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Submission to

Environment and Communications Legislation Committee

Inquiry into Environment and Other Legislation Amendment (Removing Nuclear Energy Prohibitions) Bill 2022

Summary

Nuclear energy is widely used in many countries where it provides large-scale economically competitive electricity and security of supply as well as very low carbon emissions and other air pollution. Nuclear power plants provide dispatchable energy.

Notwithstanding the excellent record of nuclear power plants in supplying reliable, affordable and low carbon electricity around the world, Australia has historic legislative prohibitions against nuclear power and other nuclear facilities in the Australian Radiation Protection and Nuclear Safety Act 1998 (ARPANS Act) and the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act).

The current bill is for the removal of prohibitions on four types of nuclear installations – fuel fabrication plants, nuclear power plants, enrichment plants and reprocessing facilities. This submission focuses on nuclear power plants; however, the other three installations are addressed briefly.

Australia needs access to all available clean zero-carbon technologies to meet the challenge of decarbonising our energy system. An essential step is the amendment of legislation to remove prohibitions on nuclear energy in Australia.

The historic prohibitions still in the EPBC Act 1999 and the ARPANS Act 1998 are barriers to the proper assessment of the merits of nuclear power as an affordable, reliable and low carbon part of Australia's energy system.

Removing the prohibitions is not a decision to build nuclear power plants but a decision to allow nuclear power to be considered on its merits. Any decision to build nuclear power plants in Australia would have meet environmental standards, be supported by communities and demonstrate financial viability.

Using nuclear energy in conjunction with wind, solar and hydropower would help provide reliable, affordable low carbon energy system for Australia into the future.

The Australian Nuclear Association strongly recommends amending the Environment Protection and Biodiversity Conservation Act 1999 and the Australian Radiation Protection and Nuclear Safety Act 1998 to remove the nuclear prohibitions and allow nuclear energy to be considered on its merits.

About the Australian Nuclear Association Inc.

The Australian Nuclear Association Inc. (ANA) is an independent incorporated scientific institution with members from the professions, business, government and universities with an interest in nuclear science and technology. Many of our members are professional scientists and engineers with considerable experience and expertise in nuclear issues.

Nuclear energy is a mature technology widely used around the world.

Nuclear electricity is a very well-established technology with over 19,300 nuclear power plant-years of commercial operation since the first commercial nuclear power plants started in the 1950s[1]. Nuclear power plants are major generators of electricity in most developed and many developing countries.

The nuclear power reactor technology has been continually improved and the modern large nuclear plants being built in many countries are very reliable. Australia can gain from the experience in the regulation and in the siting, construction and operation of nuclear power plants in many countries.

As of October 2022, there were 423 nuclear power plants in operation in 32 countries and 57 nuclear power plants are under construction[2]. Nuclear generated approximately 10% of the world's electricity in 2021[3]

Nuclear power plants are very reliable and operate at a high capacity factor – in 2021 the global average capacity factor was 82.4%[4] - providing dispatchable electricity 24 hours per day. This figure would be even higher if more and more nuclear power plants were not being used for load following. In 2020, the US fleet of nuclear power reactors operated with a capacity factor of 92.5%, compared to 35.4% for wind and 24.9% for solar[5]. Using nuclear energy in conjunction with wind and/or solar can help provide reliable, low carbon energy. The very low carbon emissions of nuclear power greatly assist countries in meeting international carbon emission commitments.

The reliability of nuclear power plants is enhanced by not requiring continuous delivery of fuel. The energy density of uranium fuel elements is very high. For example, a 1000 MWe coal plant needs over two million of tonnes of coal per year, the equivalent nuclear plant would consume only 25-30 tonnes of uranium fuel[6]. Partial refuelling (a quarter to a third of the fuel elements) of pressurised water reactors takes place every 12, 18 or 24 months[7]. This requires the plant to be shutdown typically for only about one month. CANDU reactors are refuelled online. The long time between refuelling contributes to the resilience and reliability of nuclear power plants.

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[1] *IAEA Database on Nuclear Power Reactors*, https://pris.iaea.org/pris/ Accessed 27 November 2022

[2] *IAEA Database on Nuclear Power Reactors*, https://pris.iaea.org/pris/ Accessed 27 November 2022

[3] https://ourworldindata.org/nuclear-energy Accessed 27 Nov 2022

[4] *World Nuclear Performance Report 2022.* World Nuclear Association, 2022

[5] US Office of Nuclear Energy, *Nuclear Power is the Most Reliable Energy Source and It's Not Even Close* https://www.energy.gov/ne/articles/nuclear-power-most-reliable-energy-source-and-its-not-even-close, Accessed 1 May 2021

[6] https://world-nuclear.org/nuclear-essentials/how-is-uranium-made-into-nuclear-fuel.aspx

[7] https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/nuclear-power-reactors.aspx

Nuclear power plants generate clean, very low carbon electricity.

The demand for electricity for private and industrial use, including transport and the developing electric vehicle market, will only increase. Australia must have access to all available low carbon technologies including nuclear power to ensure that our future electricity grid is reliable, low carbon, affordable and resilient.

Nuclear energy plays a key role in lowering carbon emissions from the energy sector in many countries. The median carbon emissions for the whole nuclear fuel cycle are very low and of the order of 12 grams CO_2/kWh[8]. This low carbon emission is similar to emissions from wind per unit of electricity produced and less than hydropower and solar PV. This comparison assumes that methane from hydropower is not significant and ignores the emissions from any storage or backup generators required for firming wind and solar generators.

In 2021, nuclear power plants around the world produced as much clean electricity as wind and solar combined[9]. In the European Union and USA, nuclear produces more low carbon electricity than hydropower[10].

The use of nuclear power plants enables countries to achieve low carbon emissions from electricity generation. For example, nuclear supplied 69% of electricity in 2021 in France, resulting in France having an overall electrical generation carbon emission intensity of 67 grams CO_2e/kWh[11]. This compares to 402 grams CO_2e/kWh for its neighbour Germany, which has a similar sized electricity grid, has invested heavily in VRE technologies, and is closing nuclear plants for domestic political reasons.

Nuclear power is already widely used in many countries. Most large countries that have introduced targets to achieve net-zero carbon emissions by 2050 or 2060 (e.g., South Korea, China, UK, USA, Europe, Canada) depend on large nuclear power plants and/or have good hydro-electricity plants.

Nuclear power plants produce electricity which can be despatched on demand at the request of grid operators as needed to meet market designs. Dispatchable generators like nuclear can raise or lower power output on command from the grid controllers.

As well as reducing carbon emissions, nuclear power plants also benefit the environment by removing the air pollution emitted by coal plants. They also have small land footprints and perform well in terms of a number of other environmental indicators[12].

Modern nuclear power plants are flexible and load follow.

Variable Renewable Energy (VRE) generators like wind and solar PV are non-dispatchable unless they are coupled with storage such as batteries, pumped hydro, molten salt or by other energy storage systems. The additional cost of storage or standby generators must be included

[8] IPCC, *Emissions of selected electricity supply technologies (gCO2eq/kWh)*. Table A.III.2, Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

[9] Our World in Data -*Electricity Mix.* https://ourworldindata.org/electricity-mix . accessed 23 Nov 2022

[10] IEA 2019b *Nuclear Power in a Clean Energy System*, International Energy Agency May 2019

[11] EEA 2022. *Greenhouse Gas Emission Intensity of Electricity Generation.* European Environment Agency, Oct 2022.

[12] UNECE 2021, *Life Cycle Assessment of Electricity Generation Options*, United Nations Economic Commission for Europe, https://unece.org/sites/default/files/2021-10/LCA-2.pdf

in the cost of electricity from VREs, along with the costs of any transmission systems. An electricity grid with large amount of VREs requires many generators to load follow or large amounts of storage to provide backup when the VREs are unable to generate energy.

Most of the modern light water nuclear reactors are capable (by design) to operate in a load following mode and change their power level once or twice per day in the range of 100% to 50% (or even lower) of the rated power, with a ramp rate of up to 5% (or even more) of rated power per minute[13].

Despite this capability to load follow, most nuclear power plants around the world have been operated as baseload units. This is because the high fixed capital costs and low fuel costs make it more economic to run the nuclear power plants continuously at their rated power level. With increasing amounts of VREs in an electricity grid, nuclear power plants are being designed and built with increased load following capability.

French power reactors can go from 100% rated thermal power to 30% power and up to 5% rated thermal power per minute return to full power[14]. A 1,300-MW French reactor can increase or decrease its output by 900 MW within about 30 minutes[15].

Small Modular Reactors also have fast load following capabilities; for example, the NuScale Small Modular Reactor (SMR) module can increase from 20% to 100% power in 96 minutes[16]. The Natrium reactor design uses a molten salt storage system to allow rapid response and gigawatt hour scale energy storage for many hours.

If load following is not desirable for financial, technical or other reasons, nuclear power plants could be sited next to desalination or hydrogen production facilities. The nuclear plant could divert its electrical output from electricity production to other uses to prevent having to decrease power output.

A rigorous process will be used for siting nuclear power plants.

The siting of nuclear plants will be a rigorous process involving multiple stakeholders and assessment of the suitability of sites. Australia is expected to follow the international siting standard developed by the International Atomic Energy Agency[17].

Stakeholder and social licence are important parts of the siting process. Outreach programs will involve communities in the decision-making process so as to gain support near potential sites.

Sites to be considered are likely to include locations of retiring coal plants and remote locations such as mine sites at the fringes of the grid or that are entirely off grid. Putting nuclear plant near or at locations of retiring coal plants would allow the nuclear plant to benefit from the existing grid connections, access to cooling water and an experienced workforce capable of being retained to work at nuclear power plants. The continuity of employment opportunities

[13] Technical and Economic Aspects of Load Following with Nuclear Plants. OECD 2011 https://www.oecd-nea.org/ndd/reports/2011/load-following-npp.pdf

[14] IAEA, *Non-Baseload Operation in Nuclear Power Plants: Load Following and Frequency Control Modes of Flexible Operation* Nuclear Energy Series No. NP-T-3.23 2018

[15] Power magazine, 1 April 2019 https://www.powermag.com/flexible-operation-of-nuclear-power-plants-ramps-up/

[16] NuScale, *Ensuring a Balanced Mix with Advanced Nuclear*, 2020, https://www.nuscalepower.com/newsletter/nucleus-summer-2020/featured-topic-cleaner-energy, Accessed 1 May 2021

[17] Site Evaluation for Nuclear Installations, IAEA Safety Standards Series No. SSR-1. 2019

would be of great benefit to regional communities. Installing nuclear power plants at the sites of retiring coal plants minimises the need for additional transmission lines and are likely to be close to major users of electricity.

There are also opportunities for smaller nuclear power plant at fringes of the grid and at remote locations needing reliable low-carbon electricity.

As well as reducing carbon emissions, nuclear power plants also benefit the environment by removing the air pollution emitted by coal plants.

Nuclear power plant costs are competitive and play a vital role in low carbon energy system costs.

The cost of nuclear power plants and the time taken to construct will depend on the type and size of reactor, whether the design is a first-of-a-kind or nth-of-a-kind and whether the design is finalised before construction starts. Some first-of-a-kind plants being built in France, UK and USA were much more expensive that nth-of-kind plants built in UAE, Korea and China and that are being built in Turkey, Bangladesh and Egypt.

If Australia decides to introduce nuclear power, the plants built in Australia are likely to be nth-of-a-kind plants with identical plants already built overseas. It will be important for the Australian regulator to approve the design before construction starts.

Cost is not a valid reason to prohibit a nuclear technology. Some designs are cheaper than others and the selection of a reactor design for a site in Australia will be part of a tender assessment process. Removal of the current legislative nuclear prohibitions allow properly costed proposals to be prepared for nuclear power plants. If costs are too expensive, the plants will not be built.

According to a joint report by the International Energy Agency and the OECD Nuclear Energy Agency on projected cost of generating electricity, nuclear is the dispatchable low-carbon technology with the lowest expected costs in 2025[18]. These LCOE calculations were based on a levelised average lifetime cost approach. Costs are calculated at the plant level (busbar) and do not include transmission and system costs.

System costs are important in a grid operating with significant Variable Renewable Energy (VRE) such as solar and wind. Adding low cost VREs to the grid requires backup generators or storage available for the times when the VREs are not producing electricity.

The time to build a nuclear power plant has a major bearing on its cost. Although recent construction of some first-of-a-kind power plants in Finland, France and the USA (EPR and AP1000 designs) have experienced delays and cost more than planned, the overall conclusion of the International Energy Agency study stands - in most countries nuclear is economically competitive as a generator of electricity.

The construction times of the EPR and AP1000 nuclear power plants already built and operating in China were much shorter and at lower cost than the first-of-a-kind plants of same design built in Europe and the USA.

[18] IEA/NEA *Projected Costs of Generating Electricity 2020* https://www.iea.org/reports/projected-costs-of-generating-electricity-2020 See Figure ES1

The OECD 2019 report[19] on the costs of decarbonisation highlighted the impact of the variability of wind and solar have on electricity system costs and the cost of the extra backup generators, costly transmission lines and excess capacity required.

Decarbonising Australia's electricity system will need an optimum economic mix of clean low carbon technologies to work together. Because of their intrinsic variability, the overall system cost of adding large amounts of wind and solar are larger than the sum of their individual plant level costs.

The OECD 2019 study concludes that:

"… diversity of energy sources drives down total costs of energy in a low-carbon system, whereas taking options off the table – such as nuclear – creates extra costs to society".

Nuclear power plants are amongst the safest energy technology and are getting even safer.

The Chernobyl accident is the only accident in the history of nuclear power generation in which deaths have occurred from radiation. It is important to note that the Chernobyl nuclear power plant type would not have been licenced outside the former Soviet Union.

The Fukushima nuclear accident caused great economic loss and evacuation of large numbers of people. Nevertheless, there is no clear evidence of any deaths attributable to the emission of radiation from the accident. It is estimated that the earthquake and tsunami resulted in approximately 18,500 fatalities[20].

Nuclear energy is as safe as other low energy generating sources[21]. Replacing coal generating plants with nuclear in Australia may actually lead to an improvement in safety and human health due to reductions in air pollution.

As with the aircraft industry, nuclear power plant designs are continually being improved based on the operating experience of current nuclear power plants. The nuclear risk and safety of all operating nuclear plant and new designs were reassessed following the Fukushima accident and where necessary upgraded.

The most significant design advancements in modern large-scale 1 GWe nuclear power plants and Small Modular Reactors (SMRs) are the introduction of safety features which enable these reactors to automatically shut down and remove decay heat using passive controls. This means that many modern reactors remain safe without external power supply or human intervention for an extended time.

SMRs, rated from 10 MWe to 300 MWe, are now undergoing regulatory assessment in the US, Canada and UK. SMRs have advanced safety features, are designed to load-follow, have great versatility in siting, and their modularity reduces the upfront capital cost making them easier to finance and quicker to operate.

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[19] OECD 2019. *The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables*, Nuclear Energy Agency, Organisation for Economic Co-operation and Development, OECD June 2019 NEA No 7299.

[20] https://www.britannica.com/event/Japan-earthquake-and-tsunami-of-2011/Relief-and-rebuilding-efforts

[21] Our World in Data, "What are the safest and cleanest sources of energy? https://ourworldindata.org/safest-sources-of-energy#nuclear-and-renewables-are-far-far-safer-than-fossil-fuels

Any nuclear plant to be built in Australia would be a modern design that meets international standards and satisfies stringent regulatory conditions. A nuclear plant built in Australia would be assessed, approved and licensed by the Australian nuclear regulator before construction.

Nuclear waste volumes are small and are safely and effectively managed.

High-level radioactive waste consists of the spent fuel removed from a power reactor after about 5 years generating electricity. High-level waste contains both long-lived and short-lived components. The radioactivity is in a solid ceramic material and contained in metal tubes. The radiation from spent fuel elements is readily controlled by shielding and access procedures.

All countries using nuclear power have facilities for managing radioactive waste. Experience over many years demonstrates the safe handling and storage of radioactive waste. Australia already manages a wide range of hazardous materials and has the capabilities and resources to manage nuclear waste.

Spent fuel assemblies from PWRs and BWRs are stored under water for typically 10 years in a used fuel pond at the nuclear power reactor. After 10 years, most of the short-lived radioactivity has decayed and the spent fuel assemblies can be moved to dry storage or transported to facilities for processing to remove the residual uranium and other fissile materials for recycling into new fuel.

Dry storage casks are used at many overseas reactors. The casks are round, stainless-steel canisters that hold typically 24 to 72 used nuclear fuel assemblies. This means all the spent fuel from 18 months operation (40 to 90 fuel assemblies) will fit into 2 to 4 dry storage casks.

If the spent fuel elements are not to be processed to recover and recycle resources, they can be disposed underground in deep geologic facilities. The first such facility worldwide[22] for waste from nuclear power plants is due to start operations as early as 2025.

Uranium is a very long lived naturally occurring radioactive material that was mined for the reactor fuel and the radioactivity in the spent fuel has a half-life less than that of the mined uranium. Suitable engineered geologic facilities can be built for the secure disposal of radioactive waste that will be better isolated from the accessible environment than the original uranium ore body.

Nuclear power takes full responsibility for its waste. All energy producing technologies produce waste, from the vast quantities of coal ash, the millions of tonnes of waste solar panels and the blades and turbines of wind farms. Nuclear waste is small in volume and is effectively and safely managed.

Australia currently manages low- and intermediate-level radioactive waste; we do not currently have any high-level radioactive waste. Following international experience, the cost of managing all the radioactive waste from a nuclear power plant in Australia will be included in the price of electricity generated from the plant.

Procedures and processes for managing the spent fuel and high-level radioactive waste from nuclear power plants will be part of the environmental assessment required in licencing of nuclear power plants in Australia.

[22] https://www.youtube.com/watch?v=1AJ4ipoTnA0

Removing bans on fuel fabrication plants, enrichment plants and reprocessing facilities gives Australia options for the future.

Australia has the largest known reserves of uranium in the world and is currently the fourth largest producer of uranium[23]. Uranium is exported as uranium oxide (U_3O_8). Current prohibitions prevent Australia from having the option to "value add", i.e., convert the uranium oxide into products that are of higher value. Enrichment (to increase the proportion of fissile uranium-235) and fuel fabrication could be suitable options for Australia in future in light of planned expansions of nuclear power plant fleets internationally. Similar to nuclear energy, such endeavours would be subject to intensive regulatory requirements and also international oversight. Appropriate businesses cases would also need to be developed. There are no specific reasons why enrichment and fuel fabrication plants should remain banned in Australia.

Part of implementing a nuclear power program (should this occur in Australia), is consideration of how to manage used nuclear fuel. Australia currently sends the used nuclear fuel from its research reactors overseas for reprocessing, a process where unused uranium and other materials are removed for reuse in nuclear power plant fuel. If Australia wanted to operate a carbon neutral energy system and also be truly energy independent, one way Australia could do this is by mining uranium, enriching it, making fuel assemblies, using the fuel assemblies in nuclear power plants, and then reprocessing used fuel assemblies to recycle materials back into the fuel cycle, all within Australia. Like enrichment and fuel manufacturing plants, there are no specific reasons why reprocessing facilities should remain banned in Australia.

Conclusion

Nuclear power is a viable option for Australia and could greatly benefit the reliability and affordability of our energy system and reduce carbon emissions. As demonstrated in this submission, nuclear power plants are widely used around the world. They are a safe technology, affordable and could be a real benefit to Australia's energy system. Removal of the nuclear prohibitions is not a decision to introduce nuclear power plants; that decision will come later. It is recognition that nuclear power could be a viable option and should be properly investigated to assess its suitability for Australia.

As also discussed in the submission, there is no specific reasons why enrichment, fuel fabrication or reprocessing facilities should remain banned.

[23] Australia's Uranium, https://www.world-nuclear.org/focus/australia/australia.aspx. Accessed 27 November 2022.