



ANSTO Submission

to the Senate Standing Committee on
Environment and Communications Inquiry into
the Environment and Other Legislation
Amendment (Removing Nuclear Energy
Prohibitions) Bill 2022

ANSTO

16 January 2023

Introduction and Scope

As the custodian of Australia's nuclear science, technology, and engineering capabilities and expertise, ANSTO (the Australian Nuclear Science and Technology Organisation) is pleased to make this submission to the Senate Environment and Communications Legislation Committee's Inquiry into the *Environment and Other Legislation Amendment (Removing Nuclear Energy Prohibitions) Bill 2022* (The Bill).

The Bill, if enacted, would remove current prohibitions in Commonwealth law on the licensing, construction or operation of nuclear fuel fabrication plants, nuclear power plants, enrichment plants, and reprocessing facilities.

While ANSTO is agnostic about whether Australia might in future adopt, or consider the adoption of, nuclear power, the organisation has a function under the *Australian Nuclear Science and Technology Organisation Act 1987* (Cth) (ANSTO Act), to provide expert and technical advice on matters relating to nuclear science, technology, and engineering. ANSTO participates in the international governance of peaceful uses of nuclear science and nuclear technology, including nuclear power. It represents the Australian Government in various International Atomic Energy Agency (IAEA) and Organisation for Economic Co-operation and Development – Nuclear Energy Agency (OECD–NEA) forums, in addition to its engagement with bilateral and multilateral partners.

Through ANSTO, Australia has developed a strong international role and reputation in nuclear science and technology, which has resulted in our *de facto* permanent membership of the IAEA's Board of Governors as the sole representative from the South-East Asia and Pacific Region. This position has given Australia—and ANSTO—important global responsibilities; it has also given Australia a strong voice in ongoing discussions about nuclear non-proliferation, nuclear safety, and the various peaceful applications of nuclear technology.

ANSTO maintains strong linkages with the international nuclear community to ensure that Australia is capable of understanding past, present, and future nuclear technologies. ANSTO is well placed to advise government and the Australian public on nuclear technologies. This submission contains a summary of recent developments in this area.

ANSTO has previously made submissions into Federal and State Government inquiries relevant to nuclear policy including, most recently, into the 2019 House of Representatives Standing Committee on the Environment and Energy's Inquiry into the prerequisites for nuclear energy in Australia. As discussed in detail in that submission, there are many legal, policy and practical considerations that are required for nuclear power to be introduced into Australia. In addition to the amendments proposed in The Bill, legislation would also likely be required to upgrade the existing regulatory structure so that it is capable of performing the functions required for the licensing of nuclear power reactors. In addition, there would need to be legislation governing nuclear liability in order to bring Australia into line with international legal norms. Consideration would also need to be given to:

- Waste management, transport and storage,
- Managing environmental impacts,
- Community engagement,
- Workforce capability, and
- Security implications.

Nuclear Power in the World Today

Nuclear power is an important source of global electricity supply. As of 31 December 2021, there were 437 nuclear power reactors operating across 32 countries and Taiwan, with a combined generating capacity of 389.5 gigawatts electrical (GWe), representing approximately 10 per cent of the world's electricity supply.¹

In 2021, six new reactors² were connected to grids, ten were permanently retired and 56 reactors were under construction across 19 countries. The most growth in nuclear power can be seen in Asia, where a total of 70 reactors have been connected to the grid since 2005.³ The United States is planning to add two new commercial reactors to its grid for the first time in six years, which are expected to start producing power in 2023.⁴

While the number of reactors under construction is significant, nearly half of the 437 reactors have been in operation for between 30 and 40 years. It is expected that a large majority of the reactors which are currently 30 years old or more may be retired from service over the next three decades.⁵ Decisions to extend the life of existing reactors are being made in some jurisdictions. . Ageing management programmes are underway for an increasing number of nuclear power reactors globally, especially in North America and Europe. For example, the US Nuclear Regulatory Commission (NRC) approved an application for 20-year extensions to the operating licences for two reactors in southeastern Virginia. This will extend the lifetime of these two power reactors to 80 years, allowing them to operate until 2052 and 2053, respectively.⁶

Several factors which have led to the shutdown of nuclear facilities over the past decade – including political and economic factors, financial factors, and electricity market conditions – are expected to continue to be applicable in the future, which may lead to the rate of shutdowns accelerating given the age profile of the current fleets, partly compensated by lifetime extensions.

The uncertainty regarding the potential replacement of reactors scheduled to be retired over the coming decades – particularly in Europe – means that there also is uncertainty regarding the proportion of global electricity generation that is likely to be derived from nuclear power in the coming decades. The low case estimate sees global nuclear power capacity remain essentially the same at 394 GWe in 2050, with a drop in the share of global electricity generation to 6.3%. The high case estimate, on the other hand, projects more than a doubling of installed capacity to 792 GW, corresponding to an increased share of electricity generation of 12.3%.⁷

As of 31 December 2021, 50 countries have expressed interest in introducing nuclear power. Of these, 24 are in a pre-decision phase and are currently engaged in planning activities. The remaining 26 countries are pursuing the introduction of nuclear power within two distinct groups:

¹ IAEA Board of Governors, *Nuclear Technology Review 2022*, GOV/2022/2, p. 11..

² For the purposes of this submission, the term, 'reactor/s', refers to nuclear power reactors and not nuclear research reactors, unless stated otherwise.

³ International Atomic Energy Agency (IAEA), *Nuclear Power Reactors in the World*, Reference Data Series No. 2, 2022 Edition, IAEA, Vienna, 2022, https://www-pub.iaea.org/MTCD/Publications/PDF/RDS-2-42_web.pdf.

⁴ Bechtel, *Plant Vogtle Units 3 & 4 Waynesboro, Virginia*, <https://www.bechtel.com/projects/plant-vogtle-unit-3-4/>

⁵ IAEA Board of Governors, *Nuclear Technology Review 2022*, GOV/2022/2, p. 6.

⁶ IAEA Board of Governors, *Nuclear Technology Review 2022*, GOV/2022/2, p. 11.

⁷ IAEA Board of Governors, *Nuclear Technology Review 2022*, GOV/2022/2, p. 10.

- (a) Countries considering nuclear power, including those that are performing pre-feasibility studies: Algeria, El Salvador, Estonia, Ethiopia, Indonesia, Kazakhstan, Morocco, Niger, Philippines, Senegal, Sri Lanka, Sudan, Thailand, Tunisia, Uganda, Zambia; and
- (b) Countries that have decided to deploy nuclear power and are building the infrastructure, or have signed a contract and will commence construction in the near future: Bangladesh, Egypt, Ghana, Kenya, Jordan, Nigeria, Poland, Saudi Arabia, Türkiye, Uzbekistan.⁸

Importantly, the centre of nuclear construction expertise, like nuclear power programs more broadly, has been shifting away from the Western Hemisphere in recent years. Historically, reactor vendors and service/supply chain providers were based in the United States, the United Kingdom, and France; however, Russia, South Korea, and, increasingly, China have been emerging as key suppliers.

While sanctions against Russia have opened up a market opportunity for Western countries to compete in the global nuclear technology supply chain, robustness in the Russian, Chinese, and South Korean supply chains has been resulting in lower plant costs and quicker build times.

Generation IV Reactor Designs

Currently deployable power reactors are of the third generation and are often referred to as Gen III or Gen III+ designs. These reactors are safe and reliable, but advancements in materials engineering, among other disciplines, are contributing to the development of the next generation of reactor designs. Globally, several countries are or have invested in demonstration reactors, some of which are now operational. Most recently, the United States passed a bipartisan infrastructure law which including US\$2.5 billion to support the demonstration of two advanced U.S. reactors by 2028.⁹ The Generation IV International Forum (GIF) provides the platform for facilitating international cooperation for the shared objective of developing safer and more sustainable power reactor technologies. It is an association of member countries committed to collaboration on long-term research into, and development of, advanced Generation IV reactor designs.

Australia acceded to the Framework Agreement for International Collaboration on Research and Development of Generation IV Nuclear Energy Systems in 2017, and it entered into force on 16 January 2019. ANSTO is leading Australia's participation in the GIF.

Australia is benefitting from the activities of this major international research program and maintaining and extending our national capabilities in leading-edge nuclear technologies, such as materials science and fuel technology. Participation is also providing Australia with improved knowledge and understanding of the next generation of nuclear reactor technologies and their applications, thereby furthering Australia's nuclear non-proliferation and safety objectives.

Generation IV reactors represent the next iteration in nuclear power technology and promise to use fuel more efficiently, reduce waste production, meet stringent standards for safety and proliferation resistance, and to be more economically competitive against other electricity generation technologies and previous generation reactor designs.

Enhanced features include inherently safe designs that would be considered by nuclear safety regulators to be 'walk-away safe'; the ability to 'burn' radioactive waste to close the fuel cycle; the

⁸ IAEA Board of Governors, *Nuclear Technology Review 2022*, GOV/2022/2, p. 14.

⁹ US Department of Energy, *5 Nuclear Energy Stories to Watch in 2022*, <https://www.energy.gov/ne/articles/5-nuclear-energy-stories-watch-2022>

ability to supply high-temperature process heat to decarbonise industrial activities; the reduction in reactor build costs and construction times; and strengthened non-proliferation mechanisms.

A leading Generation IV reactor design—that of the high-temperature gas reactor (HTGR), was connected to the power grid in China in December 2021 (the HTR-PM). High-temperature reactors are designed to be air-cooled, and China intends that they will be deployed in the country's interior where water resources are scarce. The first-of-a-kind HTR-PM has two reactor pressure vessels supplying heat to one common turbine, generating 210 MWe. Ultimately, it is envisaged that six high-temperature reactor pressure vessels will feed a single turbine for optimised efficiency and economy.

Another Generation IV reactor design, the sodium fast reactor (SFR), is characterised by its high level of neutron generation, which can be used either for actinide (long-lived radioactive waste) burning or fuel 'breeding'. The Russian BN-600 sodium fast reactor has been used to burn and extinguish weapons-grade plutonium since the 1990s and the newer BN-800 SFR will be used as a test-bed to trial advanced fuel forms for improved utilisation. China and India are also undertaking research and development into SFRs, with India hoping to use these reactors to breed uranium-233 fuel from thorium.

Molten salt reactors (MSRs), another advanced design, have the potential to address many of the objectives of the GIF, including the production of high-temperature industrial heat and the capacity to burn actinides in an inherently safe, yet cost effective, design. Currently, China is leading investigations into MSRs via the agency of a US\$3.3 billion research and development program. The first-of-a-kind Shanghai Institute of Applied Physics (SINAP) Thorium MSR (TMSR) 2 MWth test reactor was recently cleared for commissioning. Research and development of MSRs is also active in North America, Europe, and Asia.¹⁰

Australia is maintaining its knowledge base in advanced reactors, having completed a joint research centre project with SINAP on high-performance materials for use in molten salt reactors.

Small Modular Reactors

Small modular reactors (SMRs) are defined as nuclear power plants that generate less than 300 MWe.¹¹ The initial development of SMRs can be traced back to the IRIS program two decades ago¹², which investigated the use of proven pressurised water reactor (PWR) technology in smaller, simplified, and safer reactor designs that are easier to manufacture than large 1 GW PWRs. Since the IRIS program, the term, small modular reactor, has come to also encompass non-PWR-based technologies, including HTGRs SFRs, lead fast reactors (LFRs), and MSRs, which loosely can be termed, 'Advanced SMRs'.

Many near-term deployable SMRs—such as those in development by NuScale (United States)¹³, CAREM (Argentina)¹⁴, and SMART (South Korea)¹⁵— are PWR-based technologies. The Chinese

¹⁰ Kairos Power, *Technology*, Kairos Power LLC, 2019, <https://kairospower.com/technology/>.

¹¹ 300 MWe is enough to power approximately 250,000 homes. In contrast, a large nuclear power plant that produces 1000 MWe (or 1GWe) powers approximately 750,000 homes. See: STRATA, *The Future of Small Modular Nuclear Reactors in the U.S.*, Strata Policy, 2017, <https://www.strata.org/small-modular-nuclear-reactors/>.

¹² Petrovic, B., Ricotti, M., Monti, S., Cavalina, N., and Ninokata, H., 'Pioneering Role of IRIS in the Resurgence of Small Modular Reactors', *Nuclear Technology*, vol. 178, iss. 2, 2012.

¹³ NuScale Power, LLC, *The Carbon free power project*, 2022, <https://www.nuscalepower.com/projects/carbon-free-power-project>.

¹⁴ IMPSA, *Carem, the Argentinean Nuclear Reactor Manufactured by IMPSA, is Launched*, IMPSA, 26 July 2019, <https://www.impsa.com/en/carem-the-argentinean-nuclear-reactor-manufactured-by-impsa-is-launched/>.

¹⁵ SMART Power Co. Ltd, *Design*, Seoul, Korea, <http://smart-nuclear.com/tech/design.php>.

HTR-PM, which was connected to the power grid in December 2021, is the world's first prototype of a HTGR reactor.

A sub-class of SMRs outputting less than 10 MWe is commonly referred to as 'micro-reactors'; these reactors are designed for remote deployment to service hard-to-reach communities or mining operations, for space applications, or for mobile deployment into disaster areas. Also in development are transportable—including floating or truck-mounted—SMRs, which are designed to be returned to their point of origin at the end of their life. Russia is leading research and development activities in this area.¹⁶

Small modular reactors and Advanced SMRs have the potential to reduce build costs using a variety of strategies, including:

- the elimination of costly active safety systems by using passive safety features or inherently-safe reactor designs;
- shifting the majority of construction off-site to an enclosed factory environment using modular manufacturing techniques;
- reducing plant build times from six to eight years for large reactors to two and a half to four years for SMRs via the use of series-production methods;
- increasing learning rates to be in line with the learning rates of other industries, such as combined cycle gas turbines, shipbuilding, and aircraft manufacturing, where a high proportion of construction is factory-based;
- the use of next-generation technologies, such as reactor coolants with superior thermal characteristics, high-performance alloys, and accident-tolerant fuels; and
- innovative delivery and construction models.¹⁷

The smaller size of SMRs and SMR-based plants can offer distinct advantages for future grids:

- most SMR designs have the potential to operate in load following regimes in concert with variable renewable energy sources;
- the smaller output of SMRs will require less transmission overheads compared to large gigawatt plants;
- they are able to provide for district heating and desalination requirements; and
- they are able to provide for industrial heat requirements.¹⁸

In 2021, the IAEA published a *Technology Roadmap for Small Modular Reactor Deployment*, based on the latest inputs from Member States currently pursuing this technology, including those with reactors currently in operation or under construction.¹⁹

¹⁶ ROSATOM, *Projects*, The State Atomic Energy Corporation ROSATOM, 2019, <https://rosatom.ru/en/investors/projects/>.

¹⁷ Department for Business, Energy and Industrial Strategy (BEIS), *Advanced Nuclear Technologies – a UK framework*, Clean Energy Ministerial, BEIS, 2019, <https://www.cleanenergyministerial.org/content/uploads/2022/03/advanced-nuclear-technologies-2019.pdf>.

¹⁸ Canadian Nuclear Association, *SMR Roadmap*, 2018, <https://smrroadmap.ca/>.

¹⁹ IAEA Nuclear Energy Series No. NR-T-1.18, Vienna, 2021, <https://www.iaea.org/publications/14861/technology-roadmap-for-small-modular-reactor-deployment>

Status of the Thorium Fuel Cycle

Thorium-fuelled reactors are often championed as a possible alternative to uranium-fuelled reactors; however, the arguments put forward require some analysis and scrutiny. For example, proponents frequently claim that the thorium fuel cycle is resistant to proliferation risks. However, the production of uranium-233 during the cycle presents a potential proliferation risk that would require similar safeguards to those that are established for the current uranium fuel cycle.

Moreover, although the thorium fuel cycle theoretically is a feasible source of energy, there is limited evidence that the required significant investments to make thorium technologies commercially viable would be an improvement on the well-established reactor technologies and systems using uranium-based fuels.

As the Nuclear Fuel Cycle Royal Commission Report found, 'Energy generation technologies that use thorium as a fuel component are not commercial and are not expected to be in the foreseeable future. Further, with the low price of uranium and its broad acceptance as the fuel source for the most dominant type of nuclear reactor, there is no commercial incentive to develop thorium as a fuel.'²⁰

Developments in Fusion Reactor Technology

Fusion technology, as a large, constant, and potentially sustainable source of baseload power, is the subject of ongoing research and development activities. The great promise of the fusion reactor is that it can make a significant contribution to the world's energy supply—if it can be proved to be both viable and feasible.

The International Thermonuclear Experimental Reactor (ITER) Project is the world's largest fusion energy research and development mission, and involves six member countries and the European Union in the construction of an experimental tokamak fusion reactor in the south of France.²¹

It is planned that ITER will be the first fusion device to produce net energy—that is, to achieve a higher energy output than that which is required as input to heat the plasma. It also is intended to be the first fusion device to test the integrated technologies, materials, and physics regimes necessary for the commercial production of fusion-based electricity.²²

ANSTO, on behalf of the Australian Government and the country's fusion research community, signed a technical cooperation agreement with the ITER Organization in 2016. In so doing, Australia became the first non-member country formally to engage with the Project.

Australia's major research contributions are a diagnostic system to image the ITER plasma in real time and studies of materials under the extreme conditions that they will experience in the tokamak reactor; both are collaborations between the Australian National University and ANSTO.

A number of private companies and organisations claim to be working on projects that will achieve net production of energy from fusion before ITER.²³ However, in the absence of publicly available

²⁰ *Nuclear Fuel Cycle Royal Commission Report*, Government of South Australia, 2016, p. 24.

²¹ The six member states are: China, India, Japan, South Korea, the Russian Federation, and the United States.

²² ITER Organization, *What is ITER?*, ITER Organization, 2019, <https://www.iter.org/proj/inafewlines>.

²³ McMahon, J., 'Energy from Fusion in "a couple of years", CEO says, Commercialization in Five', *Forbes*, 14 January 2019, <https://www.forbes.com/sites/jeffmcmahon/2019/01/14/private-firm-will-bring-fusion-reactor-to-market-within-five-years-ceo-says/#33753e301d4a>.

information about these projects, it is not possible for ANSTO to comment on the veracity of these claims.

Non-Electric Applications of Nuclear Energy

Non-electric applications of nuclear energy include seawater desalination, hydrogen production, district heating, and various other industrial applications. Integrated nuclear and desalination plants are in operation in India, Japan and Kazakhstan. District heating, utilising the steam produced by nuclear power plants, is in operation in several countries around the world. NuScale LLC has recently signed a research collaboration agreement with other industry partners to develop and assess a concept for an economically optimized Integrated Energy System (IES) for hydrogen production using electricity and process heat from a NuScale small modular reactor power plant. In 2017, the IAEA published an overview of the potential use of nuclear energy for industrial systems and/or processes which have a strong demand for process heat/steam and power.²⁴ This document also maps of nuclear power reactors proposed for various industrial applications.

²⁴ *Industrial Applications of Nuclear Energy*, IAEA Nuclear Energy Series No. NP-T-4.3, Vienna, 2017, <https://www.iaea.org/publications/10979/industrial-applications-of-nuclear-energy>