (32%) during 2017.

It is useful to examine the AEMO fuel mix record for SA<sup>3</sup> Wind output is seen to vary between <10% to 80%. To compensate, gas output is 15% to >80%. This is not a long-term solution for low emissions.

## **7. The Economics of Small Modular Reactors (SMRs)**

There is one new SMR operating in Russia and two under construction worldwide<sup>4</sup>. However these are all prototypes and are not typical of a modern commercial SMR. The economics of SMRs is therefore based on estimates.

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).

Fluor (the international engineering company) has recently carried out a “bottom up” detailed cost estimate of the NuScale 720 MWe 12 module plant. This estimate conforms to the American Association of Cost Engineers class 4 cost estimates and is based on over 14,000 line items priced using Fluor’s extensive cost data or actual vendor quotes. For a Nth

<sup>3</sup> <https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/data-nem/data-dashboard-nem#average-price-table>

<sup>4</sup> Russia 70 MW floating SMR, Argentina 27 MW Carem, China 211 MW Shandong Shidaowan HTR-PM

of a Kind plant (that would most likely be deployed in Australia) the cost<sup>5</sup> is US \$3,600/kW equivalent to ~ A\$5,300 at current exchange rates. However much of the work (civil, electrical, balance of plant) would be resourced locally.

In 2020, the NuScale SMR completed the US Nuclear Regulatory Commission (NRC) design approval process. This is the first SMR to be approved by the NRC. This SMR design is complete and it is possible to make a reasonable estimate of the capital cost. First deployment is scheduled for UAMPS at its Idaho Falls site.

In 2020, SMR Nuclear Technology Pty Ltd commissioned Fluor to provide a detailed class 5 cost estimate for deployment of the updated 12 module, 924 MWe gross/884 MWe net NuScale SMR in Australia using Australia labour costs, concrete and international supply chain. The overnight cost is AUD 5,283/kW net installed capacity (0.77 exchange rate).

Total Operating and Maintenance (O&M) costs for this plant is AUD 83/kW (0.77 exchange rate).

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 cost and firming costs of renewable energy forms.

Electricity needs to be available on demand, 24 hours a day, 7 days a week and in all weather conditions (as explained under Weather-dependency above).

Nuclear is available 24 hours a day but solar, for example, may only be available for a third of the time each day. You must therefore multiply the generation cost of solar three times to get the same amount of electricity. Even then, it may not be available at the times of the day when it is required.

Although the generation costs of wind and solar are lower than nuclear, the true cost to the power system is higher. This is due to:

- (i) their low capacity factor,
- (ii) additional transmission costs and
- (iii) 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<sup>6</sup>.

A recent authoritative report (2019) by the OECD-NEA explains why the cost of electricity is increased by a high percentage of variable renewable energy (VRE) in the system<sup>7</sup>.

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<sup>5</sup> NuScale submission to the NSW Standing Committee on State Development Nuclear Inquiry

<sup>6</sup> Electric Power Consulting <https://epc.com.au/index.php/nem-model/>

<sup>7</sup> The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables, NEA No7299, 2019



## 8. Construction Time

Nuclear power plants were traditionally very large in order to capture economies of scale. In many 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 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.

## 9. “Load Following” and Grid Operation

Modern SMRs are designed to “load follow” and can support weather-dependent 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 need to be connected to the grid for safety. On loss of grid, the NuScale modules can remain in operation and are then ready to contribute to re-establishing the grid. If a NuScale 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.

## 10. Decommissioning

There is extensive experience of decommissioning nuclear power plants, with more than 140 decommissioned worldwide. After operations cease, the fuel and coolants are removed. This takes about 2 years and removes the major radiation hazards - 99% of the radioactivity is in the used fuel. The plant buildings are then dismantled and the site remediated, leaving a greenfield site that can be reused.

There is an excellent example of decommissioning a research reactor in Australia. ANSTO’s Moata research reactor at Lucas Heights operated from 1961-1995. The used fuel was removed after shutdown and sent back to the USA. In 2009/10 the reactor was completely dismantled. The concrete shielding was cut with a diamond saw and checked for radiation levels. Most of the concrete was able to be moved to landfill as industrial waste. The cost of dismantling was \$4.15m. Considering that Moata operated for 34 years and laid the foundations of nuclear research in Australia, the cost of decommissioning is clearly a small proportion of the total project cost.

## 11. Flow-on Benefits

The first NuScale SMR is planned to be sited near Idaho Falls, USA. This will be a 12 module, 924 MWe plant. The Idaho Department of Labour has forecast 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 Labour expects this will support 1,500 local jobs, equating to annual revenues of US\$389 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 infrastructure – transmission connections, cooling water supplies, admin and maintenance buildings etc – could be reused. As in the UK, the existing staff can be retrained to operate and maintain the plant, saving jobs and the local economy.

NuScale has just issued (April 2021) a report on repurposing US coal plants including the transition of workers to similar positions.<sup>8</sup>

## 12. Conclusions

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

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

Power industry infrastructure is arguably more valuable to the economy than transport infrastructure because of its flow-on benefits to other parts of the economy.

The development of nuclear power generation in Australia would 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.

SMR Nuclear Technology Pty Ltd has been pleased to provide this submission to the Federal Standing Committee on Environment and Energy and stands willing to expand on these and any other issues that the Committee may wish to raise in evidence to the Committee.

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<sup>8</sup> <http://www.smrnuclear.com.au/wp-content/uploads/2021/04/nuscale-smr-technology-an-ideal-solution.pdf>

Submitted by

**Tony Irwin**

Technical Director

**SMR Nuclear Technology Pty Ltd**

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