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# ANSTO Submission to the South Australian Nuclear Fuel Cycle Royal Commission

## 1. Introduction and scope

As the custodian of Australia's nuclear capabilities and expertise, the Australian Nuclear Science and Technology Organisation (ANSTO) welcomes the decision of the South Australian Government to establish the Nuclear Fuel Cycle Royal Commission.

This submission follows ANSTO's previous submissions to government inquiries and policy processes, including on:

- the cost of nuclear power adapted for Australian circumstances;
- emerging nuclear technologies, and international nuclear technology development efforts;
- the steps required in order for nuclear power to become a viable option for Australia; and
- other potential nuclear fuel cycle opportunities for Australia.

Previous ANSTO submissions to government inquiries into energy policy have addressed the following topics:

- Energy security and nuclear power's potential role, economic issues, legislative requirements and public issues in Australia around nuclear:
    - ANSTO Submission to the Energy White Paper – Green Paper, November 2014 (ANSTO 2014a).
    - ANSTO Submission to the Energy White Paper – Issues Paper, February 2014 (ANSTO (2014b).
    - The role of nuclear in enhancing energy security in Australia, Submission to the Select Committee for Fuel and Energy, July 2009 (ANSTO 2009a).
    - The Nuclear option as part of a diverse energy mix, Submission to the Department of Resources, Energy and Tourism, June 2009 (ANSTO 2009b).

- The need to target base-load generation as the most efficient way to address emissions, and technology considerations for base-load service with the available options:
    - The Nuclear Power Alternative for NSW, Submission to the Owen Inquiry into Electricity Supply in NSW, June 2007 (ANSTO 2007).
    - Relative Economics of Energy Generation for NSW, Submission to the Public Accounts Committee Inquiry into the Economics of Energy Generation, February 2012 (ANSTO 2012).

The selection of a site or sites for nuclear facilities is not considered in this submission.

## 2. Nuclear as a low emissions energy source

Nuclear power meets all the requirements for energy security by providing an adequate, affordable and reliable energy supply (ANSTO 2009, p 20). In addition it has significant environmental impact and public health advantages over other existing fit-for-service base-load technologies:

- nuclear power, in countries with limited potential for hydropower, is the most efficient and cost-effective low emissions fit-for-service base-load electricity generation option;
- in addition to producing negligible carbon emissions, nuclear power does not generate the small particulate pollution associated with other baseload technologies. Such pollution has significant effects on public health;
- nuclear power allows countries to grow electricity use while maintaining low emissions;
- new generation nuclear power plants under construction across the world represent a mature and safe technology; and
- future nuclear technology has the potential to further improve safety while reducing cost and up-front capital investment requirements. ANSTO's February 2014 submission to the Green Paper process reported that, according to the International Atomic Energy Agency (IAEA), 30 countries worldwide were currently operating 435 nuclear reactors for the purpose of electricity generation (IAEA 2014). A further 71 new nuclear power plants were under construction in 15 countries (IAEA 2014).

Several developing countries and emerging economies, in particular in the Asia Pacific region, are looking to nuclear power as a solution to their energy supply and security concerns. In the Asia-Pacific region, China, India, Pakistan, South Korea, the United Arab Emirates and Vietnam are continuing to increase installed nuclear capacity through the construction of new plants or through newly announced build programs. China currently has 25 nuclear power reactors under construction, India has six, South Korea has four, United Arab Emirates (UAE) has three and Taiwan has two (World Nuclear Association (WNA) 2015a; WNA 2015b; WNA 2015c; WNA 2015d; WNA 2015e). Vietnam has signed contracts with Russia and Japan for the construction of four new reactors, which are expected to be operational by 2030 (WNA 2015f).

In addition to those countries constructing nuclear power plants, several other countries in the region have announced plans for, or are seriously considering the installation of, nuclear power to provide them with base-load power. In fact, a contiguous band of countries with nuclear power or plans for nuclear power spans the Asian continent, from Turkey on the Mediterranean Sea to China and Vietnam on the South China Sea. Directly to Australia's north, Indonesia has long been considering the option of nuclear power, with plans for construction in place before being halted for review following the Fukushima accident.

**a. Reliability**

In terms of reliability, global average plant availability of operating nuclear power reactors from 2010 to 2012 was 77.8% (IAEA 2014). Countries like Brazil, Finland, Romania and Slovenia achieved availability in excess of 90%, with the United States following closely with an availability of 89% over the same period (IAEA 2014).

Between 1990 and 2004, 57% of the growth in global nuclear output was not from building new reactors, but from increasing availability of existing reactors, while another 7% came from uprating capacity, demonstrating the potential for growth in the energy output of established nuclear markets to accommodate increasing demand (Organisation for Economic Cooperation and Development (OECD) Nuclear Energy Agency (NEA) 2008, p 52).

Most significantly, nuclear power is a mature technology which, like the aircraft industry, has significantly innovated and improved safety and operational efficiency with each new generation of designs. North America, Europe and East Asia lead the world in the use of nuclear power in terms of proportion of primary energy consumption. This is reflected in the comparison of primary energy consumption between OECD and non-OECD countries.

Of the 34 OECD countries, 18 operate nuclear power reactors. Of the remaining 16 countries, 12 are importing electricity from neighbouring nuclear countries to provide electricity and stability to their grids. Of the remaining four, Iceland predominately uses geothermal power and New Zealand generates most of its power in the form of hydro-electricity. Israel's geographic location has, to date, precluded the use of nuclear power. Australia is the only other OECD country that does not utilise nuclear power.

**b. Safety**

Nuclear power is a historically very safe technology, outperforming other established technologies in human health outcomes. This is true even when the effects of nuclear accidents, which are extremely rare in comparison to other technologies, are taken into account.

The Fukushima accident brought renewed public attention to the question of nuclear safety, particularly in areas prone to earthquakes. Significantly, the radiological impact on the affected population has not involved any deaths and is currently estimated by the World Health Organisation (WHO) to be negligible amongst the general population of the Fukushima Prefecture (WHO 2013, p 8).

As was the case at Chernobyl, the psychological impact of the Fukushima accident will potentially outweigh all other health consequences (WHO 2013, p 90). However, the economic costs have been immense, and have confirmed the need for effective and independent regulation of the industry, particularly where the reactors involved are older generation technology. Following the accident, the IAEA recommended a global review of reactor safety and stress tests, which have been the basis for further improvement of the safety of operating reactors globally.

A 2013 study commissioned by Friends of the Earth states 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" (Commonwealth of Australia 2014, p 71). This fact is supported by a study released by the US National Aeronautics and Space Administration (NASA) in 2013, which found that nuclear power has likely prevented over 1.8 million deaths worldwide between 1971 and 2009 through replacing the role of fossil fuel power plants (NASA 2013). While many countries are employing natural gas as a cleaner source of electricity generation, the NASA study found that "although natural gas burning emits less fatal pollutants and GHGs [greenhouse gases] than coal burning, it is far deadlier than nuclear power, causing about 40 times more deaths per unit electric energy produced" (NASA 2013).

As emerging nuclear technologies progress to maturity, their enhanced safety features, such as passive cooling, will ensure that nuclear reactors remain one of the safest energy technologies available.

## 3. Emerging nuclear technologies

**a. Generation IV technologies**

Generation IV technology refers to the next generation of nuclear reactor designs which will use fuel more efficiently, reduce waste production, be economically competitive, and meet stringent standards of safety, security and proliferation resistance.

International efforts to research this new reactor technology are being coordinated by the Generation IV International Forum (GIF), a consortium of advanced nations committed to working together in long-term research on advanced nuclear technologies. For more than a decade, the GIF has led international collaborative efforts to develop next-generation nuclear energy systems that can help meet the world's future energy needs.

Research is focused on six reactor designs with the objective of achieving lower costs, higher efficiency, reduced waste, additional passive safety features and greater proliferation resistance. This research will enable safer and more secure use of nuclear technologies worldwide. In addition, four of the six designs being investigated are also designated for hydrogen production, potentially powering transportable energy systems in the form of hydrogen fuel cells.

Some of these reactor designs could be demonstrated within the next decade, with commercial deployment beginning in the 2030s. China has already begun construction of a prototype high temperature reactor and a molten salt reactor. Both France and Russia are developing advanced sodium fast reactor designs intended for demonstration in the next five to ten years. A prototype lead fast reactor is also expected to be built in Russia over the next ten years.

**b. Small modular reactors**

The development of Small Modular Reactors (SMRs) is the focus of significant attention in the nuclear energy industry. SMRs are modular in design and construction and have a generating capacity of approximately 300MWe or less. Whilst yet to be licensed under a regulatory regime similar to what would be established in Australia, several countries and international consortiums have recognised the promise of SMR technology, and are investing in their development.

SMRs will be scalable, requiring lower initial capital investment. As SMR units will be modular, it is envisioned that siting will be more flexible, and the extensive use of factory-fabricated components will result in significantly shorter construction times than those associated with large scale plants. Therefore, SMRs have the potential to address the two major economic impediments to installing new nuclear power – high capital costs and lengthy construction periods. Additionally, SMRs have the potential for increased safety and security measures, as described below.

*Low build costs*

A recent study by the OECD NEA concluded that one SMR would cost slightly more than one quarter the price of one large pressurised water reactor (PWR), given an output of one large PWR equal to four SMRs (OECD NEA 2011). Although the capital cost per MW would therefore be a little higher, the lower capital cost of a smaller reactor with shorter construction lead-times and faster cash-flow generation could make SMRs an attractive prospect for private utilities operating in a deregulated energy market.

*Modularity*

By definition, SMRs will be designed to allow the major nuclear steam supply system components to be pre-fabricated in a factory and shipped to the point of use for assembly. Potentially, installation of SMRs will require limited onsite preparation in comparison to traditional large nuclear power plants, which would significantly reduce the currently accepted construction times for new nuclear. Factory fabrication would also allow for economic improvements such as more predictable timelines and greater economies of scale benefits. Smaller scale construction requirements and reduced delays would result in reduced capital investment requirements and associated risk. Modularity would allow increased optionality, with the installation of additional units as energy demand increases.

*Safety and security*

The advanced nuclear power reactors, including SMRs, currently under development incorporate passive safety systems, requiring no active controls or human intervention to maintain cooling or containment in the event of malfunction or damage.

SMRs can also potentially provide added safeguards against natural disasters, sabotage and the proliferation of nuclear materials. Several SMRs currently in development are being designed to be installed underground, limiting any vulnerability to scenarios involving external impacts.

*Flexibility*

The combination of modularity and small footprint means that SMRs will be extremely flexible in their application. It is envisioned that SMRs will be used to supply power where large plants are not needed, or where there is insufficient infrastructure to support a large plant. For example, SMRs could be used to supply energy to small or isolated grids and areas with limited space or water, or to balance larger grids. Floating SMRs, such as the 35MWe Russian KLT-40S, might be used to provide power to small island states, coastal towns or isolated harbour-side industry.

As a smaller energy source, SMRs could potentially be coupled with other generation technologies to provide a reliable energy mix where large scale power plants are unsuitable.

*Fuelling/refuelling and proliferation resistance*

A key design factor for next generation SMRs is the ease with which they can be fuelled and refuelled. Some SMRs are being designed to accept new fuel in an internal fuel delivery system, allowing refuelling during operation. In addition, longer refuelling cycles will allow SMRs to achieve extremely high availability, potentially reaching upwards of 95% availability. Cassette-type fuelling systems will also allow SMR operators to swap out entire cores without the need to 'shuffle' fuel bundles as is currently the case for PWR reactors. This will further limit fuel movements, adding to proliferation resistance.

*Waste management*

Several SMRs in development in Japan, Russia and the United States will address radioactive waste management issues, and will operate with a closed fuel cycle, minimising waste and maximising energy output from each unit of fuel. A closed fuel cycle allows more efficient management of fission products and conversion of still fertile fissionable material from spent fuel.

*Deployment in the Australian setting*

As a coastal-dwelling nation with long power-grid structures, Australian power grids are required to cover vast transmission distances. Conceptually, a network of SMR power stations deployed as part of Australia's future energy mix could distribute energy production more efficiently, minimising transmission losses and benefiting regional areas. The modest output of SMRs at less than 300MWe would allow their deployment on electrical grids without upgrades to existing transmission infrastructure. Some SMRs are being designed with air-cooled condensers, which would allow their installation in locations where water is scarce.

**c. Fusion**

While fusion remains a promising technology for sustainable, low emissions technology in the long- term future (post-2035), there are significant technological challenges. These challenges are being addressed by the ITER consortium (ITER 2014), which is building a test fusion reactor in France at present, as well as some strong national programs and small scale fusion projects currently under development. Australia has a well organised fusion community centred around the internationally important facilities at the Australian National University (ANU). ANSTO's advanced nuclear materials engineering activities are also making significant contributions to the development of materials for use in fusion programs.

ANSTO's expertise in this area is internationally recognised. As such, ANSTO represents the Australian Government in our membership of the Fusion Power Coordinating Committee (FPCC) at the International Energy Agency. In this respect, ANSTO seeks to link the Australian and global research efforts to break through the technological barriers to reliable and predictable fusion energy.

**d. Thorium**

Thorium fuelled nuclear power reactors are often put forward as a possible alternative to uranium fuelled reactors on the basis of a number of arguments, not all of which are accurate. For example, proponents of thorium reactors often claim that the thorium fuel cycle is resistant to proliferation risks. However, the production of uranium-233 during the thorium fuel cycle presents a potential proliferation risk that would require similar safeguards to those in place for the uranium fuel cycle today (ANSTO 2013).

Although the thorium fuel cycle is a theoretically feasible source of energy, there is limited evidence that significant investment in future thorium technologies would improve on the well-established technologies and systems in place for the uranium fuel cycle, for which Australia is already one of the world's largest exporters. Nevertheless, ANSTO is supportive of further research efforts in this area, particularly in cases where multinational partnerships support a common design basis or mixed fuel technologies.

## 4. Requirements for nuclear power in Australia

In order for any Australian government to move from considering nuclear power to planning for it to play a role in the energy mix, a number of steps would need to be undertaken by both government and industry.

**a. Social licence**

It is essential that large-scale energy projects, including nuclear energy, gain the support of the community – particularly host communities. Any plan to establish nuclear power in South Australia would require a comprehensive strategy for community engagement. The positive effect of familiarity and understanding is evidenced by the existing increased rates of public approval for nuclear power in South Australia, where the majority of Australia's uranium exports are sourced. Such a trend – with local communities being the strongest supporters of nuclear facilities – can be seen in many countries.

ANSTO already plays a significant role in engaging the Australian community on nuclear and broader science issues. For example, in 2014-15, ANSTO welcomed more than 15,000 visitors. The majority of these visitors were school groups undertaking tours tailored to the school curriculum. ANSTO also engages through education initiatives at all levels. In addition to providing critical national landmark research infrastructure to the Australian research community, ANSTO contributes to the education and training of Australia's future nuclear experts, and scientists more broadly, through positions for undergraduate, Masters and PhD students, internships and fellowships, and support for university courses such as the Masters of Nuclear Engineering at the University of New South Wales. It is only through such engagement that the community, and future generations, can gain the necessary familiarity and expertise with nuclear technology to be in a position to make an informed decision should South Australia choose to consider further whether to include nuclear power in its energy mix.

**b. Legislative and regulatory**

Significant legislative changes would be required in order to develop a South Australian nuclear power industry. At present, nuclear power is prohibited in Australia. At the Commonwealth level, the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) effectively prohibits the construction or operation of nuclear fuel fabrication plants, nuclear power plants, enrichment plants or reprocessing facilities. In addition, the *Australian Radiation Protection and Nuclear Safety Act 1998* (Cth) prevents the CEO of ARPANSA from licensing the siting, construction or operation of such facilities by Commonwealth entities. At the South Australian level, there is a conditional ban on conversion and enrichment (see section 27 of the *Radiation Protection and Control Act 1982*).

In addition to the removal of those legislative barriers, legislation would also be required in order to upgrade the existing regulatory structure or create new a regulatory structure capable of performing the functions required for the licensing of nuclear power reactors. There would also need to be legislation governing nuclear liability in order to bring Australia into line with international norms.

**c. Skilled labour**

Australia currently does not have sufficient skilled personnel to operate a nuclear power industry. However, this situation does not present a significant constraint to development of a South Australian nuclear energy industry. Rather, a choice to include nuclear power in South Australia's energy mix would create new job and education opportunities. It has been demonstrated in all new build programmes that government commitment and the availability of training opportunities correlate with increased demand for tertiary nuclear engineering courses. In addition, with support from reactor vendors, skills gaps are generally not a limiting factor in new nuclear power programmes.

**d. Technology**

Nuclear power technology is well established in the majority of advanced economies around the globe. Should South Australia establish a nuclear power program, it is unlikely that the first power reactors built there would be first-of-a-kind plants. Rather, in order to benefit from previous operating experiences, optimisation programs, regulatory scrutiny, and economies of scale, any local nuclear power industry would likely choose an off-the-shelf design already licenced in a similarly rigorous regulatory jurisdiction.

ANSTO expects that in order for South Australia to be able to take advantage of the unique applications, improved economics, enhanced safety and security, and scalability of SMRs, the particular design will also first need to be licenced by a trusted overseas regulator.

**e. Economics**

Any decision to establish nuclear power should be based on a framework against which relevant energy technologies can be assessed. Key to this framework is the establishment of a method for economic assessment. An independent group, dedicated to assessing the economics of energy technologies in various applications, could provide South Australian energy planners with the objective economic advice necessary to achieving the optimum energy mix in a number of scenarios for the state.

**f. Waste management**

Should nuclear power be included in South Australia's future energy mix, a comprehensive spent fuel and waste management strategy would need to be put in place prior to commissioning of the first power reactor. A comprehensive strategy would include the construction and operation of a radioactive waste management facility at a site with local community support.

## 5. Other nuclear fuel cycle opportunities

**a. Front end**

Australia's known uranium resources are the world's largest, comprising 31% of the world's total reserves (Minerals Council of Australia (MCA) 2015a; WNA 2015g). The majority of these reserves can be found in South Australia. In 2012 Australia produced 8,244 tonnes of $U_3O_8$ (6,991 tU) and supplied 12% of the global market, making it the world's third- ranking producer, behind Kazakhstan and Canada (WNA 2015g). In the short to medium term, Australian uranium exports are forecast to increase to 9,600 tonnes in 2017-18, supplying 11% of global production and earning approximately $A1 billion annually (MCA 2015b).

At present, South Australian uranium is exported with limited additional value added to the ore before it is sold and shipped to countries that undertake the tasks of conversion, enrichment and fuel fabrication. With massive uranium deposits in South Australia, this is an opportunity that has not been undertaken due to legislative prohibition influenced by economic, diplomatic and social factors.

The 2007 Uranium Mining, Production and Nuclear Energy Review (UMPNER), commissioned by the Howard Federal Government, considered the challenges and opportunities for Australia becoming involved in one or more of the stages of conversion, enrichment and fuel fabrication (UMPNER 2007, p42). The UMPNER panel concluded that while there was no case for the Australian Government to subsidise entry into this value-adding industry, neither was there a strong case to discourage the development of the industry in Australia.

Eight years later, with nuclear power expanding across the Asia Pacific region, there exists an opportunity to re-examine the advantages and disadvantages of participating in other fuel cycle activities, taking into account local social, economic, political and technological factors, foreign policy issues, issues of supply and demand, and international best practice.

**b. Back end**

There have been several proposals over the past few decades for Australia to participate in the back end of the fuel cycle, that is, in storing or reprocessing spent nuclear fuel and managing or disposing of radioactive waste. Any such proposals could only be considered in the light of the discussion in Chapter 4 above.

Radioactive waste management is a well understood activity, based on mature and technologically advanced practices. Radioactive waste management facilities are in operation in many countries. The IAEA has created a range of standards regarding waste management, and organises International projects and working groups to work towards harmonisation of approaches to the safety of predisposal management and disposal of radioactive waste, and to provide a forum for exchange of experience.

Already, there exists significant expertise in waste processing and management in Australia. As the operator of the OPAL research reactor, and previously the HIFAR and MOATA research reactors, ANSTO maintains the skills, knowledge and capabilities to manage and store spent nuclear fuel and other radioactive wastes. Following the construction of the ANSTO Nuclear Medicine facility, which is due to commence operation in late 2016, ANSTO will commission the world's first industrial scale Synroc waste processing facility, using Australian technology to reduce final waste volumes by up to 97 per cent. With the rapid expansion of nuclear power throughout the region, opportunities exist to export this expertise to new and existing operators seeking efficient and effective waste management technologies that are both safe and cost effective.

## 6. Conclusion

Nuclear power is a mature technology – it has a proven track record in many countries around the world, including the Asia Pacific's largest economies – China, Japan, India and South Korea. In fact, of the major economies in the Asia Pacific region, Australia alone has excluded nuclear power from energy policy discussions.

There also exist opportunities at both the front and back end of the fuel cycle that have not yet been exploited in Australia. Any South Australian involvement in these opportunities should be based on a technologically neutral assessment of the potential benefits and risks. In this regard, the outcome of the Royal Commission will provide a strong base on which to conduct the necessary assessments, in conjunction with local expertise and international guidance.

As a recognised global actor, ANSTO maintains strong linkages with the international nuclear community to ensure that as nuclear energy use expands throughout the region, Australia is capable of understanding the past, present and future of nuclear technologies. Through such linkages, as well as its world class capabilities and expertise, ANSTO is well positioned to further assist the Royal Commission in its activities, and to support future nuclear development anywhere in Australia, including South Australia.

To this end, ANSTO is in the process of finalising a nuclear fuel cycle research and development strategy paper that may be useful to the Royal Commission in illustrating the current state of play for various technologies across the fuel cycle, and presenting scenarios in which ANSTO or another Australian stakeholder could participate further. It is anticipated that this paper will be published in the coming weeks.

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