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The Report

Introduction

1.1 The inquiry commenced on 6 August 2019 following a referral from the Minister for Energy and Emissions Reduction. The Minister requested that the Committee inquire into and report by the end of 2019 on:

> …the circumstances and prerequisites necessary for any future government's consideration of nuclear energy generation including small modular reactor technologies in Australia.

1.2 The complete terms of reference are provided in the preliminary pages.

1.3 This inquiry took place against a backdrop of three notable contextual features of energy policy:

- Climate change: governments around the world have agreed to take action on reducing greenhouse gas emissions which has led to renewed interest in nuclear technology as a source of emissions-free baseload energy.
- New technologies: as countries' energy systems change due to a significant increase in intermittent low emissions technologies, interest in new and emerging firming technologies is growing, including new generation nuclear such as small modular reactors.
- Existing moratorium: despite a research nuclear reactor operating in New South Wales, a moratorium on nuclear energy is in place in Australia which prohibits the construction or operation of nuclear power plants.

1.4 This inquiry is focused on the future. Its terms of reference refer to 'future governments' and in practical terms, Australia would not be in a position to introduce nuclear energy for at least a decade. The inquiry has therefore not sought to examine the question of whether nuclear energy should be

immediately introduced in Australia, but rather the conditions under which it may be introduced in the future. This has included consideration of the feasibility of nuclear energy in Australia in relation to economic, technological and capability factors; the suitability of nuclear energy in Australia in relation to environmental, safety and security factors, and the acceptability of nuclear power generation to the Australian people.

1.5 The Committee considered 309 submissions and undertook a program of public hearings across the country from which it drew three key conclusions:

- firstly, the Australian Government should further consider the prospect of nuclear technology as part of its future energy mix;
- secondly, the Australian Government should undertake a body of work to deepen the understanding of nuclear technology in the Australian context; and
- thirdly, the Australian Government should consider lifting the current moratorium on nuclear energy partially—that is, for new and emerging nuclear technologies only—and conditionally—that is, with approvals for nuclear facilities to require the prior informed consent of impacted local communities.

1.6 The report—entitled *Not without your approval: a way forward for nuclear technology in Australia*—is published in three sections, with each section addressing one of the above-mentioned conclusions.

1.7 The report is supplemented by Appendix A, which provides background information and a summary of the evidence received by the Committee.

1. The prospect of nuclear energy

1.8 This section of the report discusses the overarching objectives of Australia's energy system and the approach that should be adopted by the Australian Government in considering the prospect of nuclear energy technology as part of the nation's future energy mix.

1.9 The section is divided into four sub-sections that suggest Australia should be:

- goal-oriented in seeking to deliver affordable and reliable energy while fulfilling its international emissions reduction obligations;
- strategic in approaching the possibility of entering the nuclear energy industry by learning from others while building its own sovereign capability;

- holistic in thinking about nuclear technology as more than just a source of electricity generation but also for other important civilian applications; and
- community-focused by putting the community at the centre of efforts to progress consideration of nuclear energy.

Adopting a goal-oriented approach

1.10 Australia should be goal-oriented in its consideration of nuclear energy. This requires us to recognise Australia's existing nuclear capabilities and consider the prospect of nuclear energy generation against broader goals for Australia's energy system—that is, to deliver affordable and reliable energy while fulfilling international emissions reduction obligations.

Recognising Australia as a nuclear nation

1.11 Australia is already a nuclear nation, by virtue of its participation in a range of sectors in the nuclear industry from mining to research.

1.12 Australia possesses the world's largest reserves of uranium, the chemical element used to power nuclear reactors for energy production. Uranium has been mined in Australia since 1954 and we are currently the world's third largest uranium exporter; selling to North American, European and Asian countries that use uranium to generate energy.

1.13 Australia currently operates a nuclear reactor, albeit for medical research and other purposes instead of producing electricity. The Australian Nuclear Science and Technology Organisation (ANSTO) has operated a nuclear research reactor and related facilities at Lucas Heights in Sydney for over 60 years, producing radioisotopes for a range of medical applications, particularly cancer detection and treatment. ANSTO's facilities also conduct research for other medical and industrial purposes, and the reactor is also used for the irradiation of silicon ingots for the manufacture of electronic semiconductor devices.[1]

1.14 Australian nuclear science and technology is globally recognised.[2] ANSTO, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and some Australian universities participate in cutting-edge research and international collaboration on nuclear-related activities. This includes participation in the Generation IV International Forum (GIF) where Australia is contributing its nuclear and materials

1 See Australian Nuclear Science and Technology Organisation (ANSTO), https://www.ansto.gov.au, accessed 18 November 2019.

2 ANSTO, *Submission 166*, p. 1.

engineering capabilities to major international research on leading-edge nuclear technologies.[3]

1.15 The GIF brings together member countries 'committed to collaboration on long term research into, and development of, advanced Generation IV reactor designs'.[4] Australia was invited to join the GIF in recognition of our nuclear and materials engineering capabilities. Australia's participation in the GIF will help to maintain and extend our national capabilities in leading-edge nuclear technologies, and provide improved knowledge and understanding of the next generation of nuclear reactor technologies and their applications.[5]

1.16 Australia has legislation in place, including the *Australian Radiation Protection and Nuclear Safety Act 1998* and the *Nuclear Non-Proliferation (Safeguards) Act 1987*, to ensure the security and safety of nuclear activities and radioactive materials. This legislation is enforced by a robust and effective regulatory framework managed by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and the Australian Safeguards and Non-Proliferation Office (ASNO).

1.17 However, Australia currently has a moratorium in place that prohibits it from the 'construction or operation' of a number of nuclear installations, including nuclear power plants. This moratorium was introduced by Parliament in 1998 during consideration of the legislation to create ARPANSA, and at a time of strong anti-nuclear sentiment in Australia, particularly following French nuclear weapons testing in the Pacific and the 'Rainbow Warrior' incident.[6]

1.18 The Committee notes: i) Australia's existing nuclear capabilities; and ii) Australia's active participation in the nuclear industry internationally.

Reducing greenhouse gas emissions

1.19 Under the 1994 UN Framework Convention on Climate Change[7] and its associated agreements, most recently the 2016 Paris Agreement,[8] governments around the world have agreed to take action on climate change.

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3 ANSTO, *Submission 166,* p. 4.

4 ANSTO, *Submission 166,* p. 4.

5 ANSTO, *Submission 166,* p. 4.

6 See Bright New World, *Submission 166*, pp. 34-40.

7 United Nations Framework Convention on Climate Change, 1771 UNTS 107 (entered into force 21 March 1994).

8 Paris Agreement Under the United Nations Framework Convention on Climate Change [2016] ATS 24 (entered into force generally 4 November 2016; entered into force for Australia 9 December 2016).

1.20 In order to meet its international commitments, Australia needs to reduce its greenhouse gas emissions by 26 to 28 per cent below 2005 levels by 2030.[9]

1.21 Bright New World, a not-for-profit environmental organisation based in South Australia, submitted that the Intergovernmental Panel on Climate Change (IPCC) considers nuclear energy a 'mitigation technology' for addressing climate change:

> The Intergovernmental Panel on Climate Change (IPCC), in its Fifth Assessment Report, classifies nuclear energy as a 'mitigation technology'. This is echoed in the recent IPCC special report on global warming of 1.5C where nuclear increases its share of global primary energy in every scenario assessed.[10]

1.22 The IPCC defined mitigation as 'a human intervention to reduce the sources or enhance the sinks of greenhouse gases'[11] and listed mitigation technologies as including bioenergy, carbon capture and storage (CCS), a combination of bioenergy and CCS, nuclear, wind and solar.[12]

1.23 Based on life-cycle emissions profiles, the IPCC has declared nuclear energy comparable to renewable energy sources such as wind and solar photovoltaic (PV).[13] The Committee was provided with the following table from Bright New World, comparing lifecycle greenhouse gas emissions[14] from various energy sources:

9 Department of the Environment and Energy, 'Paris Agreement', at https://www.environment.gov.au/climate-change/government/international/paris-agreement.

10 Bright New World, *Submission 168,* p. 5.

11 Intergovernmental Panel on Climate Change, *AR5 Synthesis Report: Climate Change 2014,* Annex II, Glossary, p. 125.

12 Intergovernmental Panel on Climate Change, *AR5 Synthesis Report: Climate Change 2014,* 'Summary for Policymakers', p. 24.

13 Bright New World, *Submission 168,* p. 5.

14 Table is expressed as 'grams of carbon dioxide equivalent per kilowatt hour'.

Table 1.1 Lifecycle greenhouse gas emissions

Technology	Minimum gCO_2-e/KWh	Median gCO_2-e/KWh	Maximum gCO_2-e/KWh
Nuclear (PWR and BWR)	3.7	12	110
Wind (Onshore)	7	11	56
Solar PV (Utility scale)	18	48	180
Concentrated solar thermal	8.8	27	63
Coal (with carbon capture and storage)	190	220	250
Combined cycle gas (with carbon capture and storage)	94	170	340

Source: *Bright New World,* Submission 168, *p. 5.*

1.24 The Australian Nuclear Association pointed out that comparisons of carbon dioxide emissions from nuclear energy compared with hydroelectricity (hydro), wind and solar do not always take into account emissions from storage facilities or backup generators, and downplay the significance of methane emissions from hydro. The Association submitted that:

> The low carbon emissions of nuclear power is similar to emissions from wind and hydro per unit of electricity produced [IPCC 2014] and slightly less than solar PV. This comparison assumes that methane from hydro is not significant and ignores the emissions from any storage or backup generators for wind and solar. In 2018, nuclear power plants around the world produced 50% more clean electricity than wind and solar combined. In the European Union and USA, nuclear produces more low carbon electricity than hydro. Countries with nuclear energy are able to achieve very low carbon emissions from electricity generation.[15]

1.25 Mr Ian Hore-Lacy from the Australasian Institute of Mining and Metallurgy—also a Senior Advisor to the World Nuclear Association with 25 years' experience in the nuclear industry—said that there is 'no real realistic decarbonisation prospect for Australia which does not involve nuclear'.[16]

1.26 Nuclear for Climate also highlighted decarbonisation prospects, submitting that 'the development of future nuclear technologies will enable the decarbonsisation of sectors other than electricity, such as industrial heat production'.[17]

15 Australian Nuclear Association, *Submission 155*, p. 7.

16 Ian Hore-Lacy, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 21.

17 Nuclear for Climate, *Submission 135*, p. 7.

1.27 Further, Mr Tristan Prasser, who has published several articles on nuclear energy in Australia, stated that '…the contemporary experience of South Korea and United Arab Emirates, demonstrates that nuclear remains one of the most reasonable and affordable pathways to decarbonisation on a large-scale.'[18]

1.28 The Committee notes: i) Australia's commitment to reduce greenhouse gas emissions from its electricity system; ii) the IPCC's recognition of nuclear energy as a 'mitigation technology' for addressing climate change; and iii) the use of nuclear energy by other countries to decarbonise their economies.

Delivering affordable energy

1.29 Australia needs to keep its supply of energy affordable. Affordability has become increasingly important over time as Australia has been gradually losing a competitive advantage in the cost of electricity, with adverse consequences for Australian households and Australian industry, especially manufacturing.

1.30 Australia has been experiencing long term trends of increasing wholesale and domestic electricity prices. Recent months have seen the price level off and begin to decrease, but the fact remains that Australian household electricity prices have gone from one of the cheapest in the OECD to one of the most expensive.

Table 1.2 Electricity prices for households in US dollars per MWh (selected OECD countries)

	1978	1995	2015	2018
Australia	38.74	79.43	212.25	248.49
Canada	24.11	57.05	92.70	113.00
Finland	57.74	108.86	168.92	199.18
France	80.52	166.62	180.16	202.37
Germany	85.39	203.00	327.08	353.29
Japan	93.14	269.49	225.12	238.95
South Korea	66.53	112.10	124.31	110.45
United Kingdom	52.17	127.19	229.96	231.49
United States	43.10	84.10	126.51	128.89

Source: *International Energy Agency*, Electricity Information 2019, *IV.8 Table 2c.*

1.31 In Australian dollars, this means that the nominal price of electricity for Australian households rose from around AU$44 per megawatt hour in 1978, to around AU$332 per megawatt hour in 2018.[19] Since electricity is a

18 Mr Tristan Prasser, *Submission 218*, p. 4.

19 Calculations derived from information on the Reserve Bank of Australia website, https://www.rba.gov.au/statistics/frequency/occ-paper-8.html (Section 1.19a),

non-discretionary item for Australian consumers, if energy prices are not affordable it directly impacts the cost of living for Australian households.

1.32 While the above data relates to Australian household electricity prices, the Committee recognises that a similar trend would apply to Australian industry. For businesses such as manufacturing and those in trade exposed sectors where the cost of electricity is a major expense, major price increases weakens their competitiveness.

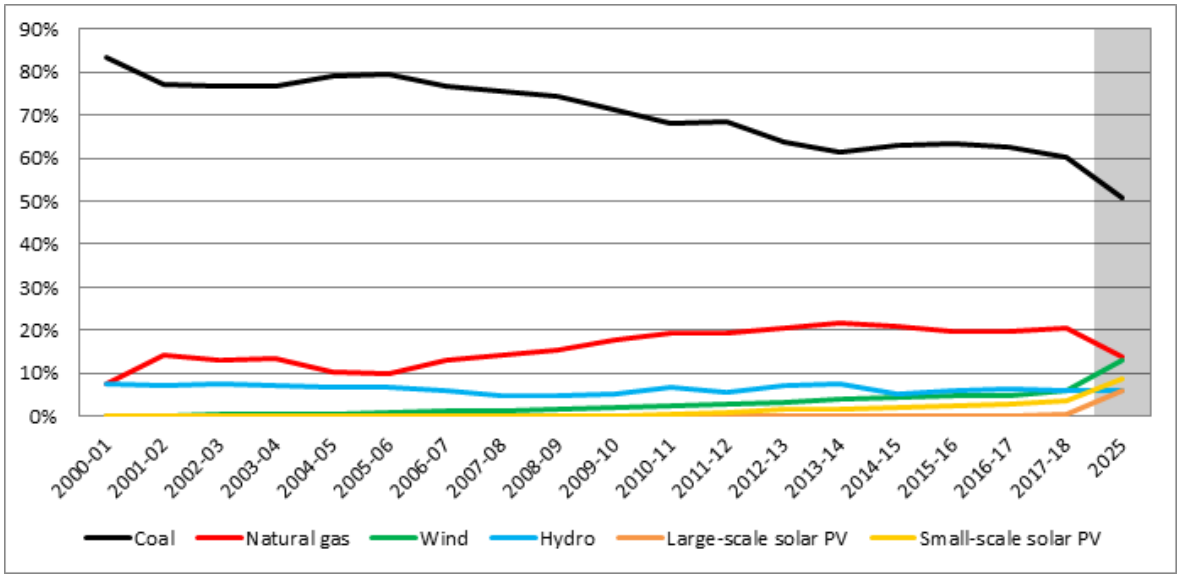
1.33 The Committee notes: i) the significant increase in the price of electricity in Australia over recent decades; ii) the loss of Australia's competitive advantage in the cost of electricity relative to other OECD countries; iii) the likely impact of higher electricity prices on households and the economy; and iv) the need to deliver affordable energy.

Delivering reliable energy

1.34 Australia needs to maintain a reliable supply of energy.

1.35 Reliability has become increasingly important over time as Australia changes its energy mix and introduces more variable renewable sources such as wind and solar PV. Figure 1 provides an overview of Australia's energy mix over time, and a possible projection towards 2025.

Figure 1 Australia's electricity generation mix 2000-2018, 2025



Sources: *Department of the Environment and Energy*, Australian Energy Update 2019, *September 2019, Table O;* Australia's emissions projections 2018, *December 2018, Figure 7.*

https://www.rba.gov.au/calculator/annualDecimal.html and https://www.rba.gov.au/statistics/tables/#exchange-rates (Table F11.1), accessed 25 November 2019.

1.36 In 2017-18, Australia's electricity generation was derived from:

- coal: 60.4% (black coal 46.6%; brown coal 13.8%);
- gas: 20.6%;
- hydro: 6.1%;
- wind: 5.8%; and
- solar: 3.8% (small-scale solar: 3.4%; large-scale solar: 0.4%).[20]

1.37 With Australia now recording world leading rates of per capita investment in clean energy, renewables are set for exponential growth. Data in a 2019 Bloomberg New Energy Finance and United Nations Environment Program report on global trends in renewable energy investment indicated that Australia is leading G20 nations in per capita renewable energy investment, with a spend of $470 per capita.[21]

1.38 The Australian National University confirmed that Australia continues to lead the world in renewable energy build rates on capacity (watts) per capita, approximately ten times faster than the world average and two and a half times faster than the next best (Germany).[22]

1.39 Renewable energy sources such as wind and solar PV are making a contribution to Australia's objective of reducing emissions and the Committee heard from witnesses to the inquiry who advocated in favour of an ongoing and increasing role for renewables in Australia's energy mix.

1.40 However, the Committee also heard evidence from witnesses about the challenges Australia's electricity system faces due to the increasing proportion of wind and solar PV entering the grid. Some of these challenges stem from the inherent variability of wind and solar due to their reliance on the weather.

1.41 This is shown in their relatively low capacity factors. The capacity factor of a power station has been defined as 'the ratio of actual electricity generated (output) over a given period of time to the maximum possible electricity generation over the same period of time'.[23] The Australian

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20 Department of the Environment and Energy, *Australian Energy Update 2019,* September 2019, at https://www.energy.gov.au/publications/australian-energy-update-2019, Table O.

21 Australian Government, 'A Fair Deal on Energy', at https://www.energy.gov.au/sites/default/files/g2395_enr103.0919_fair_deal_booklet_16pp_webv4.pdf, p. 12.

22 Australian National University, Energy Change Institute, 'Powering ahead: Australia leading the world in renewable energy build rates', https://energy.anu.edu.au/files/Renewable%20energy%20target%20report%20September%202019_1_0.pdf, 4 September 2019, p. 1.

23 Clean Energy Regulator, *Progress in 2017: Delivering Australia's 2020 Renewable Energy Target,* Glossary,

National University's Energy Change Institute estimates that large- and small-scale solar PV and wind continue to have capacity factors of 21%, 15% and 40%, respectively.[24]

1.42 The uncertainty of wind and solar PV results in a requirement for other sources of energy to back them up, otherwise referred to as 'firming'. That is, because it is impossible to accurately predict when the sun will shine or the wind will blow, these variable renewable sources of energy need to be partnered with other more reliable sources in order to alleviate shortfalls in production. Therefore, the more renewables introduced into Australia's electricity system, the more the total capacity of the system has to increase to ensure reliability of supply.

1.43 Other challenges of introducing variable renewables include their relatively low life span, the cost and complexity of integrating them into the electricity grid, the need for more transmission infrastructure and the need for better management of hazardous waste material.

1.44 Ensuring energy reliability in Australia requires a balancing of the unprecedented investment in intermittent renewables with a reliable supply of electricity when it is needed by the end user. Failing to maintain a reliable source of energy risks instability in the electricity grid and an inability to supply electricity on demand.

1.45 While Australia does not currently use nuclear technology to produce electricity, other countries do. It is notable that nuclear energy represents approximately 11 per cent of the world's total energy mix[25], with countries that use nuclear energy also using other energy sources including renewables.

1.46 The Committee received evidence about nuclear energy being a possible 'partner' for renewable energy[26] whereby its zero-emission baseload capability firms up zero-emission variable renewable sources of energy while also allowing for flexibility to ramp-up and ramp-down as needed.

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http://www.cleanenergyregulator.gov.au/DocumentAssets/Documents/Progress%20in%202017%20Delivering%20Australia%E2%80%99s%202020%20Renewable%20Energy%20Target.pdf, accessed 5 December 2019.

24 ANU Energy Change Institute, *At its current rate, Australia is on track for 50% renewable energy in 2025,* 10 September 2018, at https://energy.anu.edu.au/news-events/its-current-rate-australia-track-50-renewable-electricity-2025. It is noted that these figures are not settled, and the Committee received evidence citing various estimates for the capacity factors of solar and wind energy ranging between 15 and 40 per cent. See Ms Chloe Munro, Australian Academy of Technology and Engineering, *Proof Committee Hansard*, 1 October 2019, p. 50; Dr Mark Ho, Australian Nuclear Association, *Proof Committee Hansard,* 9 October 2019, p.5; Mr Robert Parker, Australian Nuclear Association, *Proof Committee Hansard* 9 October 2019, p. 8; Mr Barry Murphy, *Submission 12;* Mr Terry Krieg, *Submission 61*.

25 Exhibit 15, Electricité de France, 'Nuclear Energy Mission', p. [51].

26 World Nuclear Association, *Submission 259*, p. iii.

1.47 It is notable that the advent of renewables is leading to reactor designs with greater ramp-up and ramp-down capabilities aimed at helping nuclear and renewables to work in tandem. For example, the Committee was advised that nuclear reactors currently operating in France include 'built-in flexibility to compensate intermittent production, thus helping stability of the grid'.[27]

1.48 NuScale Power, America's leading developer of small modular reactors, similarly stated that its small modular reactor energy technology 'can provide the reliable, load-following power needed to address the intermittency of renewable power.'[28]

1.49 Beyond hydro, nuclear is the only mature zero emissions dispatchable source of generation or storage available. Other technologies have potential, including hydrogen, batteries, carbon sequestration and biofuels, but they remain at a lower level of maturity in their development, especially for deployment at scale.

1.50 The Committee notes: i) the significant increases in variable renewable energy sources in Australia's energy mix; ii) the need to balance the intermittency of variable renewable technologies with firming capacity; and iii) the use of nuclear energy by other countries to back up variable renewable sources of energy.

Adopting a strategic approach

1.51 Australia should be strategic in its consideration of nuclear energy. This requires us to think about the next 50 years rather than the next five and also how we might enter the nuclear energy industry by learning from other countries while building our own sovereign capability.

Collaborating with a mature nuclear industry network

1.52 Nuclear energy is a mature technology. In December 1951, the first experimental nuclear reactor to produce electricity commenced operations in the United States. In the years following, further reactors were commissioned and operated successfully in North America and Europe.[29] ANSTO's submission noted that:

> While the number of reactors under construction is significant, at the end of 2018, nearly half (47 per cent) of the 451 reactors had

27 Exhibit 15, Electricité de France, 'Nuclear Energy Mission', p. [54].

28 NuScale Power, *Submission 71*, p. 2.

29 Ian Hore-Lacy, *Nuclear Energy in the 21st Century* (4th ed.), pp. 118-119.

> been in operation for between 30 and 40 years, with a further 17 per cent in operation for more than 40 years.[30]

1.53 Over the nearly 70 years that nuclear reactors have been successfully operating around the world, the industry—its technology, processes and people—has deepened its knowledge and expertise through operational experience and research and development.

1.54 Through organisations such as the International Atomic Energy Agency, the World Nuclear Association and the OECD, international cooperation has evolved to include matters such as the provision of workforce training, planning and guidance for long-term reactor operation.[31] This evolving cooperation presents an opportunity for new countries seeking to establish a sovereign capacity for nuclear energy to capitalise on the existing expertise in other countries.

1.55 Some countries are exporting their expertise and know how, including the construction of nuclear reactors. These include the United States, United Kingdom, France, Russia, South Korea and China.[32] According to ANSTO, the recent entry of exporters like South Korea is resulting in lower plant costs and faster build times.[33] Indeed, South Korea and the United Arab Emirates (UAE) recently undertook to expand their existing cooperation in the development of nuclear energy in the UAE to include seeking opportunities in new nuclear energy markets. This could include such aspects as investment, financing, licensing, safeguards, operations, maintenance, as well as training and expertise.[34]

1.56 There are also a range of countries adopting nuclear energy for the first time. In its report, *Nuclear Technology Review 2019*, the IAEA[35] notes:

> Among the 28 Member States that are considering, planning or actively working to include nuclear power in their energy mix, 19 have initiated studies on nuclear power infrastructure, 5 have already taken a decision and are preparing the necessary

30 ANSTO, *Submission 166*, p. 3.

31 ANSTO, *Submission 166*, p. 27.

32 ANSTO, *Submission 166,* p. 5.

33 ANSTO, *Submission 166*, p. 4.

34 World Nuclear News, *South Korea and UAE to collaborate on new nuclear opportunities*, 11 September 2019.

35 The International Atomic Energy Agency is an organisation within the United Nations that works with its 'Member States and multiple partners worldwide to promote the safe, secure and peaceful use of nuclear technologies. As at 5 February 2019, it has 171 member states. See https://www.iaea.org/ for more information.

> infrastructure, and 5 have signed contracts and are preparing for or have already commenced construction.[36]

1.57 Further details provide that the UAE, Belarus, Bangladesh, Turkey and Egypt are all preparing for or have commenced construction on nuclear power plants.[37] In particular, the UAE ordered its first set of four reactors ten years ago[38] and the first of these is expected to start operation in late 2019 or early 2020, with the second scheduled a year later.[39]

1.58 While the circumstances in each country are different, reasons for countries adopting nuclear energy include meeting increasing demand for electricity, increasing energy security by reducing dependence on imports, and meeting environmental objectives. For example, the UAE identified nuclear energy as a 'proven, environmentally promising and commercially competitive option' to address the country's increasing demand for electricity, which cannot be met by domestic natural gas supplies.[40] Bangladesh is also experiencing increasing demand for electricity and is seeking to reduce its dependence on natural gas through the use of nuclear energy.[41]

1.59 Dr Stuart Hatch, Founder of Nuclear Now Alliance Australia, suggested that the UAE's experience entering the nuclear industry was instructive for Australia's consideration of nuclear energy:

> The progress in the UAE is a very interesting analogy for Australia, given that they started from scratch and poured their first concrete in, I think, 2012.[42]

1.60 The Committee notes: i) the nuclear energy industry is highly mature; ii) there is a sophisticated global network of nuclear energy countries that export their expertise and knowhow; and iii) new entrants in the nuclear energy industry rely on more mature countries and the global network.

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36 International Atomic Energy Agency, *Nuclear Technology Review 2019*, p. 6.

37 International Atomic Energy Agency, *Nuclear Technology Review 2019*, p. 6.

38 World Nuclear Association, *Nuclear Power in the United Arab Emirates,* Country Profile, at https://www.world-nuclear.org/information-library/country-profiles/countries-t-z/united-arab-emirates.aspx (accessed 19 November 2019).

39 International Atomic Energy Agency, *Nuclear Technology Review 2019*, p. 6.

40 World Nuclear Association, *Nuclear Power in the United Arab Emirates,* Country Profile, at https://www.world-nuclear.org/information-library/country-profiles/countries-t-z/united-arab-emirates.aspx.

41 World Nuclear Association, *Nuclear Power in Bangladesh*, Country Profile, at https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/bangladesh.aspx (accessed 8 December 2019).

42 Dr Stuart Hatch, Founder, Nuclear Now Alliance Australia, *Proof Committee Hansard,* Perth, 3 October 2019, p. 12.

Following others while building a sovereign capability

1.61 Since Australia already participates in aspects of the nuclear fuel cycle, it already possesses some of the capability—experience, knowledge and expertise—required to manage a nuclear energy industry, but more is needed.

1.62 ANSTO submitted that 'given the long lead times between any decision to introduce nuclear power in Australia and the commencement of operation of the first reactor, the current lack of a trained workforce should not be regarded as a constraint'.[43]

1.63 Australian Young Generation in Nuclear (AusYGN) submitted that despite the absence of a nuclear energy industry, the current and former research reactors at ANSTO's Lucas Heights campus demonstrate Australia's proven ability to operate safe nuclear facilities.[44]

1.64 SMR Nuclear Technology submitted that the reactor at Lucas Heights is a 'good example of how staff can be recruited, trained and become an efficient workforce.' SMR submitted that the construction phase for ANSTO's new OPAL reactor allowed for engineering graduates to be recruited and trained in nuclear operations, and that these graduates gained extensive operations experience during the commissioning process, resulting in 'an expert cohort of nuclear engineers' in Australia.[45]

1.65 The Committee heard nevertheless that developing the workforce to a suitable level would be a lengthy process. Dr Philip White explained that 'the workforce issues associated with a nuclear power program would be of a different order of magnitude and level of complexity', and that it would take considerable time and investment for the required capability to be reached.[46] Similarly, Dr David Jones submitted that it would be 'unlikely' that a skilled nuclear workforce could be established in Australia in less than a decade.[47]

1.66 ANSTO told the Committee that if Australia was to opt to introduce nuclear energy, the IAEA and the OECD Nuclear Energy Agency would be able to assist in the development and implementation of workforce training planning tools, the development of human resource plans and in the provision of guidance for long-term reactor operation.[48]

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43 ANSTO, *Submission 166*, p. 27.

44 Australian Young Generation in Nuclear, *Submission 241*, p. 1.

45 SMR Nuclear Technology Pty Ltd, *Submission 39*, p. 12.

46 Dr Philip White, *Submission 119*, p. [9].

47 Dr David Jones, *Submission 249*, p. 7.

48 ANSTO, *Submission 166*, p. 27

1.67 The Australian Academy of Technology and Engineering recommended pursuing international partnerships in nuclear education, research and development to further enhance workforce skills.[49]

1.68 The Committee believes that, where possible, Australia should learn from other more experienced countries but it should ultimately build its own sovereign capability as it relates to selected phases of the nuclear fuel cycle.

1.69 There are some precedents for this. Women in Nuclear submitted that Australia 'has existing expertise in nuclear technologies and large construction programs that could be utilised and expended in the event that Australia adopts nuclear energy'.[50] The Committee recognises that Australia's experience in other large and technical projects, for example, the construction of submarines, points to our ability to gain skills from abroad to boost our own capabilities.[51]

1.70 First-of-a-kind nuclear reactors generally involve new concepts, designs or prototypes, where there is limited prior experience relating to construction and operation. Some aspects may be experimental, and whether the envisaged design works as anticipated could be uncertain. Next-of-a-kind (or 'Nth-of-a-kind') nuclear reactors follow from demonstrated success in the first instance. This experience informs the design process, construction schedule and cost estimates, reducing risks as each version of the reactor is fine-tuned.

1.71 The Committee notes: i) Australia's existing nuclear capability could be leveraged for a nuclear energy industry but that more would be needed; ii) there would be opportunity to learn from other countries while building sovereign capability in Australia; and iii) the merit of entering the nuclear energy industry as a follower and adopting proven next-of-a-kind technology.

Adopting an holistic approach

1.72 Australia should be holistic in its consideration of nuclear energy. This requires us to think about the extent to which Australia might leverage nuclear technology not just to produce electricity but also for other important applications.

49 Australian Academy of Technology and Engineering, *Submission 221*, p. 5.

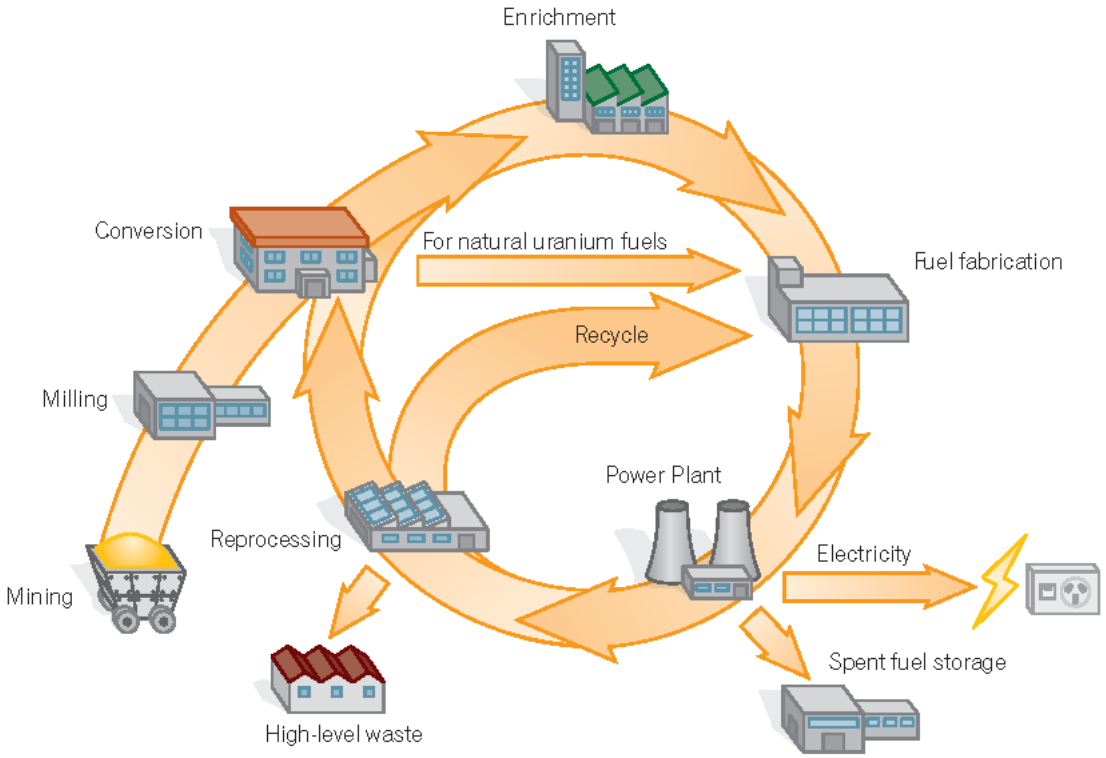
50 Women in Nuclear Australia, *Submission 154*, p. 16.

51 See Mr Douglas Gillott, *Submission 181*, p. 1.

Capturing opportunities across the nuclear fuel cycle

1.73 The nuclear fuel cycle has several stages, from mining and usage for energy generation, through to waste management. These are summarised in the graphic at Figure 2.

Figure 2 The nuclear fuel cycle



Source: *Department of the Prime Minister and Cabinet*, Uranium Mining, Processing and Nuclear Energy – Opportunities for Australia? [UMPNER Report], *2006. p. 19.*

1.74 The cycle consists of:

- exploration, extraction and milling;
- further processing and manufacture;
- electricity generation; and
- management, storage and disposal of waste.[52]

1.75 There are opportunities for Australia to be more than a customer of international providers across the entire nuclear fuel cycle. Over the long term Australia could become a supplier in selected areas of the cycle where it has an existing or potential comparative strength.

1.76 An example of an existing comparative strength in the nuclear fuel cycle is mining. Australia is currently the world's third largest supplier of

52 See: South Australia, *Nuclear Fuel Cycle Royal Commission Report*, May 2016.

uranium behind Canada and Kazakhstan. The Minerals Council of Australia submitted that:

> The Australian uranium sector directly and indirectly employs around 3000 Australians and delivers more than $600 million in export income.[53]

1.77 The Australian Workers Union submitted that:

> Nuclear Fuel Cycle could bring tens of thousands of jobs…jobs in Uranium mining are set to exceed 10,000 over the next decade, and could be several times that with a complete Nuclear Fuel Cycle.[54]

1.78 The Queensland Resources Council stated that in the event of Australia introducing nuclear energy, '[t]he number of jobs would be in the thousands in terms of both the actual mining operation and also the processing'.[55]

1.79 More generally, a report commissioned by the Minerals Council of Australia estimated that as many as 22,600 direct and indirect jobs could be created by 2040 by expanding the nuclear industry in Australia.[56] To further illustrate the potential employment benefits of developing the nuclear industry, the Minerals Council of Australia highlighted how Canada's nuclear energy industry had supported employment and stated:

> Some 60 000 Canadian jobs are directly and indirectly supported by its nuclear sector, with many in highly paid, highly skilled roles. With 5000 employed in uranium mining, 25 000 in the nuclear power sector and another 30 000 indirect jobs, the industry generates annual revenues of over C$6 billion (A$6.3 billion). Other beneficiaries are the 200-plus Canadian companies that supply products and services to Canada's nuclear industry.[57]

1.80 An area of the nuclear fuel cycle about which the Committee has heard alternative views is the possibility of Australia establishing an international facility for the storage of used nuclear fuel and radioactive waste. Both the 2006 UMPNER report and the 2016 South Australian Royal Commission (SARC) determined that Australia's geology is well-

53 Minerals Council of Australia, *Submission 266*, p. 11.

54 Australian Workers Union, *Submission 290,* p. 8.

55 Mr Ian Macfarlane, Queensland Resources Council, *Proof Committee Hansard,* 30 September 2019, p. 3.

56 S Davidson & A De Silva, *Realising Australia's Uranium Potential*, Melbourne, 2015, p. 6. See Minerals Council of Australia, *Submission 266,* p. 11.

57 Minerals Council of Australia, *Submission 266*, p. 11.

suited to hosting such a waste repository.[58] The SARC determined that establishing such a facility could generate $51 billion during its operation, and generate a wealth fund of $445 billion for South Australia over 70 years.[59]

1.81 The Committee did hear, however, that such a move may prove difficult:

> There have been many proposals and considerable controversy in Australia over the issue of nuclear waste dumps, for various levels of waste, including HLW [high-level waste], resulting in bitter political fights between and within jurisdictions, and staunch community and legal opposition.[60]

1.82 Following the release of the SARC report in May 2016, the South Australian Government conducted a community engagement program that included constituting two 'citizens' juries'.[61] These juries did not support the establishment of an international waste storage facility.[62] The South Australian Government indicated in November 2016 that it would continue investigating the proposal, noting that it would require 'bipartisanship and broad social consent, secured through a statewide referendum'.[63] In 2017, however, the Premier of South Australia indicated that the proposal would not proceed, in the absence of 'inter-generational' and bipartisan support.[64]

1.83 The Committee notes: i) the strength of the mining sector and the potential for greater job creation by expanding the nuclear industry in Australia; and ii) opportunities to leverage existing and create new comparative advantages across the nuclear fuel cycle.

Expanding Australia's nuclear medical research

1.84 Australia is already conducting medical research and diagnostics using nuclear technology.

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58 Department of the Prime Minister and Cabinet, *Uranium Mining, Processing and Nuclear Energy – Opportunities for Australia?*, 2006, p. 6; South Australia, *Nuclear Fuel Cycle Royal Commission Report,* May 2016, p. xv.

59 South Australia, *Nuclear Fuel Cycle Royal Commission Report,* May 2016, p. xv.

60 The Australia Institute, *Submission 167*, p. 35.

61 See https://nuclear.yoursay.sa.gov.au/know-nuclear/background.

62 ABC News, 'South Australia's nuclear dump proposal abandoned', https://www.abc.net.au/news/2017-06-08/sas-nuclear-dump-proposal-abandoned/8600294, 8 June 2017.

63 Government of South Australia, *Response to the Nuclear Fuel Cycle Royal Commission,* November 2016, p. 22.

64 ABC News, 'South Australia's nuclear dump proposal abandoned', https://www.abc.net.au/news/2017-06-08/sas-nuclear-dump-proposal-abandoned/8600294, 8 June 2017.

1.85 According to the Australasian Association of Nuclear Medicine Specialists (AANMS):

> Nuclear medicine uses very small amounts of unsealed radioactive materials to diagnose and treat disease. Nuclear medicine imaging is unique in that it provides doctors with information about both the anatomy of the body and its physiology.[65]

1.86 In terms of diagnostics the AANMS state:

> Nuclear medicine tests are safe and painless. They allow quick and accurate diagnosis of a wide range of conditions and diseases, such as heart disease, blood clots in lungs, bone infections, sports injuries, tumours and cancer metastasis (spread).[66]

1.87 AANMS further notes that nuclear medicine therapy can control and sometimes cure 'a range of conditions such as thyroid cancer, overactive thyroid, and bone pain caused by cancer metastasis'.[67]

1.88 ANSTO supplies around 80 per cent of Australia's radioactive isotopes used in nuclear medicine.[68] ANSTO's Health Strategy notes:

> On average, one in two Australians will benefit from the nuclear medicines produced using Australia's Open Pool Australian Lightwater (OPAL) multi-purpose reactor at some point in their lifetime to aid in the accurate diagnosis of heart disease, skeletal injuries or for the diagnosis and treatment of cancer.[69]

1.89 Moreover, ANSTO has joined the global marketplace for nuclear medicine production, and has the capacity to supply 35 per cent of the global demand for molybdenum 99, which is the precursor for the world's most widely used diagnostic imaging agent.[70]

1.90 The Committee notes: i) ANSTO's role in providing products that lead to better health outcomes for Australian citizens and citizens of other

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65 Australasian Association of Nuclear Medicine Specialists, *What is nuclear medicine*, at https://www.aanms.org.au/index.php?option=com_content&view=article&id=8&Itemid=3, accessed 5 December 2019.

66 Australasian Association of Nuclear Medicine Specialists, *What is nuclear medicine*, at https://www.aanms.org.au/index.php?option=com_content&view=article&id=8&Itemid=3, accessed 5 December 2019.

67 Australasian Association of Nuclear Medicine Specialists, *What is nuclear medicine*, at https://www.aanms.org.au/index.php?option=com_content&view=article&id=8&Itemid=3, accessed 5 December 2019.

68 ANSTO, 'Health Strategy', December 2018, p. 13, at https://www.ansto.gov.au/health-strategy.

69 ANSTO, 'Health Strategy', December 2018, p. 2, at https://www.ansto.gov.au/health-strategy.

70 ANSTO, 'Health Strategy', December 2018, p. 13, at https://www.ansto.gov.au/health-strategy.

countries to whom it exports; and ii) the expanded pool of talent and increased interest in nuclear science that would emerge if Australia were to introduce nuclear energy.

Exploring opportunities in other applications for nuclear technology

1.91 Apart from producing electricity and medical purposes, there are many other applications for nuclear technology, including:

- health (beyond cancer diagnosis and treatment, there are applications for nutrition and disease control);
- environment (such as using isotopes and nuclear techniques to assess freshwater resources, biological systems, atmospheric processes and oceanic ecosystems, and to improve agricultural practices);
- water (nuclear desalination for water security, analysis of pollutants in water and measuring water quality);
- food (irradiation to reduce post-harvest contaminants);
- industry (radiography to inspect concrete and welds for invisible flaws);[71]
- electronics (silicon irradiation);[72] and
- production of hydrogen as an alternative to fossil fuels.[73]

1.92 The Committee notes the broad applications for nuclear technology beyond electricity generation.

Ensuring ongoing compliance with nuclear non-proliferation

1.93 Presently 30 countries use nuclear technology to produce electricity.[74] These countries have followed different historical paths in their adoption and use of nuclear technology, with seven known to use nuclear technology not only for peaceful applications, but also for in the development of nuclear weapons. A further two countries - Israel and North Korea - possess nuclear weapons, but do not have a nuclear power program.[75]

1.94 During the Cold War, nuclear weapons countries increased their number of weapons while some other countries sought to acquire their own

71 International Atomic Energy Agency, 'Nuclear Technology and Applications', at https://www.iaea.org/topics/nuclear-technology-and-applications.

72 ANSTO, 'Silicon Irradiation', at https://www.ansto.gov.au/business/products-and-services/irradiation/silicon-irradiation.

73 StarCore Nuclear, *Submission 128,* pp. [10, 13]; Engineers Australia, *Submission 170,* p. 8; Nuclear Energy Institute, *Submission 171,* p. 4; Terrestrial Energy, *Submission 260,* p. 1, 8.

74 ANSTO, *Submission 166*, pp. 3-4.

75 Arms Control Association, *Nuclear Weapons: Who Has What at a Glance*, July 2019.

nuclear weapons. This heightened the risk of nuclear war which, in turn, led to the Nuclear Non-Proliferation Treaty (NPT).[76] The NPT entered into force in 1970.

1.95 The NPT recognised five countries as 'nuclear weapon states'. These states agreed to make nuclear technology available to 'non-nuclear weapon states' for peaceful purposes in exchange for a commitment from non-nuclear weapon states to never acquire nuclear weapons for themselves.

1.96 Australia joined the NPT as a non-nuclear weapon state upon ratifying the Treaty in 1973. Australia has complied with the terms of the NPT including not acquiring nuclear weapons and implementing safeguards and regulations to prevent the diversion of nuclear material.[77]

1.97 The International Campaign to Abolish Nuclear Weapons Australia (ICAN) outlined its concern about the linkages between nuclear power and nuclear weapons:

> The basic technologies for power and weapons are the same:
> - Uranium enrichment plants can produce low-enriched uranium for reactor fuel, or highly-enriched uranium for weapons.
> - Reactors produce both electricity and fissile (weapons-usable) plutonium…
> - Reactors can be operated on a short irradiation cycle to produce plutonium that is ideal for weapons production.
> - Reprocessing plants can be used to separate uranium and/or plutonium for re-use as reactor fuel, and they can be used to separate plutonium for weapons.[78]

1.98 However, this view was not universal. Dr Donald Higson disagreed with the described link between nuclear energy and nuclear weapons, stating 'there would be no proliferation risk from a domestic nuclear industry' and that 'nuclear power bears no greater relationship to nuclear weapons than petrol fuel does to napalm'.[79] That is, just because a country adopts nuclear technology for the purpose of producing electricity and other applications does not mean it is on a path to acquire nuclear weapons or the capability to build them.

1.99 There are significant technological differences in the use of nuclear technology for producing electricity versus building nuclear weapons. The reactor grade fuel used in nuclear power generation is generally

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76 Treaty on the Non-proliferation of Nuclear Weapons, 729 UNTS 161 (entered into force generally 5 March 1970; entered into force for Australia 23 January 1973).

77 Australian Safeguards and Non-Proliferation Office, *Submission 153*.

78 ICAN, *Submission 157,* p. 2.

79 Dr Donald Higson, *Submission 139*, p. [4].

unsuitable for use in nuclear weapons.[80] Mr Ian Hore-Lacy explains that weapons-grade plutonium generally consists of 'plutonium-239, with only a few percent of the other isotopes present'. In contrast, the reactor-grade plutonium produced in commercial nuclear power reactors:

> ...contains a large proportion — up to 40 per cent — of the heavier plutonium isotopes, especially plutonium-240...due to the spontaneous fission of plutonium-240, only a very low level of it is tolerable in material for making weapons. Design and construction of nuclear explosives based on normal reactor-grade plutonium would be difficult, dangerous and unreliable, and has not so far been done.[81]

1.100 Further, the Committee was advised that new generation reactors (such as small modular reactors[82] and thorium fuelled reactors) produce spent fuel that is less useable for weapons purposes.[83]

1.101 The Committee notes: i) there is no predetermined link—no inevitable cause and effect relationship—between the use of nuclear technology for nuclear energy and nuclear weapons; ii) there is, nevertheless, genuine concern held by some members of the Australian community that developing nuclear energy may be a first step towards establishing a nuclear weapons program; and iii) the importance of Australia's ongoing commitment to the NPT.

Adopting a community-focused approach

1.102 Australia should be community-focused in its consideration of nuclear energy. This requires us to recognise the importance of a social licence to operate a nuclear facility and to put the community at the centre of deliberations on nuclear energy. As the Committee heard during the inquiry, 'the single biggest challenge for this inquiry will be to gain public support'.[84]

Building a social licence

1.103 A social licence from local communities is a prerequisite for nuclear energy. That is, in order for a nuclear reactor or nuclear waste facility to be

80 Ian Hore-Lacy, 'Nuclear Energy in the 21st Century', 4th edition, 2018, p. 105.

81 Ian Hore-Lacy, 'Nuclear Energy in the 21st Century', 4th edition, 2018, p. 105.

82 Dr John Kalish, Assistant Secretary, Australian Safeguards and Non-Proliferation Office, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 41.

83 See for example: Mr James Graham, *Submission 104*, p. [5], Mr Craig Tamlin, *Submission 125*, p. 3; Mr Tony Hine, *Submission 214*, p. [3]; Mr Ian Liley, *Submission 232*, p. [4], Mr Clem Grieger, *Submission 302*, p. 26.

84 Mr Ronald James, *Submission 89,* p. 3.

built and operated, it requires approval from the local community and ongoing broad social acceptance.

1.104 Countries that operate nuclear energy plants—especially liberal democracies that are comparable to Australia—place great significance on maintaining a social license. Lessons from these countries indicate the importance of transparency in building and maintaining a high degree of trust to ensure the ongoing safety and security of nuclear facilities.

1.105 For example, France's electricity agency EDF advised that local and national acceptance is required for the nuclear program to be sustainable for its whole life cycle. Among its strategies, France has created a 'High Committee' on nuclear safety and transparency, and has a 'local information committee' established at every nuclear installation.[85]

1.106 Switzerland also advised the Committee on the lessons it had learned about local and regional involvement:

> Participation requires…
> - acceptance of the general framework by the stakeholders
> - flexibility within the general framework
> - diligent planning of time and resources
> - willingness and preparedness of the responsible authority/organisation to get involved in a participative process
> - clear definition of roles and responsibilities of all stakeholders
> - trust of the stakeholders in experts and involved authorities/ organisations
> - diligent handling of the results of the participatory process
> - …[86]

1.107 Rear Admiral Kevin Scarce, who led the 2016 South Australian Royal Commission into the nuclear fuel cycle, said that:

> Social consent is fundamental to undertaking any new nuclear project. Social consent requires sufficient public support in South Australia to proceed with legislating, planning and implementing a project. Political bipartisanship and stable government policy are essential in achieving and maintaining social consent…I think to have a fulsome community discussion on whether nuclear would be part of a future energy program for Australia—to have that discussion with the community which is critical to getting social licence—you need to remove the prohibitions which currently prohibit nuclear technologies being introduced. That doesn't mean

85 Exhibit 15, Electricité de France, 'Nuclear Energy Mission', pp. [20-34].

86 Embassy of Switzerland, 'Radioactive waste management in Switzerland', *Exhibit 16,* p. 21.

> we're going to introduce nuclear technologies, but it says to the community we're serious about discussing this and investigating whether nuclear might be part of a future energy policy for Australia.[87]

1.108 RADM Scarce reflected on the 'citizens' jury' process adopted by the Government of South Australia following the Royal Commission:

> I would suggest that the South Australian government's approach for a citizens' jury would not be the way that I would consider the citizens to be engaged: three weekends, 300 people. [88]

1.109 RADM Scarce reflected on the value of dialogue and information with local communities:

> My experience of doing this for just over a year is that the more time you spent with people, explaining the risks and how you might mitigate the risks, the more comfortable they became. They're incredibly bright; they'll pick up any holes, and they're quite capable of making the decision if we just give them the ability to do so.[89]

1.110 The Committee notes: i) a social license is a prerequisite for building and operating a nuclear facility; ii) transparency is key to building the necessary degree of trust to secure and maintain a social license; iii) information for and dialogue with local communities is required to gain their consent.

Political bipartisanship

1.111 The Committee heard evidence about the value of political bipartisanship in energy policy, including its importance in advancing the case for nuclear energy. For example, Dr Ziggy Switkowski observed that:

> As I'm sure the committee is aware, currently there is no bipartisan support for a nuclear energy strategy. The community sentiment is mixed, and the topic of nuclear energy produces strong, often emotional opposition from some quarters and is readily undermined by scare campaigns. There is no social licence at this time.[90]

1.112 RADM Scarce expressed the view that '[u]ntil we decouple this from party politics…and get to the basic issue, which is about how we generate

87 RADM Kevin Scarce AC CSC (Retd), *Proof Committee Hansard,* 2 October 2019, p. 29.
88 RADM Kevin Scarce, *Proof Committee Hansard,* 2 October 2019, p. 31.
89 RADM Kevin Scarce, *Proof Committee Hansard,* 2 October 2019, p. 31.
90 Dr Ziggy Switkowski, *Proof Committee Hansard*, 29 August 2019, p. 2.

tomorrow's electricity safely, reliably and at the lowest cost, we will never resolve it'.[91]

1.113 Mr Ronald James submitted that:

> Political objections must be brought into the public spotlight and countered with facts. If the adoption of nuclear energy is not acceptable to a political party, then the best way to change this is through public support from education.[92]

1.114 The Committee notes: i) the value of political bipartisanship in progressing consideration of nuclear energy in Australia; and ii) the historical challenges to securing political bipartisanship on Australia's energy policy.

Support across tiers of government

1.115 The Committee heard that the Commonwealth cannot act on this issue alone—cooperation across the three tiers of government will be needed. This is particularly important given that the states and territories have legislative and regulatory responsibility for aspects of nuclear energy, such as accessing the mineral resources.[93]

1.116 The inter-governmental complexities of Australia's energy system are considerable. The 2006 UMPNER report observed that:

> Australia currently has several Commonwealth regulatory entities as well as state and territory authorities…
>
> While the existing regulation of uranium mining, transportation, radioactive waste disposal and nuclear research facilities in Australia is of a high standard, significant overlaps in regulatory responsibility exist, and reform to streamline existing arrangements would improve regulatory efficiency and transparency.[94]

1.117 The Law Council of Australia described the arrangements in Australia for regulating nuclear activities as a 'patchwork quilt' of Commonwealth and state legislation.[95] Australia's legal and regulatory arrangements are discussed in more detail in Appendix A.

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91 RADM Kevin Scarce, *Proof Committee Hansard,* 2 October 2019, p. 30.

92 Mr Ronald James, *Submission 89,* p. 11.

93 Ms Robyn Glindemann, *Proof Committee Hansard,* 18 October 2019, pp. 25-26.

94 Department of the Prime Minister and Cabinet, *Uranium Mining, Processing and Nuclear Energy – Opportunities for Australia?* [UMPNER Report], 2006, p. 9.

95 Ms Robyn Glindemann, *Proof Committee Hansard,* 18 October 2019, p. 26.

1.118 The Committee notes: i) the inter-governmental complexity of Australia's energy system; and ii) the need for cooperation across tiers of government if nuclear energy is introduced in Australia.

Recommendation 1

The Committee recommends that the Australian Government consider the prospect of nuclear energy technology as part of its future energy mix by:

a. **Prioritising the delivery of affordable and reliable energy while fulfilling Australia's international emissions reduction obligations.**

b. **Adopting a strategic approach to the possibility of entering the nuclear energy industry which considers:**

   i. **collaborating with, and learning from, international partners with expertise in nuclear energy;**

   ii. **developing Australia's own national sovereign capability in nuclear energy over time; and**

   iii. **procuring next-of-a-kind nuclear reactors only, not first-of-a-kind.**

c. **Adopting a holistic approach to the possibility of leveraging nuclear technology which considers:**

   i. **opportunities to create electricity and to participate in other areas of the end-to-end nuclear fuel cycle;**

   ii. **an expansion of our activities in medical research including pursuit of applications to treat cancers;**

   iii. **opportunities for other non-energy commercial applications in areas including health, water, food and agriculture;**

   iv. **likely impacts on jobs, industry and Australia's economic competitiveness; and**

   v. **ensuring continued compliance with the Nuclear Non-Proliferation Treaty.**

d. **Putting the community at the centre of efforts to progress consideration of nuclear energy in Australia by:**

   i. **embracing a principle of transparency with the Australian public in all nuclear related matters;**

   ii. **seeking bipartisanship where possible, especially on major**

public policy decisions relating to nuclear energy; and

iii. seeking cooperation from state and local jurisdictions in Australia, where necessary.

2. The need for a body of work

1.119 This section of the report discusses a body of work that should be undertaken by the Australian Government to deepen its understanding of nuclear technology in the Australian context.

1.120 The section is divided into four sub-sections that suggest the Australian Government should commission:

- a technology assessment on different generations of nuclear reactors including an examination of their feasibility and suitability to Australia;
- an economic assessment based on 'whole system costs' for baseload and peak demand, assuming no government interventions or capital cost variances;
- a readiness assessment that identifies the major requirements that would need to be in place before Australia was ready to adopt nuclear energy; and
- a community engagement program to educate and inform Australians on nuclear technology, answer their queries and hear their views.

Commissioning a technology assessment

1.121 The Australian Government should commission a technology assessment. This requires an expert body such as the Australian Nuclear Science and Technology Organisation (ANSTO) to categorise nuclear reactors into different technology generations and advise on their status, feasibility and suitability in the Australian context and to formulate a framework to monitor their development.

1.122 There are around 451 nuclear power plants worldwide (and more under construction) representing a multitude of Generation II, Generation III and Generation III+ designs, and considerable investment is now going into Generation IV designs.

1.123 The Committee heard from many submitters and witnesses about different nuclear technologies (and the third section of this report provides a summary of these technologies). In particular, the Committee heard considerable evidence about small modular reactors (SMRs). However,

depending on their design, SMRs could be regarded as Generation III+ or Generation IV.

1.124 From a technical perspective, there is ambiguity regarding exactly which reactors fall into which generation categories. There is no agreed definition as to the appropriate categorisation of these technologies.

1.125 No Australian definition standard for nuclear technologies exists, and Australia does not undertake this type of work on a regular basis.

1.126 Australia has not undertaken a comprehensive assessment of nuclear technologies since the review headed by Dr Ziggy Switkowski AO in 2006.

1.127 There is a need for Australia to better understand the status and expected deployment of each technology, and their feasibility and suitability in the Australian context. That is, whether they are feasible on technological, economic and capability grounds and whether they are suitable on environmental, safety and security grounds.

1.128 The Committee notes: i) interest in new and emerging nuclear technologies, especially SMRs; ii) the need to ensure nuclear technologies are assessed for their feasibility and suitability in the Australian context; and iii) the need to monitor the future development of nuclear technologies.

Commissioning an economic assessment

1.129 The Australian Government should commission an economic assessment. This requires an expert body such as the Productivity Commission to undertake an economic assessment of nuclear energy in the Australian context by adopting a 'whole system costs' methodology, accounting for baseload and peak demand assuming no government interventions or capital cost variances.

1.130 The Committee reaffirms the views of many, both in favour of and against nuclear energy, that economic considerations are fundamental to any decision to introduce nuclear energy in Australia.

1.131 The Committee was told that SMRs may be a less expensive alternative. ANSTO submitted that SMRs could reduce the build costs for nuclear reactors by:

- 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.[96]

1.132 At present there is no consistent and current authoritative economic assessment available that compares the cost of electricity produced by each technology, including nuclear, in the Australian context.

1.133 The Committee gave close consideration to the Australian Energy Market Operator (AEMO) and CSIRO *GenCost 2018* report on the relative costs of energy sources.[97] However, the Committee reached the conclusion that in relation to nuclear energy, the *GenCost* report does not provide a suitable assessment, because it was unable to be verified. While the Committee was advised that the costings in the report were based on World Nuclear Association information, the Association did not concur, and other submitters and witnesses also queried the costings. CSIRO advised the Committee that the figures were being reviewed.[98]

1.134 The International Energy Agency reported different energy technologies across multiple markets for 2017 which showed the capital cost for nuclear ranging from as low as US$2,320/kW (AU$3,025.33/kW) and as high as US$6,600/kW (AU$8,606.53/kW) and the levelised cost of energy (LCOE, see below) for nuclear ranging from as low as US$60/MWh (AU$78.24/MWh) to as high as US$150/MWh (AU$195.60/MWh).[99]

1.135 The standard measurement for comparing the cost of different electricity generation technologies is the levelised cost of electricity (LCOE), which

96 ANSTO, *Submission 166*, p. 6.

97 Graham, P.W., Hayward, J, Foster, J., Story, O. and Havas, L, *GenCost 2018: Updated projections of electricity generation technology costs*, CSIRO, Australia, December 2018.

98 See Dr Jennifer Hayward, CSIRO, *Proof Committee Hansard*, 16 October 2019, p. 2; World Nuclear Association, *Submission 259*, p. 7. This matter is set out in more detail in Section 2 of Appendix A.

99 World Nuclear Association, *Submission 259*, p. 6. (USD to AUD conversion based on 2017 rate of 1.3040)

takes into account capital costs, fuel costs, operation and maintenance costs, and an assumed utilisation rate for each technology type.[100]

1.136 Selected cost estimates provided to the Committee are summarised in the table below.

Table 1.3 Selected nuclear reactor cost estimates provided to the Committee

	Friends of the Earth (Australia) SMR and 'large reactor' costings	Australian Nuclear Association and Nuclear for Climate Australia 1000MWe reactor costings	World Nuclear Association average costs for a nuclear reactor in the United States	NuScale Power capital cost estimate for Nth-of-a-kind SMR in the United States
Capital cost	n.a.	AU$6,200 per kW	AU$6,685 per kW	AU$5,248 per kW
Levelised cost	(Large) AU$150 to AU$253 per MWh (SMRs) AU$225 per MWh	n.a.	AU$140 per MWh	n.a.

Note: Each figure in this table may not be directly comparable and may rely on different data and assumptions. In addition, some figures represent capital costs per kW while others are levelised costs per MWh. Figures provided in $USD have been converted to 2018 $AUD, with the exception of NuScale whose AUD costing was provided by it at a 2019 rate (see footnote 102). Refer to submissions and Proof Committee Hansard from each organisation cited for further source information and details.

1.137 If we accept submissions that it could take ten years to establish a nuclear industry in Australia, then it becomes particularly challenging to estimate costs over ten years in advance. As we have seen with other technologies, such as wind and solar PV, costs reduce over time. Whether other technology sources—including nuclear through small modular reactors and/or other new and emerging nuclear technologies—could enjoy similar 'learning rates' and reductions in cost over time is unknown, but plausible.

1.138 It is difficult to estimate the cost of nuclear energy in countries like Australia that lack a history of nuclear energy. ANSTO stated that it was difficult to establish estimates for the LCOE for nuclear energy in countries that do not have existing nuclear industries.

1.139 While LCOE is a common method for comparing the costs of alternative energy sources, it has attracted criticism. ANSTO, for example, noted the limitations of the LCOE methodology, stating:

> The LCOE also does not capture the costs of the various externalities of the generating sources. For example, while the cost of nuclear decommissioning and waste management is accounted

100 ANSTO, *Submission 166*, p. 23.

> for in the International Energy Agency and OECD–NEA methodology, the true cost of waste from coal generation is not captured. Similarly, the cost of intermittency from solar or wind, which is displaced across the grid, is not captured.[101]

1.140 The *GenCost 2018* report also acknowledged the shortcomings of LCOE as a basis for determining the true cost of each technology, saying:

> as the share of variable renewables rise, which is a high expectation given their continuing cost reduction, more balancing capacity will need to be added for system reliability purposes. Consequently, LCOE is expected to become increasingly less useful as a technology cost comparative measure and as an indicator of electricity prices.[102]

1.141 In order to estimate the true cost of energy sources, assessments must be undertaken on a consistent basis with respect to the cost of capital and taking into account different demand profiles for commercial, industrial and household consumers, levels of subsidies and environmental externalities, decommissioning and waste expenses, and costs to the broader electricity network such as increased burdens on administration, connection and firming.[103]

1.142 An alternative to the LCOE methodology is the 'whole of system costs' (or 'system costs') method of analysis. The difference between LCOE and system costs models is that LCOE compares technologies while a system costs model attempts to represent the actual electricity system, which can then be augmented with new projects or policy changes.[104]

1.143 Bright New World explained the advantage of the system costs model, stating:

> ... it is entirely possible to build a system based on technologies which are able to provide a generic unit of electricity cheaply on paper; however, when assembled together to form a system, the system itself becomes very, very expensive. That's because electricity is not a simple tradeable product that is easily stored

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101 ANSTO, *Submission 166*, p. 23.

102 Graham, P.W., Hayward, J, Foster, J., Story, O. and Havas, L, *GenCost 2018: Updated projections of electricity generation technology costs*, CSIRO, Australia, December 2018, pp. 23-24.

103 For an overview on LCOE methodology, see US Energy Information Administration, *Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019,* at https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf.

104 See OECD Nuclear Energy Agency, *The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables,* 29 January 2019, at https://www.oecd-ilibrary.org/nuclear-energy/the-costs-of-decarbonisation_9789264312180-en;jsessionid=TMsUucejRHsOwSEZK1jZxusz.ip-10-240-5-188.

> like other simple tradeable products. It's much more a service than a product, and the service that is required is full reliability with stability—stability in cost and stability in supply.[105]

1.144 The Committee notes: i) the economics of nuclear energy is contested; ii) there are challenges in estimating costs ten or more years in advance; and iii) the weaknesses of the LCOE methodology of cost analysis and the benefits of the 'whole of system costs' analysis methodology.

Commissioning a readiness assessment

1.145 The Australian Government should commission a readiness assessment. This requires an expert body such as the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) to identify the major requirements that would need to be in place before Australia was ready to adopt nuclear energy.

Understanding the timeline

1.146 There are differing views on how long it would take to develop nuclear energy in Australia. For example:

- A submission from SMR Nuclear Technology Pty Ltd stated that a small modular nuclear reactor could be operational 'around 7 years after the law is changed to lift the prohibition on nuclear power'.[106]
- NuScale Power estimated that it would have SMRs online in the United States by 2026[107] and Australia may therefore consider introducing SMRs in the years that follow.
- The Australia Institute estimated that it may take until 2040 for a nuclear power plant to become operational in Australia.[108]
- Nuclear for Climate Australia presented a timeline whereby 20 nuclear power plants could be completed from 2030 to 2050.[109]
- The Switkowski Report stated (in 2006) that 'the earliest that nuclear electricity could be delivered to the grid would be 10 years, with 15 years more probable'.[110]
- ARPANSA's submission stated:

105 Dr Benjamin Heard, Founder, Bright New World, *Proof Committee Hansard*, Adelaide, 2 October 2019, p. 12.

106 SMR Nuclear Technology Pty Ltd, *Submission 39*, p. 11.

107 NuScale Power, *Submission 71*, p. 1.

108 Australia Institute, *Submission 167*, p. 4.

109 Nuclear for Climate Australia, *Submission 135*, p. 25.

110 Department of the Prime Minister and Cabinet, *Uranium Mining, Processing and Nuclear Energy – Opportunities for Australia?*, 2006, p. 2.

> Realistically, reaching the operational stage for the first nuclear power plant in Australia could not take much less than 15 years from the time a decision is taken to move in this direction; it is not unlikely that it would take longer time to complete construction and commence operations, possibly much longer.[111]

- The Department of Industry, Innovation and Science advised that it would take 10 to 15 years to develop sufficient skilled workers to operate nuclear power plants and related fuel cycle activities.[112]

1.147 A joint submission from environmental groups including Greenpeace, the Australian Conservation Foundation, the Wilderness Society and Friends of the Earth Australia, provided no specific timeline, but noted that selected projects in other countries had been 'abandoned, sharply curtailed or postponed'.[113] However, other evidence noted that the roll out of selected projects in other countries was on plan and on budget.[114]

1.148 The Committee notes: i) contested views on how long it would take for a nuclear energy industry to begin in Australia; ii) a timeline of ten years or more would likely be required before a nuclear reactor could be procured and operational in Australia; and iii) rather than being a constraint, ten years or more would be time well spent to ensure the various aspects of readiness were put in place.

Understanding the requirements

1.149 Moving towards nuclear energy would require extensive planning, preparation and development. Although Australia would be a new entrant to the nuclear energy industry, the Committee acknowledges the experience and expertise within ANSTO and also ARPANSA as strong platforms on which to build.

1.150 Women in Nuclear Australia submitted that ANSTO, ASNO and ARPANSA are well established bodies and could form a basis for a future regulatory body for a nuclear power industry.[115]

1.151 Australia would need to prepare for the introduction of nuclear energy across a range of areas including waste management, health and safety, workforce capability, and security and governance.

111 ARPANSA, *Submission 136*, p. 10.

112 Department of Industry, Innovation and Science, *Supplementary submission 211.1*.

113 Nine environment groups and state conservation councils, *Submission 219*, pp. 5-6.

114 Dr Donald Higson, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 58.

115 Women in Nuclear Australia Inc., *Submission 154*, pp. 11-12.

Addressing the issue of waste management

1.152 The Committee heard that an issue of particular concern relating to nuclear energy is waste management. It is very important that waste from the production of energy is well managed.

1.153 Radioactive waste associated with nuclear technology is generally classified into three categories: low, intermediate and high-level waste:

- Low-level waste usually comprises items such as rags, tools, paper and clothing, and is limited to small amounts of radioactivity.
- Intermediate-level waste usually comprises materials with a higher level of radioactivity, but still consists of only around four per cent of the radioactivity of all nuclear waste.
- High-level waste accounts for only three per cent of the volume of total radioactive waste, and results from nuclear power generation.

1.154 Australia currently produces low and intermediate-level waste, but no high-level waste.[116]

1.155 The Committee heard that waste from both renewable and non-renewable energy sources is hazardous to human and environmental health and that Australia has a mixed record on how it manages the disposal and storage of such waste.

1.156 For example, solar panels contain toxic compounds and batteries can contain toxic heavy metals. The Committee was told that there is presently no viable recycling pathway for solar panels at the end of their life. Mr James Fleay of Down Under Nuclear Energy told a public hearing that '…the point is that solar panels and wind turbines currently go into landfill…'[117] The Committee also heard that the recycling of solar panels and wind turbines would require an enormous amount of energy.[118]

1.157 It is notable that nuclear energy produces a lower volume of waste than coal-fired power production. To illustrate, a 1000MW(e) nuclear plant produces around 30 tonnes of solid waste each year (where spent fuel is not reprocessed), compared with around 300,000 tonnes of ash for the same sized coal plant.[119]

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116 ANSTO, *Submission 166*, p. 9.

117 Mr James Fleay, Down Under Nuclear Energy [DUNE], *Proof Committee Hansard,* 3 October 2019, p. 6.

118 Mr James Fleay, Down Under Nuclear Energy [DUNE], *Proof Committee Hansard,* 3 October 2019, p. 6.

119 Nuclearinfo.net (University of Melbourne), 'Waste from Nuclear Power', http://nuclearinfo.net/Nuclearpower/WebHomeWasteFromNuclearPower, accessed 18 November 2019.

1.158 It is also notable that new generation reactors create less waste, particularly designs that include a 'closed cycle' process. Advanced nuclear reactor designs include more efficient and effective use of fuel, to reduce waste.[120]

1.159 The IAEA maintains a series of Safety Guides to provide guidance on radioactive waste management to member States[121], and Australia's regulator operates under legislative rules and strict frameworks to safely manage waste.[122]

1.160 In long-standing nuclear countries, waste has been firstly stored at the same site where the nuclear plants operate. While this has proven effective and safe, it is notable that some of these countries have started looking for new solutions to manage their waste after decades of plant operation. Some nuclear countries are assessing options for a centralised permanent location to store nuclear waste.

1.161 At present, spent fuel waste from reactors is typically stored for a period of five to ten years in a cooling pond, followed by thirty to forty years in a dry storage cask (above ground). The heat generation and radiotoxicity will generally reduce by around 70 per cent in the first ten years.[123]

1.162 The Committee notes: i) the importance of waste management; ii) Australia's experience in managing low and medium level nuclear waste, but not high level; iii) the relative low volumes of waste created by nuclear energy generation; iv) the relatively high hazardous nature of the waste created by nuclear energy generation; v) the decades of experience of managing waste in other mature nuclear energy countries; vi) that, in the event of introducing nuclear energy, Australia would need to decide if one or more central repositories for storing waste would be required or if each reactor would be responsible for storing its own waste; and vii) that such decisions would be informed, in part, by the nuclear technology being adopted and thus the nature and volume and radioactive life of the waste generated.

Addressing the issues of health and safety

1.163 It is notable that while some witnesses were genuinely concerned about the safety of nuclear energy, the evidence heard by the Committee points

120 Ian Hore-Lacy, *Nuclear Energy in the 21st Century* (4th ed.), p. 42.

121 International Atomic Energy Agency, 'Specific Safety Requirements', https://www.iaea.org/publications/search/topics/radioactive-waste-and-spent-fuel-management/type/safety-standards-series/type/safety-fundamentals/type/general-safety-requirements/type/general-safety-guides/type/specific-safety-requirements>; accessed 19 November 2019.

122 ARPANSA, *Submission 136*, p. 7.

123 ANSTO, *Submission 166*, p. 10.

to nuclear energy being the safest form of energy in the world based on comparative mortality rates of different energy sources.

1.164 As indicated in Table 1.4, the Committee received evidence that a lower number of deaths per unit of energy is attributed to nuclear energy generation than to other electricity production methods.[124]

Table 1.4: Mortality rate per PWh (PetaWatt – million billion watt-hours) of electricity generated

Electricity production technology	Deaths
Coal – China	90,000
Coal – USA	15,000
Oil	36,000
Biofuel	12,000
Gas	4,000
Hydro	100
Hydro - including disasters	1,400
Solar– Rooftop	440
Wind	150
Nuclear-Including Fukushima and Chernobyl	90

Source: Mr Terry Ryan, Submission 14*, p. 4 (citing K Emanuel, Massachusetts Institute of Technology).*

1.165 The perceived public health risks of nuclear energy were discussed at length during the course of this inquiry. In this regard, the Committee notes ANSTO's 60 years of efficient waste management and the detailed guidance produced by international actors like the IAEA on the safe disposal of nuclear waste, which is discussed in more detail above. This experience and history highlights that any potential health risks stemming from nuclear waste are manageable within a clearly developed and detailed waste management strategy.

1.166 Regarding the health and safety risks posed to the workforce, the data highlighted by the 2016 South Australia Royal Commission into the Nuclear Fuel Cycle indicates that the modern nuclear fuel cycle operates well within 'applicable regulatory limits for workers, the public and the environment'.[125] Further, data presented to this Committee has shown that uranium industry workers are exposed to lower annual doses of radiation than those received by airline crews.[126]

124 See Mr Terry Ryan, *Submission 14*, p. 4; Mr Terje Petersen, *Submission 17*, p. 4; Nuclear Economics Consulting Group, *Submission 144*, p. 13.

125 Report of the South Australian Nuclear Fuel Cycle Royal Commission, 2016, p. 135.

126 Minerals Council of Australia, *Submission 266*, p. 14.

1.167 The Committee also heard about the health risks to communities living near nuclear energy facilities. In this regard, the Committee notes ANSTO's advice that nuclear power outperforms 'other established electricity generation technologies' in relation to health outcomes, even when the effects of nuclear accidents are considered.[127]

1.168 Similarly, safety risks are a key consideration of nuclear energy, and are closely related to the health risks. The Committee heard a variety of views on the relative safety of nuclear energy, ranging from the potentially significant consequences of an accident to the track record of nuclear energy generation, which historically has resulted in fewer accidents and worker injuries/deaths than any other energy source.

1.169 The Committee notes: i) the importance of health and safety; ii) the strong safety record of nuclear energy compared to other energy sources; iii) the experience and track record of the industry in managing health and safety risks; and iv) the need for effective safeguards for effectively managing a domestic nuclear energy industry.

Addressing the issue of workforce capability

1.170 Developing a skilled workforce to support any potential nuclear energy generation capability in Australia is key to the adoption of nuclear energy.

1.171 While Australia does possess some existing expertise in this area, particularly at ANSTO's research reactor, this workforce would require expansion prior to any potential move to adopt nuclear energy. The Committee heard about the long lead-times associated with training a skilled workforce and the need for a clear strategy to achieve an effective local workforce capacity.

1.172 The Committee heard about international trends regarding the export of nuclear energy expertise, and the role this could play in training and preparing an Australian workforce to manage a nuclear energy industry in the long term.

1.173 In this regard, it is notable that training and education opportunities in nuclear physics and engineering are already available at some Australian universities.[128] However, these educational opportunities are limited at present, and significant expansion would be required in order to achieve an effective and capable nuclear workforce in the long term.

1.174 The Committee notes: i) the importance of a capable workforce, ii) existing nuclear technology expertise in Australia and existing education programs relating to nuclear science and engineering in Australia; and iii) the need

127 ANSTO, *Submission 166*, p. 14.

128 Dr Ziggy Switkowski, *Submission 41*, p. 2.

to expand the capacity of the existing workforce and education and skill development programs.

Addressing the issues of security and governance

1.175 Three of the central security considerations examined in the course of this inquiry were outlined by the Australian Safeguards and Non-Proliferation Office (ASNO), namely: sabotage on facilities; theft of nuclear materials; and the implications for possible nuclear weapons proliferation.[129]

1.176 In order to ensure that these security issues are adequately managed, robust governance and regulatory arrangements need to be in place. In practice, these arrangements are informed by IAEA standards. In terms of aspects like security infrastructure, IAEA assistance and advice is available.[130]

1.177 In regard to matters of nuclear non-proliferation, the IAEA plays a more direct role, being entrusted with the process of verifying compliance with the various non-proliferation treaties via its inspection program.

1.178 ASNO already administers a safeguards system wherein all nuclear facilities and material are regulated pursuant to the Nuclear Non-Proliferation (Safeguards) Act 1987. This legislative framework incorporates Australia's obligations under various international treaties and agreements.

1.179 In the event that Australia introduces nuclear energy in the future, additional responsibilities for the regulator would need to be determined.[131] As a result, the effective regulation of a potential nuclear energy industry is another central requirement that would need careful and detailed consideration prior to any move towards the adoption of nuclear energy in Australia.

1.180 The Committee notes: i) the importance of security and governance; ii) the existing governance and regulatory systems relating to security that are managed by ASNO; and iii) the need for additional responsibilities for the regulator in the event of Australia introducing nuclear energy.

A community engagement program is required

1.181 The Australian Government should commission a community engagement program. This would require a program that would roll out

129 Australian Safeguards and Non-Proliferation Office (ASNO), *Submission 153*, p. [1].

130 ASNO, *Submission 153*, p. [2].

131 ASNO, *Submission 153*, p. [2].

nationally to educate and inform Australians on nuclear technology, and hear their views and answer their queries.

Building on the community-focused approach

1.182 As outlined earlier in this report, Australia should be community-focused in its consideration of nuclear energy. This requires us to recognise the importance of a social licence to operate and to put the community at the centre of deliberations on nuclear energy.

1.183 However, notwithstanding energy policy being the subject of considerable public debate over recent years, the Committee is concerned that there may be limited public knowledge about how Australia's energy system works due to its political, economic and technological complexity.

1.184 Furthermore, nuclear technology is a highly complex topic and there is limited education in Australia on the technology and how it works. For example, ANSTO stated that there is 'significant misunderstanding' about the risks associated with exposure to radiation and the controls in place to ensure the safety of workers and public.[132]

1.185 Similarly, Mr Terry Krieg suggested there is 'widespread community ignorance and misunderstanding' in relation to nuclear energy.[133]

1.186 Reporting on the discussion at a 2017 symposium on the findings of the South Australian Royal Commission, the ANU Energy Change Institute stated that 'current understanding of nuclear issues in Australia is often not based on empirical evidence and data'.[134]

1.187 The fact that nuclear science and technology has been negatively portrayed in popular culture compounds the problem stemming from limited public knowledge, making it easier for misunderstandings to arise and easier for people to run scare campaigns against nuclear energy.

1.188 Several submissions to the inquiry called for greater public awareness to support the acceptance and introduction of nuclear energy in Australia. For example, Mr Ronald James told the Committee:

> …..The greatest risk to it is public perception, not cost. ….A major public awareness program will be the deciding factor to enable the successful introduction of nuclear energy into Australia.[135]

132 ANSTO, *Submission 166,* p. 25.

133 Mr Terry Krieg, *Submission 61,* p. [44].

134 ANU Energy Change Institute, *Submission 160,* p. [3].

135 Mr Ronald James, *Proof Committee Hansard*, 30 September 2019, p. 22.

1.189 Similarly, Mr Bernd Felsche identified public education about nuclear power as an important prerequisite to the introduction of nuclear energy in Australia:

> As the target of mass media sensationalism and activist scare campaigns, the public deserves a balanced education regarding nuclear technologies. An education that presents how the risks are managed by technology and processes in an industry that globally has the lowest mortality rates of all power generating technologies.[136]

1.190 The Committee notes: i) the Australian people deserve an opportunity to be better informed about facts and information relating to nuclear technology; and ii) a need for a community engagement program that provides two-way dialogue on issues relating to nuclear technology.

136 Mr Bernd Felsche, *Submission 129*, p. 2.

Recommendation 2

The Committee recommends that the Australian Government undertake a body of work to progress the understanding of nuclear energy technology by:

a. **Commissioning the Australian Nuclear Science and Technology Organisation (ANSTO), or other equivalent expert reviewer, to undertake a technological assessment on nuclear energy reactors to:**

   i. **produce a list of reactors that are defined under the categories of Generation I, II, III, III+ and IV;**

   ii. **advise on the technological status of Generation III+ and Generation IV reactors including small modular reactors;**

   iii. **advise on the feasibility and suitability of Generation III+ and Generation IV reactors including small modular reactors in the Australian context; and**

   iv. **formulate a framework to be used by Government to monitor the status of new and emerging nuclear technologies.**

b. **Commissioning the Productivity Commission, or other equivalent expert reviewer, to undertake an independent assessment of the economic viability of nuclear energy generation in the Australian context with account for:**

   i. **both baseload and peak demand;**

   ii. **whole of system costs;**

   iii. **variances in the cost of capital, government subsidies, and other interventions;**

   iv. **economic costs;**

   v. **environmental outcomes including carbon emissions; and**

   vi. **other alternative energy sources.**

c. **Commissioning the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), or other equivalent expert reviewer, to lead and coordinate a whole-of-government assessment that identifies the major requirements that would need to be in place before Australia was ready to adopt nuclear energy, particularly:**

i. **waste management;**

ii. **health and safety;**

iii. **workforce capability;**

iv. **security; and**

v. **governance issues.**

d. **Commissioning an expert body to manage an independent community engagement program that would educate and inform Australians on nuclear technology, answer their queries and hear their views.**

3. Lifting the moratorium

1.191 This section of the report discusses lifting the current moratorium on nuclear energy so that nuclear technologies have an opportunity to be fairly considered alongside other possible energy sources. Rather than a total and immediate lift of the moratorium, only a partial lift for new and emerging technologies is proposed, subject to the results of a technology assessment and a commitment to community consent as a condition of approval for nuclear facilities.

1.192 The section is divided into two sub-sections that suggest the Australian Government should:

- lift the moratorium partially by thinking discerningly about what types of nuclear technology should be considered; and
- lift the moratorium conditionally subject to the results of a technology assessment and the prior informed consent of impacted communities.

Lifting the moratorium partially

1.193 The Australian Government should adopt a nuanced, technology-driven approach to lifting the moratorium. In thinking discerningly about what types of nuclear technology Australia should consider, the current moratorium should be maintained for old nuclear technologies and lifted for new and emerging technologies.

The moratorium on nuclear energy

1.194 A moratorium on nuclear energy currently exists in Australia, as expressed in federal legislation.

1.195 The *Australian Radiation Protection and Nuclear Safety Act 1998* (Cth) (ARPANS Act) prohibits the 'construction or operation' of a number of nuclear installations, namely:

- a nuclear fuel fabrication plant;
- a nuclear power plant;
- an enrichment plant; and
- a reprocessing facility.[137]

1.196 The *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) also expressly prohibits the relevant minister from approving the 'construction or operation' of the same facilities.[138]

1.197 The Committee heard that Australia is 'one of only around 15 countries with some kind of formal opposition to nuclear energy.'[139]

The case for removing the moratorium

1.198 One of the arguments heard by the Committee in favour of removing the moratorium is that it is an unfair anomaly in Australia's otherwise free market economy to have one particular technology effectively banned. As a result, nuclear energy cannot be properly assessed for its potential contribution to Australia's energy mix, nor its capacity to attract interest from investors.[140]

1.199 The Australian Taxpayers' Alliance said that it supports lifting the moratorium 'in order to lay the groundwork for encouraging private investment with the right regulatory framework in place.'[141]

1.200 Similarly, SMR Nuclear Technology explained:

> If the moratorium on nuclear power generation is lifted, SMRs could be deployed and become be a game-changer in Australian power system planning, progressively replacing obsolete power generators in the Australian power system as they close down over the next 30 years.[142]

1.201 Government agencies confirmed that the current moratorium constrains their ability to undertake work or research on nuclear energy. CSIRO advised the Committee that the Government is unable to spend public

137 *Australian Radiation Protection and Nuclear Safety Act 1998* (Cth), section 10.

138 *Environment Protection and Biodiversity Conservation Act 1999* (Cth), section 140A.

139 Dr Tom Biegler, *Submission 56*, p. 2.

140 See for example: SMR Nuclear Technology Pty Ltd, *Submission 39,* p. 14; StarCore Nuclear, *Submission 128,* p. [4]; Australian Taxpayers Alliance, *Submission 263,* p. 15.

141 Australian Taxpayers' Alliance, *Submission 263*, p. 2.

142 SMR Nuclear Technology, *Submission 39*,p. 15.

money on research into nuclear power or associated matters,[143] and the Australian Energy Market Operator said it conducts no assessments of the suitability of nuclear energy.[144]

1.202 Major think tanks and other organisations with demonstrable expertise in energy provided similar evidence.[145] For example, a representative of the Grattan Institute stated that when he was involved in the development of the Garnaut Climate Change Review:

> ... it was made clear that it was inappropriate for us to model nuclear in that scenario, because it was illegal in Australia. We had to go and do it separately from the government's remit. So it does provide ... a significant barrier, even though it may not be a legal barrier, to being able to have that conversation [about nuclear energy].[146]

1.203 Dr Ziggy Switkowski was concerned that retaining the moratorium places a constraint on decision making that may not suit today's realities:

> Should we change the Environmental Protection and Biodiversity Conservation Act? Absolutely…We should not be making decisions in 2019 based upon legislation passed in 1999 reflecting the views of 1979.[147]

1.204 The Committee notes that the 2006 Switkowski Review's key findings included recognition that legal and regulatory barriers would need to be removed to allow growth of a nuclear industry.[148]

1.205 Ten years later, the SA Royal Commission report recommended that:

> …the South Australian Government pursue removal at the federal level of existing prohibitions on nuclear power generation to allow it to contribute to a low-carbon electricity system, if required.[149]

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143 Mr John Phalen, Chief Research Consultant, Science Strategy, Commonwealth Scientific and Industrial Research Organisation (CSIRO), *Proof Committee Hansard*, Canberra, 16 October 2019, p. 5.

144 Dr Alex Wonhas, *Committee Hansard*, Sydney, 29 August 2019, p. 18.

145 Dr Ziggy Switkowski, *Committee Hansard*, Sydney, 29 August 2019, p. 3; Mr Tony Wood, Energy Program Director, Grattan Institute, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 34; SMR Nuclear Technology Pty Ltd, *Submission 39*, p. 14; Australian Taxpayers' Alliance, *Submission 263*, p. 2; Minerals Council of Australia, *Submission 266*, p. 5.

146 Mr Tony Wood, Energy Program Director, Grattan Institute, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 34.

147 Dr Ziggy Switkowski, *Committee Hansard*, Sydney, 29 August 2019, p. 3.

148 Department of the Prime Minister and Cabinet, *Uranium Mining, Processing and Nuclear Energy – Opportunities for Australia?*, 2006, p. 2.

149 South Australia, *Nuclear Fuel Cycle Royal Commission Report,* May 2016, p. xv.

1.206 The Committee also heard that the moratorium discourages consideration of Australia as an investment destination for nuclear energy, which results in industry proponents not spending the time investing and preparing for a nuclear industry suitable to the Australian context. For example, StarCore Nuclear told the Committee that:

> While the moratorium remains in place it effectively mutes any real discussion on the installation of nuclear facilities. Investors require certainty and while there is a barrier to nuclear power there is little point in even considering the possibility. StarCore has first-hand experience of this. In discussion with companies with mining projects and operations around Australia about the potential for the application [of] Small Modular Reactors (SMRs) at their operations, the conversation stops at the ban.[150]

1.207 The Committee notes: i) the current moratorium is an anomaly in Australia as it effectively bans one particular type of technology; ii) it constrains energy-related research and analysis of government agencies; iii) it constrains energy-related research and analysis of non-government think tanks; and iv) it acts as a disincentive for nuclear energy proponents to assess the feasibility and suitability of nuclear technology in the Australian context and proactively propose solutions.

The case for maintaining the moratorium

1.208 A joint submission by a number of environmental groups and conservation councils supported retaining the moratorium, arguing that nuclear power:

- is costly;
- does not have community support;
- would disempower traditional landowners;
- brings environmental problems associated with radiaoactive waste; and
- would delay the development of better climate change policies.[151]

1.209 The abovementioned joint submission summarises most of the main arguments heard by the Committee in favour of maintaining the moratorium and these issues are addressed elsewhere in this report.

1.210 An additional argument in favour of maintaining the moratorium is that nuclear energy is unsafe, as shown by the accidents at Three Mile Island (USA) in 1979, Chernobyl (former Ukraine) in 1986 and at Fukushima

150 StarCore Nuclear, *Submission 128,* p. [4]. See also SMR Nuclear Technology Pty Ltd, *Submission 39,* p. 14; Australian Taxpayers Alliance, *Submission 263,* p. 15.

151 Submission by nine national environment groups and state conservation councils, *Submission 219*, pp. 6-8.

(Japan) in 2011. Most witnesses that discussed these incidents focused on Chernobyl and Fukushima rather than Three Mile Island.

1.211 The Chernobyl incident took place in 1986 and was described by ANSTO as 'the worst nuclear accident in history'. The incident was caused by the explosion of the reactor core and a fire in the reactor facility. This resulted in 134 workers developing acute radiation syndrome which led to 28 deaths. It also exposed the surrounding area to iodine in the atmosphere. ANSTO stated that there are 'generally positive prospects for the future health of most civilians exposed to radiation as a result of the incident', but that the accident nevertheless 'resulted in the displacement of 220 000 civilians from their homes.'[152]

1.212 The Fukushima incident occurred in Japan in 2011. ANSTO described the cause and impact and stated that the Fukushima incident:

> '… was the result of hydrogen explosions in several reactor units that occurred when cooling of the reactor cores could not be maintained due to the severing of power and water supplies following an earthquake and two tsunami waves. It is reported that 50 000 households, comprising 156 000 people, were displaced as a result of the compound disaster.'[153]

1.213 The Committee notes: i) genuine public concern about the dangers that presented at the Chernobyl and Fukushima incidents; and ii) it did not hear any views in favour of Australia adopting the nuclear technologies that were deployed at Chernobyl and Fukushima.

The case for a partial-lift of the moratorium on nuclear energy

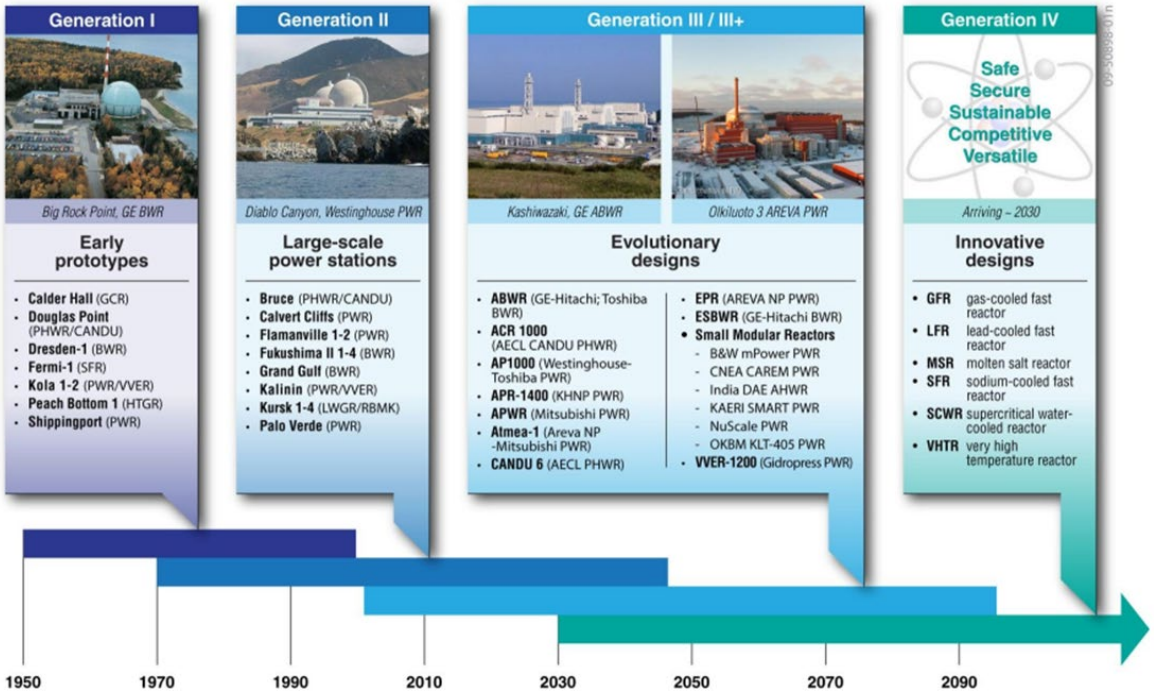
1.214 The Committee heard from various people and organisations in favour of nuclear energy who expressed a particular interest in the prospect of Australia adopting new and emerging nuclear technologies, especially SMRs. In light of concerns about the old technologies and interest in new and emerging technologies, there is a case for a partial-lift of the moratorium in favour of Generation III+ and Generation IV nuclear technologies, to the exclusion of earlier generations.

1.215 Nuclear reactor designs are generally broken down into 'generations' according to technology used, which has changed over time, shown in Figure 3 below:

152 ANSTO, *Submission 166,* p. 15.

153 ANSTO, *Submission 166,* p. 15.

Figure 3 Nuclear reactors by generation



Source *J E Kelley, 'Generation IV International Forum', January 2014.*

1.216 The reactors used at the Chernobyl and Fukushima plants were first generation and second generation technologies - referred to as Generation I and Generation II.

1.217 Generation I reactors were first introduced in the 1950s and the last Generation I reactor closed in 2015.

1.218 Generation II reactors were first introduced in the 1970s and they continue to be part of the existing fleet of reactors in operation around the world which also includes Generation III reactors and Generation III+ reactors. Nuclear power plants generally last for many decades; hence the mixture of old and new technology in operation.

1.219 Nuclear technology has advanced considerably since its earliest incarnation, and research and development is now well underway on Generation IV reactors. For example, ANSTO advised the Committee that:

- a leading Generation IV reactor design, the high temperature gas reactor, is in the commissioning phase in China;
- sodium fast reactor technology is already being used in Russia, while China and India are undertaking research and development on newer iterations; and
- molten salt reactors (MSR) are the subject of a $US3.3 billion research and development program in China, with a test reactor due for

completion within the next five years. Research into MSR is also active in North America and Europe.[154]

1.220 Australia, as a member of the GIF, is participating in work towards the molten salt reactor and the very high-temperature reactors.[155] Both of these reactor designs aim to provide efficient operation and a reduction in radioactive waste.[156]

1.221 NuScale Power advised the Committee that the first small modular reactor, using 'a safer, smaller and scalable version of pressurized light water reactor technology', is expected to be commercially available in 2026.[157]

1.222 The Committee heard that a key consideration is whether to plan for a small number of large nuclear reactors or a large number of small nuclear reactors. Evidence offered to the Committee on this question varied.

1.223 For example, the Australian Nuclear Association advised either option could be suitable:

> The nuclear generation units suitable for installation in Australia could be the currently operating APR1000+ pressurised water reactors (PWR) designed and manufactured by South Korea, and NuScale's Small Modular Reactor (SMR) currently being licenced by the [United States Nuclear Regulatory Commission] USNRC.[158]

1.224 Dr Ziggy Switkowski expressed the view that the 'window for large gigawatts to go in nuclear generators has now closed for Australia'.[159] Dr Switkowski explained that this was in part due to the mixed views in the community in relation to nuclear energy. Dr Switkowski added that:

> Given that the investment in a power station, particularly a big one, would begin at US$10 billion and go up from there, and it would take around 15 years to make it work, you can't progress without strong community support and bipartisanship at the federal level — and there is not too much evidence of that.[160]

1.225 This reflects a global trend away from larger nuclear power plants to smaller energy facilities, including SMRs. Dr Switkowski added:

154 ANSTO, *Submission 166,* p. 5.

155 Joint Standing Committee on Treaties, Report 171, 'International Trade in Endangered Species – Amendments; Women in Combat Duties – Reservation Withdrawal; Generation IV Nuclear Energy – Accession', May 2017, p. 37.

156 Generation IV International Forum, 'Generation IV Systems', < https://www.gen-4.org/gif/jcms/c_59461/generation-iv-systems>, accessed 20 November 2019.

157 NuScale Power, *Submission 71*, p. 1.

158 Australian Nuclear Association, *Submission 155*, p. 16.

159 Dr Ziggy Switkowski, *Committee Hansard*, 29 August 2019, p. 2.

160 Dr Ziggy Switkowski, *Committee Hansard*, 29 August 2019, p. 2.

> Will there be an opportunity for small modular reactors? I think there will be, especially in regional Australia, to power small towns with populations of about 100,000 [and] to support mining sites and desalination plants.[161]

1.226 The potential use of SMRs at mine sites was also raised by Dr Roger Clifton, who highlighted the ability to deconstruct and move the SMR, stating:

> ...mine sites could be powered and desalinated by an SMR for the duration of the mine. Rehabilitation of the minesite is facilitated by trucking the reactor out.[162]

1.227 Further, the Committee was told that when paired with desalination capabilities, nuclear power can be a 'net producer of water' in Australia.[163] The Committee also heard about the prospects of new reactor designs that use molten salt mixtures, such as thorium, as the primary coolant and as the fuel instead of water.

1.228 NuScale Power described its SMRs as having 'features and capabilities not found in currently offered large nuclear power plants' and advised that SMRs can be 'constructed in considerably less time compared to large nuclear plants'.[164]

1.229 New and emerging nuclear technologies continue to improve, introducing greater safety and efficiency features into their designs, including

- simpler designs to make them easier to operate;
- longer lifetimes;
- passive safety features that allow operators more time to solve problems and ways for heat to naturally dissipate, in case of a cooling system failure; and
- less waste.[165]

1.230 The Committee received evidence that newer generations of nuclear reactors will incorporate better safety features and fuel efficiency, be more sustainable, produce less waste and reduce the risk of proliferation.[166]

1.231 In particular, the Committee was told that small modular reactors will have design elements that include the passive 'walk away' safety features

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161 Dr Ziggy Switkowski, *Committee Hansard*, 29 August 2019, p. 3.

162 Dr Roger Clifton, *Submission 261*, p. 10.

163 Bright New World, *Submission 168,* p. 11.

164 NuScale Power, *Submission 71*, pp. 1-2.

165 Ian Hore-Lacy, *Nuclear Energy in the 21st Century* (4th ed.), p. 42.

166 OECD Nuclear Energy Agency, 'Nuclear Energy Today', 2nd edition, 2012, p. 23; Australian Nuclear Science and Technology Organisation (ANSTO), *Submission 166*, p. 4.

mentioned above, requiring no operator intervention to apply safeguards in the event of an incident.[167]

1.232 Emeritus Professor Erich Weighold agreed, advising that advances in technology make modern reactors 'extremely safe':

> The probability of core damage or the loss of structural integrity (CDF) for modern nuclear reactors is close to one in a million years. Small Modular Reactors (SMR) are even safer, with a CDF of only 5 in a billion years.[168]

1.233 The Committee heard that new generation technologies including small modular reactors are more water efficient than reactors of the past, using alternate methods for cooling the reactor core. For example:

- modern SMRs can be air cooled and do not require large quantities of water, so do not need to be located near a river or on the coast;[169] and
- high-temperature gas reactors are designed to be cooled by air rather than water, and China intends to deploy them in its arid interior.[170]

1.234 The Committee concluded that whichever nuclear reactor design or model could be suitable for Australia, the pending availability of Generation III+ and Generation IV nuclear power plants would allow for a technology leap over the old generations.

1.235 The Committee recognises that an additional benefit of leapfrogging technology is that it would allow Australia to enter at a high point in the evolution of nuclear power plant designs and technology. The significant costs and legacy assets of larger, earlier generation plants are weights carried by other countries. By contrast, Australia has the opportunity to learn from the lessons of others and to enter the industry by adopting new and emerging technologies only – that is, to effectively leap-frog the old and embrace new and emerging technologies.

1.236 The Committee notes: i) the advances that have taken place in nuclear technology in the decades since the reactors used at Chernobyl and Fukushima were designed; and ii) the potential benefits of Generation III+ and Generation IV nuclear technologies, especially SMRs.

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167 SMR Nuclear Technology Pty Ltd, *Submission 39*, p. 5.

168 Emeritus Professor Erich Weigold, *Submission 123*, p. [2].

169 SMR Nuclear Technology Pty Ltd, *Submission 39*, p. 6. See also Down Under Nuclear Energy, *Submission 159,* p. 12.

170 ANSTO, *Submission 166,* p. 5.

Lifting the moratorium conditionally

1.237 The Australian Government should place two conditions on a partial-lift of the moratorium. That is, the technologies for which the moratorium is lifted should be subject to a technology assessment and any approval for a nuclear power plant or waste disposal facility should be subject to the prior informed consent of impacted local communities.

Abiding by the results of a technology assessment

1.238 As already outlined in the second section of this report regarding the need for a body of work, it is recommended that a technology assessment be undertaken by ANSTO that will advise on the feasibility and suitability of Generation III+ and Generation IV reactors including small modular reactors.

1.239 The Committee notes: i) the importance of ensuring that any nuclear reactor that is built and operated in Australia should be feasible and suitable; and ii) that recommendation 2a of this report recommends a technology assessment on Generation III+ and Generation IV technologies for their feasibility and suitability.

Honouring the will of the people

1.240 Finally, the Committee believes the will of the people should be honoured by requiring broad community consent before any nuclear facility is built. That is, nuclear power plants or waste facilities should not be imposed upon local communities that are opposed to proposals relating to nuclear facilities presented to them.

1.241 The Committee notes that during the inquiry, negotiations were continuing between the Australian Government and communities in South Australia in relation to the establishment of a National Radioactive Waste Management Facility for low- and intermediate- level waste. On 7 November 2019 the Minister for Resources and Northern Australia announced that in a ballot conducted by the Australian Electoral Commission 61.6 per cent of voters in the community of Kimba had expressed support for locating the proposed facility there, showing 'a clear level of support for the proposal amongst eligible participants'. The Minister advised that the results of the ballot would be considered alongside 'other indicators of community support' including further consultations, as well as relevant technical information, before a final

decision on the facility would be reached.[171] This experience serves as a case study on engaging an Australian community on a decision relating to a nuclear facility impacting their local area.

1.242 The Committee notes: i) the importance of honouring the will of local communities that may be impacted by a nuclear power plant or waste facility; and ii) the South Australian experience of community engagement in relation to establishing a radioactive waste management facility in Kimba.

Recommendation 3

The Committee recommends that the Australian Government allow partial and conditional consideration of nuclear energy technology by:

- **a. maintaining its moratorium on nuclear energy in relation to Generation I, Generation II and Generation III nuclear technology; and**
- **b. lifting its moratorium on nuclear energy in relation to Generation III+ and Generation IV nuclear technology including small modular reactors, subject to the results of a technology assessment (see recommendation 2a) and a commitment to community consent as a condition of approval (see below).**

Further, the Committee recommends that:

- **c. the Australian Government, in cooperation with relevant state and territory governments, respect the will of the Australian people by committing to a condition of approval for any nuclear power or nuclear waste disposal facility being the prior informed consent of local impacted communities, obtained following extensive consultation with local residents including local Indigenous peoples.**

Ted O'Brien MP
Chair

11 December 2019

171 Senator the Hon Matt Canavan, Minister for Resources and Northern Australia, 'National radioactive waste management facility—Kimba community ballot', Media Release, 7 November 2019.