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The Contribution of Nuclear to a Reliable, Affordable and Low-Emissions Energy Future for Australia

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

Small Modular Reactors (SMRs) could become a game-changer in Australian power system planning for 2020/2030.

The repeal of Australia's 20-year legislative ban on nuclear power generation is necessary to enable SMR nuclear generation to be considered as a key element of Australia's future power system.

1. Reliability

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

SMRs with unit outputs of 50-300 MW are particularly suitable for the Australian grid. SMRs are designed with features that enable them to work effectively in a grid system that has variable renewables.

The leading US example is the NuScale SMR. Up to twelve 50 MW modules can be accommodated in one power plant to provide a gross output of 600 MW. The NuScale plant is specifically designed to automatically adjust its output to compensate for the variable generation from wind turbines.

Modern SMRs are also inherently safe, avoiding Fukushima-type accidents.

The NuScale module sits in a large "swimming pool" enabling the reactor to be cooled indefinitely without attention. The US Nuclear Regulator has confirmed that the NuScale plant does not require any emergency electrical generators to keep the plant safe. A NuScale reactor would have survived even a Fukushima- type accident.
Also modern SMR generating plant can be air cooled and does not require large quantities of water. They do not need to be located near a river or on the coast.

2. Affordability

Modern SMRs could become the lowest-cost generation available in Australia.

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. This has important strategic implications for the NEM and the entire economy.

3. Reduced Emissions

Australia has not yet been successful in significantly reducing emissions from electricity generation.

Australia's annual emissions from electricity generation for the year December 2012 were 191 million tonnes CO2-e (National Greenhouse Gas Inventory).

Five years later, and billions of dollars spent on wind and solar, Australia's annual emissions from electricity generation for the year March 2017 were 188 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 have large hydro resources (Norway) or have nuclear as part of their energy mix (France, Belgium).

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

In 2016, 2,490 TWh was generated by nuclear power reactors worldwide, saving over 2 billion tonnes CO2-e emissions (World Nuclear Association).

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 CO2-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 300 MW SMR nuclear generator by 2030 and up to 3000 MW by 2040.

The construction and operation of a nuclear power plant in Australia is presently prohibited by two Commonwealth Acts:

- Environmental Protection and Biodiversity Conservation Act 1999 S.140A
- Australian Radiation Protection and Nuclear Safety Act 1998 S.10.

Similar prohibitions were legislated in Queensland, NSW, Victoria and WA.

The prohibitions were 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 the 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 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. Our Roadmap to Deployment is appended to this submission.

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.

Following the announcement of the *Nuclear Fuel Cycle (Facilitation) Bill 2017*, our company provided you with information on the contribution that nuclear power could make to a reliable, affordable and low-emissions energy future for Australia.

Thank you to the Senators who responded to our submission. For those few Senators who expressed concerns about some issues, we are providing this additional information responding to all of the points that they raised.

5. Safety

With nuclear energy, safety is the most well-known concern. However, it is not so well-known that nuclear energy has the lowest incidence of death and accidents amongst all energy production technologies, comparable to renewables, and an incidence many times lower than fossil fuels.

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 Small Modular Reactors (SMRs) have 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 USA nuclear regulator (NRC), one of the world's toughest and most respected regulators, has recently found that the NuScale plant would be safe even without any standby electrical supplies. The NuScale SMR is the first nuclear reactor design to have achieved this accreditation.

SMRs are designed to be installed below ground level. This protects them from external hazards and also gives a high level of protection against unauthorised access. The reactor building is able to withstand aircraft impact.

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.

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.

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 Nyngan solar plant has 1,350,000 PV panels on frames supported by 150,000 posts but produces only 102 MW peak output.

iv) Land Area

Wind and solar require large areas. For example, the 56 MW Moree (NSW) solar plant occupies 280 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 produces 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. This 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 also produces 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. Licensing of this type of facility is in progress in Sweden, Finland and France.

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 and 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.

Renewables, 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.

7. Economics

Given their operating life of 60-80 years, it is likely that SMRs will be Australia's lowest-cost generation source.

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.

By comparison, the Finkel Report estimated LCOEs for other reliable technologies in 2020:

- Supercritical coal: A$76/MWh
- Gas CCGT: A$83/MWh
- Gas OCGT: A$123/MWh

The final cost of modern SMRs in Australia will depend on location-specific and financing factors to be determined during feasibility studies.

8. Construction Time

Modern SMRs are 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.

9. "Load Following" and Grid Operation

Modern SMRs are designed to "load follow" and can support weather-dependent renewables. They 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 plant had been operating in South Australia at the time of the September 2016, the grid could have been restored quicker than it was. 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.

Conclusion

SMR Nuclear Technology Pty Ltd has been pleased to provide this Supplemental Information to the Australian Senate and stands willing to expand on these and any other issues that Senators may wish to raise.

Tony Irwin
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