A case for Nuclear Power Generation in Australia

C. S. Cooper, PhD

Introduction

In response to *Environment and Other Legislation Amendment (Removing Nuclear Energy Prohibitions) Bill 2022*, I have issued this submission, arguing for the adoption of nuclear power generation in Australia. The focus will be on Small Modular Reactors (SMR), in particular those designed by NuScale.

Current State of Power Generation

Australia currently produces approximately 188 TWh of electricity per year from fossil fuels. Of all electricity produced, approximately 92% comes from a combination of coal (28.7%), Oil (36.2%) and Natural Gas (27.1%) [1]. Despite this, we account for approximately 1% of global emissions [2].

Economic Impacts of Renewables

While renewable usage has increased in recent years, it will be prohibitive to replace these energy sources with solar and wind, in terms of both economic and social costs. Other countries have attempted this, such as Germany. In the wake of the 2011 Fukushima Disaster [3], Germany began a switch from nuclear to solar and wind. As a result of closing their nuclear plants, energy prices have risen from 47.18 €/MWh in March 2021, to 469.35 €/MWh in August 2022 [4], with a 2024 forecast of 7125.86 €/MWh [5]. Furthermore, their energy grids have grown very unstable [6]. While some of this can be attributed to the Ukraine War, Germany experienced blackouts and energy instability well before the conflict [7]. Grids across Europe are experiencing supply difficulties [8], [9]. Switzerland, once a bastion of green energy, is considering banning electric car charging because of electricity shortages [10].

As Australia is a net exporter of energy, if we follow the same path as Germany and other countries, we will experience similar (if not worse) economic hardship. We account for only 1% of global emissions; by contrast, the USA accounts for 11.9% and China accounts for 24.3% [2]. China is building more than half the world's new coal power plants [11], which will more than offset any reductions benefit Australia could offer. We would destroy our economy, ultimately for nothing. This doesn't mean we shouldn't pursue a policy of reducing emissions. Nuclear provides the way to reduce our emissions and avoid the economic turmoil faced by European nations.

NuScale Small Modular Reactors

A Small Modular Reactor is a scaled down version of a conventional nuclear reactor. The reactor design developed by NuScale offers various safety advantages over other SMR designs and conventional large-scale reactors.

Like all nuclear reactors, SMRs work by splitting Uranium atoms in its fuel core, controlling the reaction via Boron control rods moved in and out of the core, and siphoning off the heat via a coolant fluid (usually water) to drive a turbine. NuScale’s design is unique in that its cooling and safety systems are passive [12].

Most designs (small and large) require active pumps to push coolant through the core. NuScale’s design does not. The device is sufficiently small that the cooling loop can be driven by simple convection, much like water boiling on a stove. As the fuel core heats up through fission, the coolant runs through channels in the core and boils. The boiling water rises up through the reactor, into a heat exchanger, where water from a secondary loop absorbs heat from the coolant. The now cooled water is allowed to fall back down into the core, where the process repeats. The water in the secondary loop boils upon absorbing heat from the main loop, and drives a turbine to generate electricity. No active cooling is required.

In addition to this passive cooling mechanism, NuScale reactors are designed to operate submerged in water. In the event that the convection-based cooling is insufficient, such as during a loss of coolant accident (LOCA), pressure valves on the reactor’s outer hull automatically open to admit water from outside the reactor into the space around the core. This allows heat to be transferred via convection from the core to the outside water [13].

The added benefit of a NuScale reactor is in its control rod mechanism. In other designs, the control rods are moved in and out by motor actuators that need to be powered. If power is lost to the actuators, the rods cannot be moved into the core to shut down the reactor, which leads to disaster. NuScale’s design incorporates electromagnets as their control actuators, which need power only to move the rods out of the core. If power is lost, the magnets switch off, and the control rods fall by gravity back into the core. There is no need for backup generators or active emergency systems [14].

When dealing with conventional nuclear, each new plant must be designed for the location and environment in which it is built. This leads to costly safety certification and long budget overruns [13]. NuScale resolves this problem with a standardised design for their reactor modules, which can be installed in their VOYGR plants: reactor banks of two, four, six, and twelve modules, based on the requirements of the location. Furthermore modules can be turned on and off, as local demand requires. Because the design is standardised, it only needs to be certified by safety regulators once. The modules can be built on an assembly line and shipped to where they are needed [15].

NuScale reactors will require only 5% of the fuel of a conventional reactor. It is designed to use standard light water reactor fuel, consisting of Uranium enriched to 5%. Each module is designed for a two-year refuelling cycle, and will produce 73 MW of electricity at full power [16].

Australia has an added advantage in that we have 30% of the world's Uranium supply [17]. We can mine, enrich, and prepare Uranium fuel with minimal reliance on foreign countries, thereby strengthening our energy security and independence.

Why Nuclear Disasters won't happen in Australia

If Australia employs NuScale reactors to replace fossil fuels, the principal concern is the danger of nuclear disasters such as Chernobyl, Fukushima, and Three Mile Island [18]. It is stressed that these disasters are unlikely in Australia for a number of reasons.

Chernobyl happened, fundamentally, because of Soviet culture. It was rooted in lies and deception, not just of the West but of its own people. The philosophy of the Soviets was hostile to meritocracy and education, viewing those as bourgeois. As such, the RBMK reactor at Chernobyl was intentionally designed to be operable with a minimal amount of training or understanding of the underlying physics. They used natural Uranium instead of enriched, which required a huge amount of fuel to be used. The use of natural Uranium also necessitated a dangerously high positive void coefficient – meaning that the more steam present in the core's coolant channels, the higher the core's reaction rate. Some Western reactors do have a positive void coefficient, but the RBMK's coefficient was many hundreds of times higher. The natural Uranium in the core also meant that the control rods did their job too well and reduced reaction rate too much. So the Soviets attached graphite tips to the control rods, which accelerated reactivity and offset the effect of the control rods. Finally, the Soviets did not build containment buildings over their reactors, unlike the West. This, combined with the incompetent management of Anatoly Dyatlov and his underlings' inexperience and timidity, resulted in the Chernobyl Disaster. The tragedy is compounded by the fact that the RBMK designers knew exactly how Chernobyl Disaster could occur when they designed it, and the KGB covered it up and lied to the Chernobyl management [19], [20].

Fukushima's reactors were of a Western design, which didn't have the problems of the RBMK. They had operated fine for forty years before the disaster [21]. When the earthquake hit in 2011, the plant's safety systems acted quickly and shut the reactors down. Diesel generators kept the coolant pumps running. When the tsunami hit, the generator compartment was destroyed. The coolant pumps failed, and the cores melted down. However, because the reactors had containment buildings, much of the fallout was contained [22]. While Fukushima was a Level-7 on the Nuclear Accident scale, it was far, far less significant than Chernobyl in terms of contamination and casualties [23].

Three Mile Island was also a Western-designed reactor. The accident occurred because of a faulty sensor on a coolant relief valve. The control systems recognised the valve was open only because power was being delivered to it. In reality, the valve had not functioned properly, and caused a coolant leak. Coolant escaped the reactor and caused a partial meltdown. The site has since been decommissioned. It is rated as a Level-5 incident [24].

NuScale's designs, incorporating all the knowledge gathered from these accidents, are intended to prevent such disasters. There are no graphite tips on the control rods or positive void coefficient, because the system uses properly enriched Uranium. As the coolant and safety systems are passive, there is no risk of a faulty sensor causing leaks, or a requirement for backup diesel generators. Furthermore, flood damage is of minimal concern, as the reactors are designed to operate submerged in water. Therefore, accidents such as these are highly unlikely.

Australia is in the middle of a tectonic plate, and as a result we rarely experience earthquakes or tsunamis. Also, our power generation capacity is further inland than Fukushima, so in the unlikely event of a tsunami, a NuScale VOYGR plant would be far removed from any damage.

Finally, Australia's culture and work ethic is radically different from those of Communist countries. We value safety, effectiveness, merit, and education highly and respectfully. We value our citizens and our way of life above petty secrecy. As a result, we will not have the problems of the Soviets.

The Waste Problem

Nuclear reactors produce highly radioactive waste, and NuScale's SMRs are no exception [18]. However, the issue is the amount.

Every two years, the modules need refuelling. Within the spent fuel rods, approximately 97% is still perfectly useful fuel, and only 3% is waste. Using practices developed and employed by French company Orano, we can reprocess the nuclear fuel to filter out the waste. The remaining useful material can then be placed back into the reactor. The waste products are then mixed with boron-silicate glass, which locks the radiation away. The glass is then stored in stainless steel canisters for disposal [25].

The best disposal method for Australia would be in deep boreholes. A hole is drilled, 50 cm wide and 5 km deep. The lower half of the hole is filled with the canisters, and the hole backfilled with concrete and bentonite clay. The wellhead is then covered with topsoil, upon which trees can be planted. By the time natural geological processes expose the top of that waste, hundreds of millions of years will have passed, and the waste will no longer be radioactive. This process is the cheapest, quickest, and most effective with the technology we have available [26].

Weapons Proliferation

The risk of nuclear weapons is over-exaggerated, especially for NuScale's design. The fuel for nuclear reactors of NuScale's design requires Uranium at 5%

enrichment. In order to build a theoretical bomb, the Uranium must be enriched to at least 20%; for a feasible bomb, the enrichment must be closer to 90% [27]. Australia can resolve this concern by placing a restriction on enrichment over 15%, allowing a buffer for technological advancement, in case future reactors – potentially producing less waste – require a higher enrichment level.

There is legitimate concern, however, in the recycled fuel. As stated above, 97% of the used fuel is still good. 96% is Uranium, but 1% is Plutonium, which can be used in nuclear weapons. However, this is resolved by requiring that all Plutonium be mixed with Uranium in the form of Mixed-Oxide Fuel, which can power the reactor. Plutonium used to generate electricity is Plutonium not used to make bombs [25].

Costs and Benefits

Using NuScale technology, Australia can reach net zero without causing economic turmoil for our citizens. NuScale cites a plant construction cost of $4144 per kW production capacity. To replace our current fossil fuel generation of 188 TWh per year, we will require a nuclear production capacity of approximately 21.7 GW from nuclear. This requires at least 300 NuScale modules, each operating at 73 MW, across 25 VOYGR plants. A single VOYGR plant can be built in less than three years [28]. The total cost will be approximately $89 billion, which can be spread over ten years. That amounts to approximately 7.0% of Australia's 2020 GDP and 15% of Australia's 2021 tax revenue [29]. For comparison, Australia spent over $300 billion in one year on COVID-19 [30], [31]. It is thus well within our financial capabilities to make this transition.

Each VOYGR plant has an emergency exclusion zone around it, as with any nuclear plant. While conventional plants have an area up to sixteen kilometres in radius, VOYGR plants require only two kilometres, owing to the inherent safety features of the NuScale technology [15]. This allows VOYGR plants a far smaller land footprint than conventional nuclear or fossil fuel plants. If these plants are built on the sites of decommissioned coal plants, they will use far less land and can be attached to existing distribution infrastructure. The remaining land around the plant can be filled with trees and greenery [32].

At a full conversion to nuclear, approximately 36 tonnes of waste will be generated per year[1]. This amounts to about 1.4 grams per capita per year[2]. Using the borehole disposal technique, a single 5-km borehole will contain over three years of waste[3]. During the sixty-year VOYGR lifespan, Australia will produce less

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[1] This is based on an assumption of 8 tonnes of fuel in core, 3% waste mass, and a 2-year refueling cycle. NuScale has cited a core mass of 5% of conventional cores, which have a fuel mass around 100 tonnes [33]. 8 tonnes has been selected as a high estimate for these calculations.

[2] Using a population of 25,422,788 people from the 2021 Census [34].

[3] A waste canister is 133 cm tall and contains 400 kg of vitrified waste, 17% waste to 83% glass [35]. Based on this, a borehole will contain 112,360 kg of waste, over 3.5 times the yearly production of 36,000 kg. Thus, a single hole will last over three and a half years.

waste per person than could fill a coffee cup, and drill nineteen holes to contain that waste. If each hole is separated by 100 metres in a spiralling arrangement, the disposal site will occupy an area of land smaller than Stadium Australia. A perimeter around the site can be demarcated and the whole area filled with trees, becoming a self-enforcing nature preserve (as there is no radiation, but people will be averse to developing anything on the area).

The benefits of nuclear extend beyond electricity generation:

- There are a number of processes for converting CO_2 emissions back into oil, closing the carbon cycle. But this requires large amounts of energy that presently come from fossil fuels, defeating the purpose. Nuclear is emissions-free, and thus enables the implementation of these carbon recycling techniques [36, p. 2].
- The energy from nuclear can be employed in the pyrolysis of used plastics back into their hydrocarbon constituents, recycling them back into oil [37].
- It can power the pyrolysis techniques used to recycle used solar panels and batteries, thereby reducing the e-waste sent to landfill [38].
- Nuclear can finally unshackle the hydrogen car. Hydrogen for vehicles is extracted from methane using steam reforming, which releases large amounts of CO_2 and defeats the purpose of the hydrogen car. With emission-free nuclear power, the hydrogen can be extracted straight out of water using electrolysis or thermolysis [39].

Conclusion

Using NuScale's SMR technology, our power grid can be made emissions-free. The technology can be deployed effectively across Australia using existing infrastructure, and the materials and fuels required are all found on our lands. This ensures our energy independence, increases our reliance on Australian jobs and industry, and improves our energy security. Because of the design's inherent features, we will be shielded against accidents that have plagued earlier designs. Australia's philosophy of hard work, honesty, and skill will ensure that disasters like Chernobyl will never happen. If the goal of Australia over the next few decades is net-zero emissions, this is the path to take.

Bibliography

[1] "Australian Energy Statistics, Table O Electricity generation by fuel type 2020-21 and 2021," Department of Industry, Science, Energy and Resources, Apr. 2022. Accessed: Dec. 01, 2022. [Online]. Available: https://www.energy.gov.au/publications/australian-energy-statistics-table-o-electricity-generation-fuel-type-2020-21-and-2021

[2] "Fact sheet on Global Emissions PDF," Climate Change Authority, Feb. 2021. Accessed: Dec. 01, 2022. [Online]. Available: https://www.climatechangeauthority.gov.au/sites/default/files/2021-03/2021Factsheet%20-%20Global%20emissions.pdf

[3] K. Appunn, "Q&A: Why is Germany phasing out nuclear power and why now?," *Clean Energy Wire*, Aug. 16, 2022. Accessed: Dec. 01, 2022. [Online].

Available: https://www.cleanenergywire.org/news/qa-why-germany-phasing-out-nuclear-power-and-why-now

[4] B. Alves, "Average monthly electricity wholesale price in Germany from January 2019 to October 2022," Statista, Nov. 2022. Accessed: Dec. 01, 2022. [Online]. Available: https://www.statista.com/statistics/1267541/germany-monthly-wholesale-electricity-price/

[5] "Germany Electricity Price," Trading Economics, Nov. 2022. Accessed: Dec. 01, 2022. [Online]. Available: https://tradingeconomics.com/germany/electricity-price

[6] "Germany running on dwindling supply of gas," *Yeni Şafak*, Nov. 30, 2022. Accessed: Dec. 01, 2022. [Online]. Available: https://www.yenisafak.com/en/world/germany-running-on-dwindling-supply-of-gas-3656359

[7] "With blackouts looming, German government holds disaster preparation day, promotes 'cooking without electricity,'" *RT News*, Oct. 01, 2021. Accessed: Dec. 01, 2022. [Online]. Available: https://www.rt.com/news/536361-germany-blackouts-power-ad/

[8] "Electricity Maps," 2022. Accessed: Dec. 01, 2022. [Online]. Available: https://www.electricitymaps.com/

[9] Y. Khan, "Lack of Wind Pushes Europe's Power Prices Higher, Just as Cold Sets In," *Wall Street Journal*, Dec. 02, 2022. Accessed: Dec. 03, 2022. [Online]. Available: https://www.wsj.com/articles/lack-of-wind-pushes-europes-power-prices-higher-just-as-cold-sets-in-11669981726

[10] J. Shaw, "Swiss look to ban use of electric cars over the winter to save energy," *Hot Air*, Dec. 01, 2022. Accessed: Dec. 03, 2022. [Online]. Available: https://hotair.com/jazz-shaw/2022/12/01/swiss-look-to-ban-use-of-electric-cars-over-the-winter-to-save-energy-n514785

[11] A. Vaughan, "China is building more than half of the world's new coal power plants," *New Scientist*, Apr. 26, 2022. Accessed: Dec. 01, 2022. [Online]. Available: https://www.newscientist.com/article/2317274-china-is-building-more-than-half-of-the-worlds-new-coal-power-plants/

[12] "NuScale Technology," NuScale Power, LLC., 2022. Accessed: Dec. 02, 2022. [Online]. Available: https://www.nuscalepower.com/technology

[13] "Passive Systems," NuScale Power, LLC., 2022. Accessed: Dec. 06, 2022. [Online]. Available: https://www.nuscalepower.com/benefits/safety-features/passive-systems

[14] C. Lobscheid, "Control rod drive mechanism (CRDM) with remote disconnect mechanism," US10847272B2, Nov. 24, 2020 Accessed: Dec. 06, 2022. [Online]. Available: https://patents.google.com/patent/US10847272B2/

[15] ANSTO Staff, "What are small modular reactors and what makes them different?," ANSTO, Jul. 2020. Accessed: Dec. 02, 2022. [Online]. Available: https://www.ansto.gov.au/news/what-are-small-modular-reactors-and-what-makes-them-different

[16] "Design Innovations," NuScale Power, LLC., 2022. Accessed: Dec. 03, 2022. [Online]. Available: https://www.nuscalepower.com/technology/design-innovations

[17] "Australia's Uranium," World Nuclear Association, Oct. 2022. Accessed: Dec. 03, 2022. [Online]. Available: https://www.world-

nuclear.org/information-library/country-profiles/countries-a-f/australia.aspx

[18] "Nuclear Power Stations are not appropriate for Australia - and probably never will be," *Climate Council*, Jan. 18, 2022. Accessed: Dec. 05, 2022. [Online]. Available: https://www.climatecouncil.org.au/nuclear-power-stations-are-not-appropriate-for-australia-and-probably-never-will-be/

[19] "Sequence of Events - Chernobyl Accident Appendix 1," World Nuclear Association, Jun. 2019. Accessed: Dec. 03, 2022. [Online]. Available: https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/appendices/chernobyl-accident-appendix-1-sequence-of-events.aspx

[20] "RBMK Reactors - Appendix to Nuclear Power Reactors," World Nuclear Association, Feb. 2022. Accessed: Dec. 03, 2022. [Online]. Available: https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/appendices/rbmk-reactors.aspx

[21] "Fukushima: Background on Reactors," World Nuclear Association. Accessed: Dec. 03, 2022. [Online]. Available: https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/appendices/fukushima-reactor-background.aspx

[22] "Fukushima Daiichi Accident FAQ," World Nuclear Association. Accessed: Dec. 01, 2022. [Online]. Available: https://www.world-nuclear.org/focus/fukushima-daiichi-accident/fukushima-daiichi-accident-faq.aspx

[23] *Fukushima and Chernobyl: Myth versus Reality*, (Jun. 25, 2019). Accessed: Dec. 01, 2022. [Online Video]. Available: https://www.world-nuclear.org/archived-content/fukufocus/fukushima-and-chernobyl-myth-versus-reality.aspx

[24] "Three Mile Island Accident," World Nuclear Association, Apr. 2022. Accessed: Dec. 01, 2022. [Online]. Available: https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/three-mile-island-accident.aspx

[25] "Orano - From exploration to recycling," Orano Group. Accessed: Dec. 01, 2022. [Online]. Available: https://www.orano.group/en/nuclear-expertise/from-exploration-to-recycling/world-leader-in-recycling-used-nuclear-fuels

[26] P. Brady *et al.*, "Deep Borehole Disposal of High-Level Radioactive Waste," Sandia National Laboratories, Aug. 2009.

[27] "Fact Sheet: Uranium Enrichment: For Peace or for Weapons," Center for Arm Control and Non-Proliferation, Aug. 2021. Accessed: Dec. 03, 2022. [Online]. Available: https://armscontrolcenter.org/uranium-enrichment-for-peace-or-for-weapons/

[28] "A Cost Competitve Nuclear Power Solution," NuScale Power, LLC., 2022. Accessed: Dec. 06, 2022. [Online]. Available: https://www.nuscalepower.com/benefits/cost-competitive

[29] "Taxation Revenue, Australia," Australian Bureau of Statistics, 26 Apr 22. Accessed: Dec. 03, 2022. [Online]. Available: https://www.abs.gov.au/statistics/economy/government/taxation-revenue-australia/latest-release

[30] “Economic Response to COVID-19,” Australian Treasury, May 2021. Accessed: Dec. 05, 2022. [Online]. Available: https://treasury.gov.au/coronavirus

[31] P. Karp, “The 2021 federal budget reveals huge $311bn cost of Covid to Australian economy,” *The Guardian*, May 11, 2021. Accessed: Dec. 05, 2022. [Online]. Available: https://www.theguardian.com/australia-news/2021/may/11/federal-budget-2021-papers-reveals-huge-cost-of-covid-australian-government-economy-economic-stimulus-packages

[32] “NuScale SMR Technology - An Ideal Solution for Repurposing U.S. Coal Plant Infrastructure and Revitalising Communities,” NuScale Power, LLC., 2021. Accessed: Dec. 05, 2022. [Online]. Available: https://mc-67443a0a-0a3b-4888-8568-874354-cdn-endpoint.azureedge.net/-/media/Nuscale/Files/Technology/Technical-Publications/nuscale-smr-technology-an-ideal-solution.ashx?rev=d48edd73fb5f464f8bdb593a76a4aa38&hash=23600A270CB394AC79C1F7B662648859

[33] “Fuel Consumption of Conventional Reactor,” Nuclear Power, 2022. Accessed: Dec. 03, 2022. [Online]. Available: https://www.nuclear-power.com/nuclear-power-plant/nuclear-fuel/fuel-consumption-of-conventional-reactor/

[34] “Population,” Australian Bureau of Statistics, 2022. Accessed: Dec. 06, 2022. [Online]. Available: https://www.abs.gov.au/statistics/people/population

[35] E. Vernaz and B. Bonin, “Glass packages and manufacturing processes,” in *Nuclear Waste Conditioning*, CEA, 2008, pp. 28–30. Accessed: Dec. 06, 2022. [Online]. Available: https://www.researchgate.net/publication/281185592_Nuclear_waste_conditioning

[36] M. D. Garba *et al.*, “CO2 towards fuels: A review of catalytic conversion of carbon dioxide to hydrocarbons,” *J. Environ. Chem. Eng.*, vol. 9, no. 2, p. 104756, Apr. 2021, doi: 10.1016/j.jece.2020.104756.

[37] S. D. Anuar Sharuddin, F. Abnisa, W. M. A. Wan Daud, and M. K. Aroua, “A review on pyrolysis of plastic wastes,” *Energy Convers. Manag.*, vol. 115, pp. 308–326, May 2016, doi: 10.1016/j.enconman.2016.02.037.

[38] “Reclaim’s Recycling Process,” Reclaim PV Recycling. Accessed: Dec. 03, 2022. [Online]. Available: https://www.reclaimpv.com/our-recycling-process/

[39] “Clean Hydrogen Production,” NuScale Power, LLC. Accessed: Dec. 03, 2022. [Online]. Available: https://www.nuscalepower.com/environment/clean-hydrogen-production