The Parliament of the Commonwealth of Australia

Not without your approval: a way forward for nuclear technology in Australia

Report of the inquiry into the prerequisites for nuclear energy in Australia

House of Representatives
Standing Committee on the Environment and Energy

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Energy is a highly contested area of public policy in Australia.

Like the rest of the world, Australia is amidst an energy transition as we seek to deliver affordable and reliable energy while also reducing emissions. This is no easy feat and it requires a preparedness to consider, among other things, new and emerging technologies, including nuclear technology.

In adopting a referral from the Minister to inquire into nuclear energy, it was important for the Environment and Energy Committee to take an evidence-based approach and to bring dispassionate independence in assessing the evidence that came before us.

The Committee worked well together to inquire into a very important topic over a relatively short period of time. The Committee consisted of members of the Government, the Opposition and the cross-bench, so it may not surprise people to learn that we had differing opinions.

Nevertheless, I believe this report—entitled *Not without your approval*—provides a way forward for nuclear technology in Australia by proposing three recommendations to the Commonwealth Government. Firstly, that it consider the prospect of nuclear technology as part of its future energy mix; secondly, that it undertake a body of work to progress the understanding of nuclear technology in the Australian context; and thirdly, that it consider lifting the current moratorium on nuclear energy partially—that is, for new and emerging nuclear technologies only, and conditionally—that is, subject to the results of a technology assessment and to a commitment to community consent for approving nuclear facilities.

Ted O'Brien MP
Chair

Committee Membership

Chair	Mr Ted O'Brien MP	
Deputy Chair	Mr Josh Wilson MP	
Members	Mrs Bridget Archer MP	Ms Zali Steggall OAM MP
	Mr Josh Burns MP	Mr Rick Wilson MP
	Hon Dr David Gillespie MP	Mr Trent Zimmerman MP
Supplementary Members	Hon Keith Pitt MP (from 20 August 2019)	Mrs Fiona Phillips MP (from 17 September 2019)

Terms of reference

The Australian Government supports an energy system which delivers affordable and reliable energy to consumers while fulfilling Australia's international emissions reduction obligations.

Successive Labor and Coalition governments have maintained a bipartisan moratorium on nuclear electricity generation in Australia. Australia's bipartisan moratorium on nuclear energy will remain in place.

Australia's energy systems are changing with new technologies, changing consumer demand patterns and changes in demand load from major industries. At the same time the National Electricity Market is seeing a significant increase in capacity in intermittent low emissions generation technologies.

The Committee specifically inquire into and report on the circumstances and prerequisites necessary for any future government's consideration of nuclear energy generation including small modular reactor technologies in Australia, including:

- waste management, transport and storage,
- health and safety,
- environmental impacts,
- energy affordability and reliability,
- economic feasibility,
- community engagement,
- workforce capability,
- security implications,
- national consensus, and
- any other relevant matter.

The inquiry will have regard to previous inquiries into the nuclear fuel cycle including the South Australian Nuclear Fuel Cycle Royal Commission 2016 commissioned by the Labor Government in South Australia and the 2006 Switkowski nuclear energy review.

List of recommendations

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.

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.

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.

List of abbreviations

AEMO	Australian Energy Market Operator
ANSTO	Australian Nuclear Science and Technology Organisation
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
ARPANS Act	*Australian Radiation Protection and Nuclear Safety Act 1998* (Cth)
ASNO	Australian Safeguards and Non-Proliferation Office
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
GenCost report	The CSIRO and AEMO report *GenCost 2018: Updated projections of electricity generation technology costs,* December 2018.
GIF	Generation IV International Forum
IAEA	International Atomic Energy Agency
OECD	Organisation for Economic Co-operation and Development
NPT	Nuclear Non-Proliferation Treaty, 1970
SARC	South Australian Royal Commission on the nuclear fuel cycle, 2016
SMR	Small Modular Reactor(s)
[Solar] PV	Photovoltaic

Switkowski Review	The *Uranium Mining, Processing and Nuclear Energy – Opportunities for Australia?* report (2006). Also known as UMPNER.
UMPNER	The *Uranium Mining, Processing and Nuclear Energy – Opportunities for Australia?* report (2006). Also known as the Switkowski review.
UNFCCC	United Nations Framework Convention on Climate Change, 1994
WNA	World Nuclear Association
kW (e)	Kilowatt (electric): 1,000 watts of electricity
MW (e)	Megawatt (electric): 1 million watts of electricity
GW (e)	Gigawatt (electric): 1 billion watts of electricity

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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.

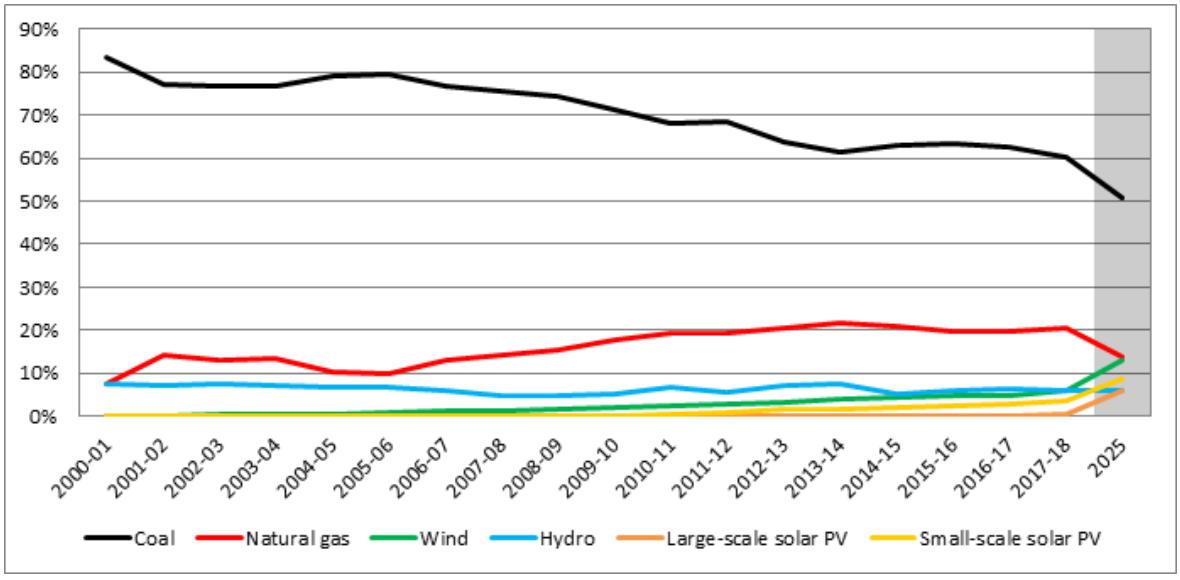
1.33 The Committee notes: i) the significant increase in the price of electricity in Australia over recent decades; ii) the loss of Australia's competitive advantage in the cost of electricity relative to other OECD countries; iii) the likely impact of higher electricity prices on households and the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

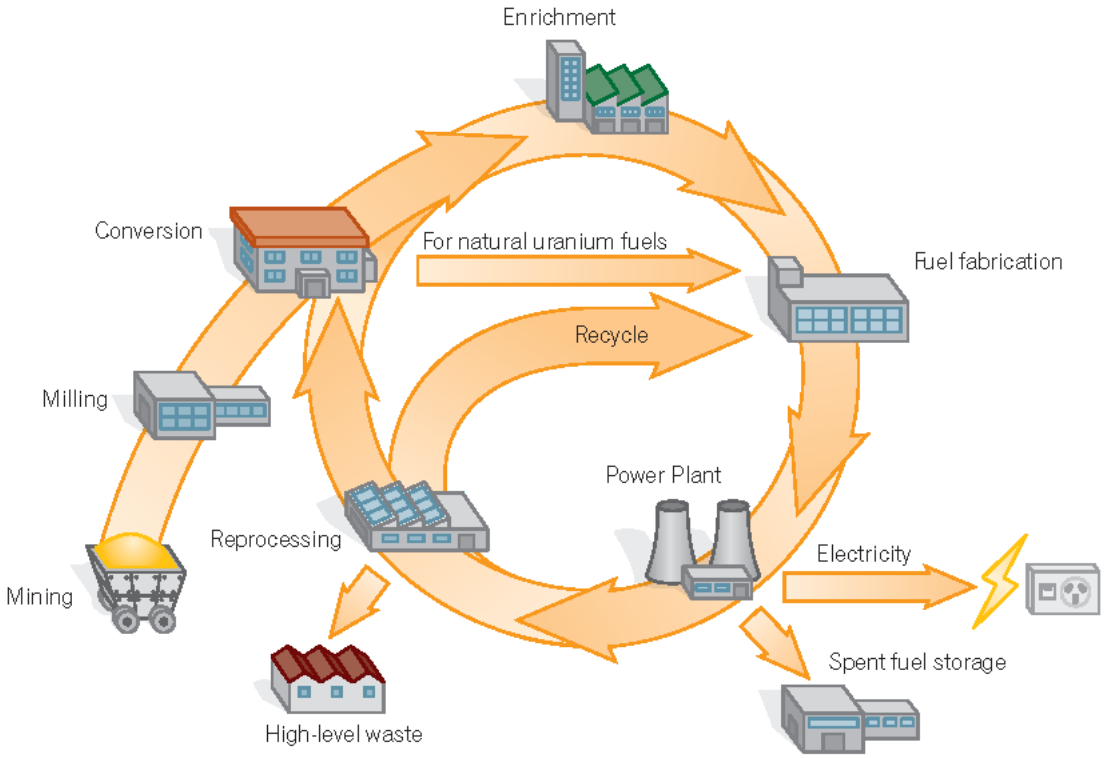
50 Women in Nuclear Australia, *Submission 154*, p. 16.

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

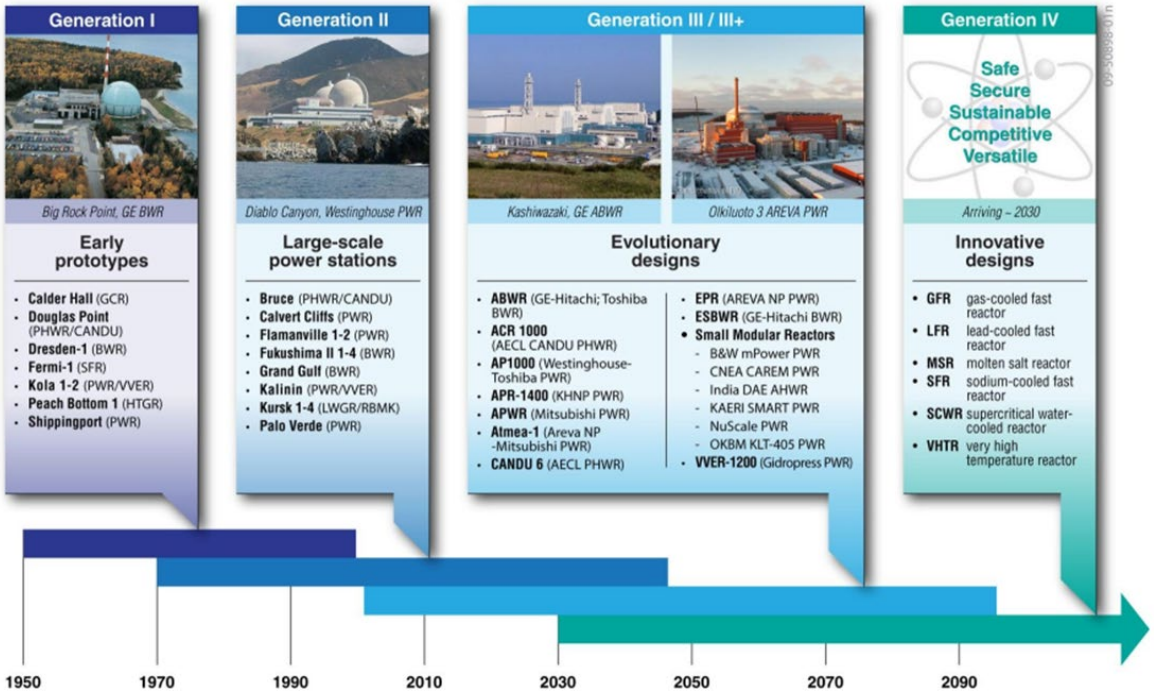
1.214 The Committee heard from various people and organisations in favour of nuclear energy who expressed a particular interest in the prospect of Australia adopting new and emerging nuclear technologies, especially SMRs. In light of concerns about the old technologies and interest in new and emerging 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.

Labor Members' Dissenting Report

A Dangerous Distraction

1.1 For Australia to change the long-held bipartisan position against the development of a nuclear power industry in Australia it would have to make sense to do so. Yet on any analysis it doesn't, as the evidence to this inquiry has shown. Above all, there is no economic case for pursuing nuclear energy.

1.2 In fact the events (like Fukushima), innovations and advances in renewable energy, and emerging climate and energy system developments of the last ten years have made nuclear power even less relevant and appropriate in the Australian context at a time when nuclear power is already in decline elsewhere. There is simply no case for wasting time and resources on a technology that is literally the slowest, most expensive, most dangerous, and least flexible form of new power generation.

1.3 With respect to all the key considerations—namely, our future energy needs, the changing nature of our energy system, the comparative costs and delivery timelines of different sources of generation, the serious risks and dangers to the environment and public health, and the impact in terms of regional nuclear proliferation—the pursuit of nuclear energy in Australia would be deeply irrational.

1.4 On the basis that Government members were prepared to ignore the evidence and support recommendations that Australia should move towards the use of nuclear energy, Labor members cannot support the inquiry report.

1.5 There is no basis for lifting the legislative prohibition on nuclear energy (Recommendation 3). There is no need for additional work or specific investigations into the science or economics of nuclear energy (Recommendation 2) as Australia already has significant expertise and engagement in this space through the Australian Nuclear Science and Technology Organisation (ANSTO), the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), the Australian Energy Market Operator (AEMO), the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and through our nuclear-related international treaty-based collaborations. Devoting resources to a nuclear wish-fulfilment exercise, including what sounds like a nuclear propaganda exercise (e.g. 'manage a community engagement program that would educate and inform Australians') would be a costly and wasteful distraction.

1.6 For those reasons Labor members of the Committee moved to delete Recommendation 2 and insert an alternative recommendation, as follows:

> **Recommendation B**
>
> The Committee recommends the government maintain support for the relevant energy agencies, including AEMO, ANSTO, ARPANSA, ASNO, and others, and reverse the funding cuts it has made to scientific and research agencies like the CSIRO, so that Australia can maximise the benefits, innovation, job and export opportunities that exist as part of a properly managed energy transition.

1.7 Australia's focus – and the government's focus – needs to be on settling a national energy policy that delivers affordable and reliable power as we move more rapidly to decarbonise our electricity system, and in turn, address our present state of liquid fuel insecurity.

1.8 On that point, responding to perhaps the clearest and certainly the most unchallenged theme of the hearing evidence, Labor members moved a recommendation (see below) that the government's first priority should be the design and settlement of a national energy policy; the glaring absence of which means that Australians pay more for their power because investment in new generation, storage, and transmission is being stymied through uncertainty, and it means Australia continues to be off-track with respect to the government's inadequate emission reduction target under the Paris Climate Agreement.

1.9 Given the weight of evidence to the inquiry in support of this common sense recommendation it is surprising that government members voted against its adoption:

Recommendation A

The Committee recommends the government focus on delivering a settled national energy policy as its highest priority within the energy portfolio so as to ensure that Australia can make a rapid, efficient, and effective transition to a decarbonised electricity system that delivers reliable and affordable power to households and businesses alike while making a substantial contribution guided by the science in the global effort to address climate change.

1.10 As Dr Ziggy Switkowski said at the first public hearing for the inquiry:

> …[W]hat is the role for government? To produce a coherent national energy strategy which is ideally technology agnostic, balances costs with resilience and risk, delivers on national emissions targets, restores energy as a source of national competitive advantage and has bipartisan support.[1]

1.11 When Mr Ian Macfarlane, Chief Executive of the Queensland Resources Council was asked, at the Brisbane hearing, 'would you agree with Dr Switkowski that the No. 1 priority in Australia is a settled national energy policy framework?' he answered:

> Of course I would, having been the longest serving energy minister in Australia and seeing the various and diverging views. Until we settle on a single energy policy you'll continue to have the investor uncertainty that is creating all sorts of issues combined with the unreliability of the grid, due to different mixes of energy which don't sustain the frequency and, therefore, are prone to blackouts and shortages of energy at certain peak periods. So it would be, in my opinion, a great outcome to achieve a single national energy policy. [2]

1.12 When Mr Patrick Gibbons of the Minerals Council of Australia was asked 'Would you agree that getting a settled national energy policy that balances the need for us to have affordable and reliable power going forward and addresses the Paris Climate Agreement is the No. 1 priority to deal with that investment problem?' he said:

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

2 Mr Ian Macfarlane, CEO, Queensland Resources Council, *Proof Committee Hansard*, Brisbane, 30 September 2019, p. 2.

> Pretty clearly I think there is an issue around the National Electricity Market not being able to provide a long-term signal that people are prepared to invest in. That then gets us to the next point, which is that governments have been grappling with this issue as it has become more apparent and the consequences have become more apparent. The National Energy Guarantee, put in last year, is a very clear attempt to do that, as is underwriting new generation investment policy, because what that's really getting at is the heart of the investment quandary that's confronting the energy sector today.[3]

The Global Context: Nuclear Power in Decline

1.13 To consider Australia's position from a global perspective it is important to note that nuclear power has been in decline across the globe for years. Contrary to those who would like to create the impression that nuclear energy is expanding as a source of electricity, the *World Nuclear Industry Status Report*[4], issued in September 2019, provides the following salient information:

- nuclear power generation peaked in 2006, the number of reactors in operation in 2002, the share of nuclear power in the electricity mix in 1996, the number of reactors under construction in 1979, construction starts in 1976. As of mid-2019, there is one unit less in operation than in 1989.
- The nuclear share of the world's gross power generation has continued its slow decline from a historic peak of 17.46 percent in 1996 to 10.15 percent in 2018.
- In 2018, ten nuclear countries generated more power with renewable than with fission energy. In spite of its ambitious nuclear program, China produced more power from wind alone than from nuclear plants. In India, in the fiscal year to March 2019, not only wind, but for the first time solar out-generated nuclear, and new solar is now competitive with existing coal plants in the market. In the European Union, renewables accounted for 95 percent of all new electricity generating capacity added in the past year.
- Globally, wind power output grew by 29% in 2018, solar by 13%, nuclear by 2.4%. Compared to a decade ago, non-hydro renewables generate over 1,900 TWh more power, exceeding coal and natural gas, while nuclear produces less.

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3 Mr Patrick Gibbons, Principal Adviser, Energy, Coal and Uranium, Minerals Council of Australia, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 49.

4 See World Nuclear Industry Status Report, 2019, https://www.worldnuclearreport.org/The-World-Nuclear-Industry-Status-Report-2019-HTML.html, accessed 12 December 2019.

- A record 165 GW of renewables were added to the world's power grids in 2018, up from 157 GW added the previous year. The nuclear operating capacity increased by 9 GW.
- Over the past decade, levelized cost estimates for utility-scale solar dropped by 88%, wind by 69%, while nuclear increased by 23%. Renewables now come in below the cost of coal and natural gas.

Timing: too late, too slow

1.14 Australia needs to move quickly to be part of concerted global action to keep the rise in global average temperatures to well below 2 degrees, and to take advantage of the employment and technology-development opportunities inherent in emerging energy systems.

1.15 Time is of the essence. Australia is not acting effectively to reduce emissions and is not on track to meet our emission reduction targets under the Paris Climate Agreement, let alone deliver reductions that are consistent with the goals of that agreement. By any reasonable estimate, a nuclear power plant could not be fast-tracked into operation in Australia much sooner than 2035. Aside from all the other reasons for not pursuing nuclear, it is simply too slow.

1.16 As Professor John Quiggin observed in his evidence:

> In my view, energy and environment policy in Australia is in a very bad situation. We have rising emissions of carbon dioxide. If we meet our Paris commitments by 2030, it will only be through once-off accounting devices, leaving us with no path to achieve the reductions in emissions that need to be achieved by 2030, with greater ambition, and certainly by 2050.[5]

1.17 According to Dr Matthew Stocks, a research fellow in the School of Electrical, Energy, and Materials Engineering at the Australian National University (ANU):

> Thirty-one years ago, I sat in a seminar at ANU and I said, 'Nuclear was the solution to climate change.' I believed at that time that that was the way we should be going forward and that we did not really have an alternate solution. My view has changed significantly in that 31 years. I believe that we need to act on climate change in a time frame which does not lend itself to Australia now shifting towards nuclear being a big part of that

5 Professor John Quiggin, *Proof Committee Hansard*, Brisbane, 30 September 2019, p. 7.

> solution. I think that is really supported by what the world's view is in terms of change at the moment.[6]

1.18 There is no prospect of Australia being able to generate nuclear power inside a decade. In response to a question taken on notice, ANSTO observed that in relation to workforce capability alone:

> …it would take between 10 to 15 years to develop sufficient numbers of skilled workers to operate a future power reactor / reactor fleet or to contribute to any other nuclear fuel cycle activities that might be established.[7]

Costs: nuclear is 'frightfully expensive'

1.19 One of the most blinding myths about nuclear power is that while it is slow and complex to deliver, and while it involves significant health and environmental risks, it is nevertheless capable of delivering cheap electricity. That is simply not true.

1.20 The fact is that nuclear energy, in the words of AK Saxena, Senior Director, Electricity and Fuel Division, The Energy and Resources Institute, New Delhi, is 'frightfully expensive', and it has only ever been delivered through very considerable government financial support.

1.21 Despite being an industry with 60-plus years of development, the capital cost of nuclear energy per kilowatt hour has increased, and there is no apparent 'learning curve' with respect to cost reductions, which is in stark contrast to the rapidly declining cost of renewable energy.

1.22 Projects under construction in the United Kingdom and France, both of which have well-established nuclear industries, bear this out. The following exchange with Dr Jim Green, President and National Nuclear Campaigner, Friends of the Earth Australia, is instructive on this point:

> **Mr JOSH WILSON:** I think the most important thing for this committee is setting public policy based not on corporate claims or paper fantasies but on reality. We're often pointed to France, France being a country that has a very high proportion of electricity from nuclear power. EDF is delivering a reactor in France, and the Hinkley Point C reactor in the UK. Just in the last week, there have been further time blowouts and cost blowouts in relation to both of those projects. In the case of the UK project, Hinkley Point C, they've added a further nearly A$3 billion, or two

6 Dr Matthew Stocks, Research Fellow, the Australian National University, *Proof Committee Hansard,* Canberra, 18 October 2019, p. 1.

7 Department of Industry, Innovation and Science, Supplementary Submission 211.2, Answer to Questions on Notice, p. [4].

> billion pounds, and that large reactor—which all economic theory and practice would tell you is going to deliver power at a cheaper cost than a smaller version—is based on a government commitment to a strike price of A$165 per megawatt hour for 35 years, indexed to CPI.
>
> **Dr Green:** That's the guaranteed return to the developers. I don't think that's necessarily the electricity production costs. But they've been guarantee that payment—92 British pounds per megawatt hour.
>
> **Mr JOSH WILSON:** Which is the twice the going price of electricity.
>
> **Dr Green:** Yes, exactly. The subsidies over the lifetime of Hinkley Point, one nuclear power plant, albeit a very large one, with 3.2 gigawatts, are estimated to be A$55 billion—that's the lowest estimate I've seen—to A$91 billion. That's for one nuclear power plant. It's obscene. The UK government are not entirely stupid, but they've walked into this deal and it's appalling. The subsidies are extraordinary and they will go on for decades. They will hurt consumers and they will hurt poor people the worst, and this is exactly what we've avoided, thanks to the infinite wisdom of John Howard.[8]

1.23 In any case, the most reputable analysis of cost in the Australian context is the *Gen Cost 2018* Report by AEMO and the CSIRO which shows that nuclear energy, whether large-scale or small-scale, is exorbitant.

1.24 In the course of the Sydney hearing on 29 August 2019 it was pointed out that the transition under way in our energy generation system, transmission grid, and market would need new generation sources that were quick to be delivered, flexible in terms of variable power contribution, cost competitive on a total system cost basis, and with low capital costs considering the pace of change and disruption that is occurring. Nuclear power does not meet any of these requirements.

1.25 At that Sydney hearing the Chair of the AEMO, Dr Alex Wonhas, said:

> What we find today at current technology cost is that unfirmed renewables in the form of wind and solar are effectively the cheapest form of energy production. If we look at firmed renewables, for example wind and solar firmed with pumped hydro energy storage, that cost, at current cost, is roughly comparable to new build gas or new build coal-fired generation.

8 Dr Jim Green, President and National Nuclear Campaigner, Friends of the Earth Australia, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 9.

> Given the learning rate effect that we have just discussed, our expectation is that renewables will further decrease in their cost, and therefore firmed renewables will well and truly become the lowest cost of generation for the NEM.[9]

1.26 There is no genuinely commercial nuclear power industry to speak of anywhere in the world. In recent years the most significant companies in the nuclear power industry, Westinghouse (USA) and AREVA (France), have gone bankrupt. Past and current nuclear projects are dependent upon government support, usually involving both direct funding and commitments to uncompetitive long-range power purchase agreements. Nuclear power plants cannot obtain private insurance; their disasters are underwritten by government.

1.27 At the 29 August Sydney hearing Dr Ziggy Switkowski said there is 'no coherent business case to finance an Australian nuclear industry',[10] and he added 'I have emphasised that one of the things that have changed over the last decade or so is that nuclear power has got more expensive rather than less expensive'.[11]

1.28 Professor Andrew Blakers, a professor of engineering at the ANU, observed:

> You have to ask: why is it that nuclear is completely stagnant and renewables are now two-thirds of global net new generation capacity, and 100 per cent in Australia? The answer is very simple: renewables, like wind and solar, are much cheaper than any alternative, including nuclear. That's why almost all new generation capacity in Australia, and most of it around the world, is wind and solar. This is not likely to change any time soon because the cost of wind and solar are now low. They continue to fall year by year and they will continue to fall throughout the 2020s.
>
> By the time we get to 2030, which is the earliest possible time that you could have a nuclear reactor ready to go into service, if everything went right, wind and solar will be up around 80, 90, 100 per cent of all electricity generation. There will just be no room for nuclear on a gross generation side of things, let alone the need for flexible operation in the face of the high level of renewables, which Matt [Dr Matthew Stocks, ANU] just alluded to. In short,

9 Dr Alex Wonhas, Chief System Design and Engineering Officer, Australian Energy Market Operator, *Committee Hansard*, Sydney, 29 August 2019, p. 23.

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

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

> nuclear missed the boat because it is too expensive. It doesn't really matter if we legalise nuclear, or whatever, it just can't catch wind and solar; they're so far ahead now.[12]

1.29 Professor Ian Lowe, Emeritus Professor in the School of Environment and Science at Griffith University, said:

> The basic point I want to make is that nuclear power doesn't make either economic or political sense in 21st century Australia. Even groups who are very friendly to nuclear power, like the Switkowski committee, the Uranium mining, processing and nuclear energy report in 2007 and the South Australian Nuclear Fuel Cycle Royal Commission, have concluded that there is no commercial case for nuclear power in Australia.[13]

Energy Needs

1.30 Australia needs investment in new sources of reliable and affordable power generation, supported by a 21st Century transmission system, while ensuring that carbon emissions from the electricity sector are reduced as quickly as possible.

1.31 This involves managing a transition that is already occurring at a time of significant technological change and market disruption. As the Australian Energy Market Commission said in evidence to the Committee:

> Looking forward, in terms of the work program and the reform agenda, the commission is prioritising reforms in five key areas so customers can access safe, secure, reliable energy at the lowest possible cost as we transition. The reforms are based on five key trends we are seeing in the market.
>
> First, there is a shift from large, geographically concentrated generation to small, geographically dispersed generation. This requires us to rethink how it is that we plan and develop the grid and how it is that we better coordinate generation and transmission investment which will lead to getting reliable supply for consumers.
>
> Secondly, power system services that were previously provided for free as a by-product of power generation are now not necessarily provided by the new generation entering the mix. This requires us to find ways of procuring enough of these technical services to keep the power system secure.

12 Professor Andrew Blakers, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 2.

13 Professor Ian Lowe, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 55.

> The third trend is that customers are increasingly adopting small-scale solar and energy storage technologies. This requires us to integrate these distributed energy resources and to rethink how network infrastructure is used so customers and the grid can get the most out of these technologies.
>
> The fourth is that the power system and the market are increasingly underpinned by digital technologies that make it easier to choose and control how, when and where policy is delivered and used. We are increasingly focusing on involving market frameworks so customers can signal their needs in real time and be rewarded for doing so.
>
> Lastly, more variable demand from customers and more variable supply from generators makes forecasting and balancing supply and demand a challenge. The link between financial incentives facing market participants and the physical needs of the system is important to maintaining this balance. We're looking at ways to restore and reinforce that link.[14]

1.32 Some members of the community and some members of the Committee seem to take it as an article of faith that renewable energy and storage technology has already reached its limit to contribute to our future energy needs. Those who questioned whether Australia could ever reach 20 per cent renewable energy by 2020 have blithely ignored the early achievement of that target, and, in the course of the 2019 election campaign, turned up their scorn in describing Labor's target of 50 per cent by 2030 as "economy wrecking". Yet the Department of Energy's latest update (Australia's emissions projections 2019) includes a projection that by 2030 the share of renewable energy in the National Electricity Market will be 51 per cent!

1.33 The majority Committee report shows a lack of balance and attention to the evidence when it supports the proposition that nuclear energy is necessary to decarbonise the electricity sector, which in turn assumes that firmed renewables are incapable of achieving that outcome. In the relevant section of Chapter 1 the report quotes extensively from proponents of nuclear power. It fails to refer to evidence from energy sector experts like the scientists from the Australian National University who gave detailed explanations of how this could occur.

14 Ms Suzanne Falvi, Executive General Manager, Security and Reliability, Australian Energy Market Commission, *Committee Hansard*, Sydney, 29 August 2019, p. 19.

1.34 For example, in evidence to the Committee Professor Blakers referred to work that he and other ANU colleagues had undertaken in 2017 on precisely this point:

> The cost of balancing 100 per cent renewables has three components: storage, transmission and occasional spillage—when all the storage is full and you've got lots of wind and sun. The three components are roughly equal. Transmission is required so you can shift energy from a place where the wind and sun are good to where the wind and sun are bad, on a particular day. Storage is to time shift so that if it's a very sunny, windy day, like yesterday, we can store for a day in the future when it's not sunny and windy. Spillage is required because if you build enough storage to absorb all the solar and wind then you'll have built storage that you use once every five years and you're paying for things you don't need. So it's a balancing. Basically, the cost of wind and solar now is about $50 per megawatt hour. If you want to firm up 100 per cent wind and solar you'll add $25 on top, so you'll get to $75 a megawatt hour. That $75 a megawatt hour is below the spot price in every state in all periods in the last financial year; in other words, a fully backed up, firmed solar-wind base with some existing hydro is cheaper to run than the entire current electricity system, and this reflects the fact that wind and solar just keep falling in price.[15]

Waste

1.35 Nuclear waste is dangerous and remains dangerous for an extraordinary length of time. It is not just costly but technically difficult to store nuclear waste. Indeed, despite the fact that the nuclear power industry has existed for 70 years, there is no permanent high-level nuclear waste repository in operation anywhere in the world (though Finland appears to be close to delivering the first).

1.36 The mining of uranium in Australia has resulted in numerous unresolved contamination and remediation issues. The following exchange involving Associate Professor Gavin Mudd, a mining and environmental expert with 25 years' experience, is instructive:

> **Mr JOSH WILSON:** I don't want to interrupt you, but to bring that to a conclusion, this is in the details of your submission. The Ranger mine: $800 million plus and the risk that the site can't fund remaining rehabilitation from expected production revenue. Mary

15 Professor Andrew Blakers, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 5.

> Kathleen: further rehabilitation works. Nabarlek: groundwater contamination. Rum Jungle: extreme water pollution issues. Olympic Dam: tailings seepage. In all of these instances, despite the best Australian know-how and the learnings from these mine operations, you have all kinds of ongoing, unresolved problems with enormous associated costs.
>
> **Prof. Mudd:** Absolutely. At Rum Jungle I think we've already spent another $10 million or $15 million over the last fifteen years just on studies to work out what we do next. At Olympic Dam at the moment, I argued in the last assessment process for the previous expansion in about 2009-10 that once they've finished mining the tailings should be excavated and put into the pit, like Ranger is doing. Unfortunately BHP argued in response that it's impractical to put tailings in a pit during operations, which of course is not what I said. Ranger has finished mining the pit and now they're putting the tailings back in. That is an expensive process, but the standards for Ranger have been set right from the start. The promises have always been made that those standards can be met. Now we're finding that they are very expensive. Of course they are. That's always been the concern with Ranger—that the bond that's held aside is not sufficient to cover the sort of works required to achieve those sorts of standards. I could go into much greater detail, having been involved there for over twenty years. The standards that Ranger sets are good standards: putting the tailings back in the pit, covering all the waste rock and so on back into the pit. The basic standards and ideas that Ranger is asked to meet are top notch. I don't know of any other mine in the world that is required to demonstrate a case that they're [*sic*] tailings are not going to be causing groundwater contamination for at least 10,000 years.[16]

1.37 While Australia has operated the Lucas Heights OPAL reactor for decades we still do not have a permanent arrangement in place for storing even low-level and medium-level waste. Presently work is being done to establish a national radioactive waste facility that will permanently dispose of low-level waste and temporarily store intermediate-level waste. Representatives of the National Radioactive Waste Management Facility Taskforce advised the Committee that this process has been in train for 40 years without resolution. It has cost $55 million in spent or budgeted funds to date, and to construct the facility it is estimated to cost a further $325 million. The Committee was advised that a budget and timetable for

16 Associate Professor Gavid Mudd, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 17.

the delivery of the permanent repository of intermediate-level waste does not exist because at this stage government has not decided on a responsible entity for that task.

Environment, Health, Non-Proliferation

1.38 Nuclear energy involves unique risks to human health and the environment, and it is strongly associated with and related to the acquisition of nuclear weapons. Any decision to pursue nuclear energy technology would have regional geo-political consequences.

1.39 Even a small and exceptionally well-run nuclear medicine reactor like the OPAL facility operated by ANSTO continues to feature accidents and safety issues. Indeed in 2017 there was a Level 3 incident (on the International Nuclear and Radiological Event Scale) at ANSTO involving the exposure of a worker resulting in radiation symptoms which was the most serious incident reported in the world that year.

1.40 In the case of the OPAL facility the requisite emergency management plan requires the Health Department of New South Wales to maintain an adequate supply of iodine treatments. Earlier this year, France expanded the radius of its iodine treatment preparations by 2.2 million people in order to cover a radius of 20 kilometres around each nuclear plant rather than 10 kilometres which had been the treatment zone set in 2016.[17]

1.41 As Fukushima demonstrated, there is no such thing as a safe nuclear plant. That disaster has so far cost $200 billion, there are still 40,000 people displaced, and contaminated water continues to be discharged into the environment. The operator, TEPCO, has said the clean-up/remediation may take 30-40 years, and the Japan Centre for Economic Research has estimated the final cost at between $470-660 billion.[18]

1.42 There is a well-established link between nuclear power generation and the development of nuclear weapons capability. That was acknowledged in the evidence provided to the inquiry by representatives from the Australian Safeguards and Non-Proliferation Office (ASNO) and the Arms Control and Counter-Proliferation Branch, International Security Division, Department of Foreign Affairs and Trade (DFAT).

1.43 For example, Mr Jeff Robinson of DFAT said:

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17 'France to give millions of residents iodine pills while EDF spots problems in six nuclear reactors', *The Local*, 18 September 2019, https://www.thelocal.fr/20190918/france-to-give-millions-of-people-iodine-pills-in-case-of-nuclear-accident, accessed 12 December 2019.

18 'Clearing the Radioactive Rubble Heap that was Fukushima Daiichi, 7 Years On', *Scientific American*, 9 March 2018, https://www.scientificamerican.com/article/clearing-the-radioactive-rubble-heap-that-was-fukushima-daiichi-7-years-on/, accessed 12 December 2019.

> …nuclear is an area very much of dual-use technology. There are nuclear energy benefits but also concerns about nuclear weapons. The nuclear non-proliferation treaty very much acknowledges that with its three main pillars. One is disarmament, which relates to the countries that already had nuclear weapons when the NPT came into force. But also, very strongly, the second and third pillars are nuclear non-proliferation.[19]

1.44 He further observed:

> DFAT doesn't have a particular view on the appropriateness of each country, including Australia, as to its sources of energy. Our concerns relate to the potential for those things to go down a path that may lead to broader international security concerns.[20]

1.45 Australia recognises the dual-use aspect of nuclear technology with its attendant proliferation risks in its uranium supply agreements. There are also broader geo-political and security concerns. To claim otherwise is blind, naïve, and dangerous.

Social License

1.46 The Committee received more than 5000 emails from Australians who regard the consideration of nuclear power as a pointless and dangerous distraction.

1.47 Australians are rightly concerned and sceptical about nuclear power. Events like Fukushima have justified that concern.

1.48 As Dave Sweeney, Policy Analyst and Nuclear Campaigner, Australian Conservation Foundation, said in evidence to the Committee:

> I suppose from all of that the take-home message for the committee, from my perspective, is that there are strong, continuing and unresolved issues and concerns. Many of these have been identified in detail in the joint environment group submission to the committee, and many have been touched upon and distilled into the joint civil society statement on domestic nuclear power, which was written by a collection of environment, public health and Indigenous trade and faith based organisations representing many millions of Australians across a broad

19 Mr Jeff Robinson, Assistant Secretary, Arms Control and Counter-Proliferation Branch, International Security Division, Department of Foreign Affairs and Trade, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 42.

20 Mr Jeff Robinson, Assistant Secretary, Arms Control and Counter-Proliferation Branch, International Security Division, Department of Foreign Affairs and Trade, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 42.

> demographic and geographic lens. Some of those issues continue to be unresolved issues and concerns. Of course, these are issues around safety, security, cost as well as the time of nuclear as a response mechanism to the urgent need for energy and climate action and policy. And there are the really profound and unresolved issues of radioactive waste, and I think it's really salutary for the committee to take a look at the Australian domestic nuclear waste situation and how difficult, how divisive and how slow that has been to advance a pathway forward for the management of long-lived low- and intermediate-level waste and to translate that into potential management for the highly problematic high-level radioactive waste that would come from any reactors.
>
> I say to the committee that, if the choice was between burning coal and using uranium, our nation would be facing a difficult series of discussions, but it's clearly not, and there really is no social licence for the nuclear sector. As Dr Green just said quite compellingly, existing reactors are costly and underperforming; future reactors are non-existent—one's too dear, one's not there and neither are the basis for a creditable national energy policy. Surely that is what we need to identify and advance. The Australian Conservation Foundation is, along with many, many civil society groups, clearly of the view that nuclear is a dangerous distraction to the real energy choices, challenges and opportunities that we face as a nation. We strongly support the current legal prohibition and strongly support moves to a renewable energy future fund. We also look at the guidance provided by Prime Minister Morrison to this issue. He said that what would be needed would be a power source that would not require massive public subsidies and would deliver cheaper electricity. On those two lenses alone, nuclear simply fails to deliver.[21]

1.49 The Minerals Council of Australia recently circulated the results of a survey that purported to show support for nuclear energy was increasing. In fact the survey showed that 60 per cent of Australians did not support a change to current laws and restrictions on nuclear power. As with all surveys of relatively small sample size one must consider the context in which a response was sought. First, it is notable that the 'qualitative' sessions were assembled by first excluding people identified as having 'extreme negative attitudes towards nuclear as an energy source' yet

21 Mr Dave Sweeney, Policy Analyst and Nuclear Campaigner, Australian Conservation Foundation, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 3.

there's no indication that people with strong positive views were similarly excluded.

1.50 Second, the material used as the basis of the quantitative survey at various points is wrong, inaccurate, and misleading. For example:

- The Executive Summary says information about Small Modular Reactors (SMRs) is an important part of the argument and goes on to say that 'The news that they are smaller, safer and cheaper is important'. But this is not 'news' because SMRs don't exist and indeed these are merely optimistic vendor claims that are inconsistent with both the evidence and the industry's record.
- The Executive Summary identifies 'case studies' that were considered to be motivating in terms of generating a positive response, for example, 'We already use nuclear products made from uranium for medicine, so uranium could also be used for power'. This is described as a key argument, when it is nonsensical: the OPAL reactor at Lucas Heights is not a power reactor and does not produce high-level waste.
- The Executive Summary identifies the top four facts that drive positive opinion, but two of these claims are not facts: (1) the claim that 'Nuclear is the only zero-emissions energy source capable of meeting Australia's energy demand' is not a matter of fact, but rather a self-serving assertion; and (2) the claim that France generates 75 per cent of its electricity from nuclear is inaccurate (it is 72 per cent) and misleading (France has committed to reducing the share of nuclear energy to 50 per cent by 2035). If you want a clearer picture of the nuclear industry in France consider the October 2019 audit report released by the French Finance Minister on the Flamanville reactor currently under construction by EdF. This project, which began in 2007 and was expected to commence operation in 2013, has been massively delayed, will not begin loading fuel until 2022 at the earliest, and is already four times over budget.

1.51 The Minerals Council survey claims to have achieved majority support for lifting the current ban on nuclear energy in Australia once those surveyed were (a) able to consider some 'balanced messaging and facts about nuclear', which the information presented was clearly imbalanced and inaccurate; and (b) were told that a majority of Australians supported lifting the ban (which at that point, even within the context of the survey itself was untrue).

Small Modular Reactors

1.52 Claims were made to the Committee by nuclear power vendors in particular that small modular reactors (SMRs) would in future prove to be dramatically cheaper and safer than existing nuclear technology.

1.53 By contrast, economists like Professor John Quiggin, whose submission included detailed reference to the substantial delays and cost blowouts in current nuclear projects, made the point that the optimistic claims for SMRs are questionable in the absence of evidence:

> I think there are reasons for being sceptical that small modular reactors will be the panacea that has been suggested by some. The first is, of course, that they don't yet exist. As somebody said, the paper based designs are always the most efficient ones. Everything works on paper.[22]

1.54 Similarly, Simon Holmes à Court, Director of the Smart Energy Council and an adviser at the Energy Transition Hub, observed:

> This brings us to small modular reactors. Firstly, as the committee has heard from many, they don't exist—or, rather, they exist only on paper, which makes them very low down the technology-readiness scale. I explained that in more detail in my submission. Heroic efforts are now in play to realise these plants, but even the most advanced are expected to be completed around 2027. It will be a number of years before these pilot plants are commercialised, and well into the 2030s before they're progressed to a point where they are bankable. It's quite likely that the first plant in Australia would not be generating a megawatt hour of power until the 2040s. It's fanciful to believe that we now know what they will cost, especially when the nuclear sector has an appalling track record on time lines and budgets. Dr Jon Koomey, a renowned US energy academic, wrote recently that he has adopted a 'show me' stance with the nuclear sector: 'Don't tell me what you're going to do and at what price show me; I'll believe it when I see.'[23]

1.55 And Jim Green, President and National Nuclear Campaigner, Friends of the Earth Australia, gave detailed evidence in relation to the costs of SMRs:

> Thanks for the invitation to speak. Mr O'Brien, I would respectfully ask you to revisit and reconsider your express view that small modular reactors and other new technologies are

22 Professor John Quiggin, *Proof Committee Hansard*, Brisbane, 30 September 2019, pp. 7-8.

23 Mr Simon Holmes a Court, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 54.

leading to 'cleaner, safer and more efficient energy production'. That argument would be compelling if there were fleets or networks of these SMRs operating anywhere in the world and operating successfully, but as you know, and as Dr Switkowski mentioned in his testimony, there are no such networks anywhere in the world, so we have no idea if or how a network of SMRs might operate in Australia. Further, there isn't even one single SMR operating anywhere in the world. There isn't even one prototype SMR operating anywhere in the world. So operating SMRs, of which there are precisely none, clearly provide…

…I was reading the Minerals Council's submission yesterday. They assert that the CSIRO and Energy Market Operator GenCost 2018 study was wrong with its SMR cost estimates. That study gave a figure of a construction cost of $16,000 per kilowatt, and I agree that's wrong. In Argentina the cost is $32,400 per kilowatt, that's twice the figure from CSIRO and the Energy Market Operator. In Russia it's $14,800 per kilowatt for their floating nuclear power plant. In China the figures are very rubbery, but we have a figure from the World Nuclear Association of just under $9,000 per kilowatt. So I would say that the CSIRO and Energy Market Operator costs are reasonable, but there's a wide degree of variance and a high degree of uncertainty. Another way we could arrive at the figure would be to look at the cost of large reactors and add a premium for a first-of-a-kind plant and a premium for smaller reactors, because of the inevitable diseconomies of scale. The only large reactor under construction in the US is in Georgia—it's called Plant Vogtle—and the cost of that is over A$16,000 dollars per kilowatt. So once again I would suggest that the CSIRO and Energy Market Operator figures are reasonable and quite possibly an underestimate, whereas the Minerals Council complains that NuScale's estimates should be taken at face value.[24]

24 Dr Jim Green, President and National Nuclear Campaigner, Friends of the Earth Australia, *Proof Committee Hansard*, Melbourne, 1 October 2019, pp. 1-2.

1.56 There is no basis for believing that SMRs will defy the history of the nuclear industry and the logic of economies of scale by being any cheaper than large-scale nuclear plants, which are extraordinarily expensive.

Mr Josh Wilson MP
Deputy Chair

Mr Josh Burns MP
Member

Mrs Fiona Phillips MP
Supplementary Member

Dissenting Report from Zali Steggall MP

Foreword

1.1 Firstly, I would like to commend the Chair of this inquiry, Mr Ted O'Brien MP, for a thoughtful and consultative approach to a very difficult topic. The Chair has managed to conduct a thorough inquiry whilst managing a tight timeframe of six months.

1.2 In this dissenting report, I outline my concerns in respect to the majority's main report (Report) and recommendations. I also discuss further prerequisites that emerged during the inquiry as well as recommendations which should be taken into account for any future government considering nuclear.

1.3 As for the Report, I comment on aspects of the Report in line with the terms of reference including:

a) waste management, transport and storage;

b) health and safety;

d) energy affordability and reliability;

f) community engagement;

i) national consensus; and

j) other relevant matters.

1.4 This dissenting report discusses j) other relevant matters and makes further recommendation not discussed in the Report such as:

- a long term emissions reduction target; and
- national energy policy.

1.5 I support recommendations 1 and 2 in the Report, whilst noting that it is my view that an independent community engagement program should educate and inform Australians on all energy technologies including nuclear. I do not support recommendation 3, which seeks conditional removal of the moratorium on some nuclear technologies.

1.6 The Committee adopting recommendation 3 is pre-emptive. Obtaining a social license is an essential prerequisite to any consideration of raising the moratorium on nuclear energy.

Introduction

1.7 The moratorium on nuclear energy has been maintained by bipartisan support for the last several decades. This is significant; lifting the moratorium should not be done without bipartisan support.

1.8 Nuclear energy comes with a certain amount of risk. The accidents at Chernobyl and Fukushima, the environmental impacts of uranium mining and the risk of proliferation of nuclear weapons were all discussed during the inquiry.

1.9 Due to these inherent risks, any inquiry into the moratorium on nuclear energy should include balanced scrutiny of the evidence and facts presented. Substantial evidence both for and against lifting the moratorium on nuclear energy was received, yet the report overwhelmingly refers to evidence in support. In so doing, the Report overstates benefits and understates risks of the technology.

A) Waste management, transport and storage

1.10 During the inquiry waste management emerged as an important consideration to lifting the moratorium on nuclear energy. The Report at paragraph 1.152 identifies the importance of well managed waste.

1.11 Nevertheless, the Report understates the difficulties associated with nuclear waste management in Australia and the lack of consensus on long term waste disposal. At paragraph 1.160 the Report states:

> 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.

1.12 The difficulty finding long term storage locations for nuclear waste is common to all nuclear nations. Evidence was received from Mr. Simon Holmes à Court who talked on his recent overseas experiences visiting decommissioned nuclear facilities where waste is stored:

> Recently, just two weeks ago, I was in Massachusetts and was driving in the area of the Yankee Rowe power station, which is an interesting plant in that it was one of the first commercial plants in the US—so it was not owned by the Department of Energy—and one of the first to be decommissioned. I was very interested in it because it has been decommissioned back to bare grass. They've done a really good job in taking it back, except for one issue, which is the waste. The waste sits in canisters on site. There are 16 canisters—big, stainless steel. They are encased in concrete and then steel and then concrete on the outside. They are 100 tons each. They have an armed presence looking after them…I did a fair bit of research after that and found out that those casks have been there since the plant stopped generating in 1992. So, within a few years, that site will have been a waste repository for longer than it was ever a nuclear power plant. Those canisters sit there because the Department of Energy hasn't been able to commission a central federal repository.[1]

1.13 Mr Holmes à Court continued:

> There are 200 different suits against the federal government over that repository. So, in the meantime, this waste sits on the edge of this small community in Massachusetts. There is a 24-hour armed presence. The day I went, there were 12 cars in the car park, and every couple of years the owner sues the federal government for the cost of maintaining that—$10 million a year to maintain these 16 casks. And that will be the case at every facility in the US until they have a federal repository—something that they have been trying to get for about 60 years.[2]

1.14 The Committee heard from Mr. Richard Weller, Convenor of Climate Future who reinforced this:

> Cost assessments of nuclear power generally don't include the cost of storing waste. This fact alone should disqualify nuclear power. There is no storage facility available, and one is not likely to be,

1 Mr Simon Holmes à Court, *Proof Committee Hansard*, Canberra, 18 October 2019.

2 Mr Simon Holmes à Court, *Proof Committee Hansard*, Canberra, 18 October 2019.

> either. We have never designed a facility with a useful life of 100,000 years. There is also no stable method for the storage of radioactive materials for such a long time nor any method for cleaning up an old power station site for reuse for agriculture or accommodation.[3]

1.15 Dr Ziggy Switkowski AO detailed the difficulty:

> No country has yet commissioned and completed a spent fuel or high-level nuclear waste facility. Australia has even struggled to get traction to build a small, low-level facility in Central Australia. The costs of spent fuel storage in reactor decommissioning may be high and may be a potential burden on future generations extending into the hundreds of years.[4]

1.16 It is essential that we transparently and accurately convey the obstacles and issues associated with contentious technologies.

1.17 We have not reached consensus in respect to low to medium waste let alone heavy waste that would result from any increase in nuclear technologies.

B) Health and safety

1.18 Whilst some evidence purported to characterise nuclear energy as 'clean, cheap and safe', substantial evidence was received to the contrary, particularly in respect to safety. Due to its hazardous nature, understanding of health and safety must be a prerequisite for consideration of lifting the moratorium on nuclear energy.

1.19 On the evidence, the Report significantly understates potential health impacts and safety risks. The Report suggests at paragraph 1.163 that:

> The evidence heard by the Committee points to nuclear energy being the safest form of energy in the world based on comparative mortality rates of different energy sources.

1.20 Table 1.4 purports to support this. I note that the source of this table could not be verified and as such cannot be considered credible evidence.

1.21 Inclusion of this evidence understates the very real danger of nuclear energy as well as misleads on the down-stream health effects that are

3 Mr Richard Weller, Convenor, Climate Future, *Proof Committee Hansard*, Sydney, 9 October 2019.

4 Dr Ziggy Switkowski, *Committee Hansard*, Sydney, 20 August 2019.

caused by radiation and nuclear incidents. In particular incidents like Fukushima and Chernobyl.

1.22 The Electrical Trades Union emphasized this, stating:

> All human made systems fail. When nuclear power fails it does so on a massive scale. The human, environmental and economic costs of nuclear accidents like Chernobyl and Fukushima have been massive and continue.[5]

1.23 The Committee heard from Dr Ingrid Johnston, Senior Policy Officer at the Public Health Association who detailed these ongoing effects:

> Unfortunately, previous experience with the five major nuclear accidents so far have provided us with an insight into the far-reaching health effects. Along with the immediate and longer-term physical health issues, psychological and social effects are found. Severe healthcare problems are created by evacuation and long-term displacement, especially for the most vulnerable people such as the elderly and those in hospital. Public health responses required after the Fukushima disaster included the evacuation of 150,000 people; stable iodine prophylaxis to reduce the uptake of radioactive iodine by the thyroid; morgue management for radioactive dead bodies; protection of food and drinking water supply, including monitoring intake of contaminated food and water; monitoring of radioactivity and estimations of exposure; a massive decontamination exercise through disposal of contaminated soil and wastes; and public communication around risks.[6]

1.24 As for the safety claims of nuclear, the Report repeatedly includes reference to the improved safety benefits of new design reactors. Paragraph 1.230 states:

> The Committee received evidence that newer generations of nuclear reactors will incorporate better safety features.

1.25 The Report also cites Emeritus Professor Erich Weighold at paragraph 1.232, who submitted that advances in technology make modern reactors 'extremely safe'.

1.26 Contrary to this, the Committee also heard evidence by M.V Ramana, Professor and Simons Chair in Disarmament, Global and Human Security at the University of British Columbia, which questioned the safety benefits of new technologies. Ramana stated:

5 Electrical Trades Union, *Submission 164*.

6 Dr Ingrid Johnston, Senior Policy Officer, Public Health Association of Australia, *Proof Committee Hansard*, Canberra, 18 October 2019.

> …when they talk about an inherently safe design or how there are no accident possibilities, they're talking about a single reactor unit in a certain configuration. When they actually try to deploy, often SMR proponents find that they have to do two things. One is that they may have to deploy multiple units in one site. The NuScale design, for example, is being sold in 12-packs, so there will be 12 reactors at one particular site. As we saw in Fukushima, this is a source of potential safety hazards because, if there is a problem with one of these units, it will affect how we can deal with other surrounding units. In Fukushima, for example, because of high radiation levels due to a meltdown in one reactor unit, the personnel could not access nearby units.[7]

1.27 The evidence continued:

> The second issue is that, in order to cut costs, many of these reactor designs call for reducing other safety precautions which are outside of the reactor—for example, reducing what's called the emergency planning zone, the area where the local government units are trained to be able to evacuate people or take other kinds of action in the event of an accident. SMR vendors would like the EPZ to be shrunk to within the plant boundary so that no local governments are involved, because it costs money for them to plan for this, do emergency drills and so on and so forth, and they want to save a little bit of money that way.[8]

1.28 Despite taking issue with the Report failing to properly reflect the disparity in evidence received, I support the recommendation that the Australian Government commission a technology assessment that would clarify the extent of health and safety impacts with inclusion that the assessment be independent and environmental and carbon emissions be addressed.

D) Energy affordability, reliability and emissions reduction

1.29 I agree with paragraph 1.9 in the Report which states that:

> Australia should be goal-oriented in seeking to deliver affordable and reliable energy while fulfilling its international emissions reduction obligations.

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7 MV Ramana, *Proof Committee Hansard*, 24 October 2019.

8 MV Ramana, *Proof Committee Hansard*, 24 October 2019.

1.30 However, there have been several misrepresentations throughout the Report that overstate nuclear energy's ability to meet these goals, particularly in comparison to other technologies.

i) Affordability and economics

1.31 The Report discusses the importance of energy affordability. It highlights power prices faced by consumers in recent years.

1.32 Although the Report acknowledges that the economics of competing technologies is contested, I have concerns with some of the portrayal of nuclear specifically, in its ability to assist with energy affordability.

1.33 At paragraph 1.27 of the Report Mr Tristan Prasser stated:

> …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.

1.34 This was directly contradicted by evidence submitted by The Australia Institute who cited the 2018 World Nuclear Industry Status Report which states:

> Nuclear new-build is simply not competitive under ordinary market economy rules anywhere.[9]

1.35 The Report also limits this comparison of costs to nuclear only, such as in table 1.3. Whilst I acknowledge the difficulty of using traditional levelised cost of electricity analysis to compare technologies, there must be some representation of the method used to compare technologies in the Report as it currently is the most useful method to do this.

1.36 For example, a group of nine conservation organisations submitted a Lazard levelised cost of electricity analysis from November 2018 which stated a nuclear cost of A$166-280/MWh as compared to $A43-83/MWh for wind and A$55-68/MWh for solar.[10]

1.37 Analysis of competing technologies is essential and the Report should have reflected this. Dr John Koomey echoed this submitting:

> The context of competition is also relevant. Photovoltaic and wind generation (along with associated battery storage) have fallen dramatically in recent years…In the decade or two it will take to bring small commercial reactors to market, solar, wind, and storage technologies will undergo additional doublings of

9 The Australia Institute, *Submission 167*.

10 Joint submission by nine national environment groups and state conservation councils, *Submission 219*.

> cumulative production, dropping their already attractive costs significantly.[11]

1.38 The Committee heard from Mr. Tim Buckley from the Institute for Energy Economics and Financial Analysis (IEEFA) who further elaborated that due to the attractive renewables costs, international investors were not seeking to finance new nuclear developments. He stated:

> The example I wanted to quote was a speech that was given last Friday by the largest and most successful utility in America and, potentially, the world. It's the CEO of NextEra Energy. The CEO, James Robo, gave a presentation last Friday….Why do I focus on NextEra? It is the most successful and largest utility in America... It's also one of the biggest nuclear players in the world. Mr James Robo said: We see renewables plus battery storage without incentives being cheaper than natural gas and cheaper than existing coal and existing nuclear. And that is game changing.[12]

1.39 The Report does not accurately reflect the evidence received on affordability and economics. It is unlikely that new nuclear will be able to compete with renewables without any kind of timeframe it could be operational in Australia, especially given the rate of price deflation of renewables. However, I support the technology assessment as set out in recommendation 2 as it may clarify this further.

ii) Reliability

1.40 The Report discusses the importance of firming for the increasing amounts of renewables coming on to the grid. At paragraph 1.42 it states:

> …that because it is impossible to accurately predict when the sun will shine and the wind will blow, these variable renewable sources need to be partnered with more reliable shortfalls in production.

1.41 At paragraph 1.46, the Report states that nuclear could be a 'partner' for renewables. Firming the renewables and allowing for ramp-up and ramp down as needed.

1.42 Contrary to the conclusion, the Committee heard evidence from the Australian Energy Council (AEC) suggesting that existing nuclear would be ill-suited to firm renewables due to the lack of these essential characteristics i.e flexibility. The AEC submitted:

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11 Dr John Koomey, *Submission 295*.

12 Mr Timothy Buckley, Director, Energy Finance Studies, Australasia, Institute of Energy Economics and Financial Analysis, *Proof Committee Hansard*, Sydney, 9 October 2019.

> The downside to nuclear power is that the conventional designs used overseas are inflexible and difficult to turn on and off. Indeed, during periods of excess supply, it may even be more costly to reduce the output of these nuclear plants than to spill renewable generation.[13]

1.43 Several nuclear proponents referenced throughout the Report suggest that future technologies like Small Modular Reactors (SMR) may be able to rectify these issues such as costs and inflexibility.

1.44 Evidence was received from Engineers Australia that suggested these technologies remain speculative and difficult to assess, stating:

> There is no clarity on the likely role, function and scale that SMR technology may have in a future energy market. This encourages speculation about SMRs as: a like-for-like substitute for the expected withdrawal of coal fired generation; or conversely, unnecessary because rapid developments in renewable energy technologies will meet any needs. Neither is a strong basis for assessment of the likely need or contribution of nuclear energy or, for that matter, any technology.[14]

1.45 Further, the necessity of using nuclear to firm renewables is not settled. Dr Matthew Stocks, from the Australian National University (ANU), gave evidence that Australia has plentiful sources of firming capacity in the form of pumped hydro sites:

> In Australia, we found 3,000 sites with about 300 times the energy storage capacity of what we actually need. So there is absolutely no shortage of pumped hydro opportunities in Australia, or anywhere in the world.[15]

1.46 Simon Holmes à Court went further and questioned the necessity of baseload power required to firm renewables in total, stating:

> There is a widespread perception that as these 'baseload' generators are retired they must be replaced 'like for like' with generators sharing similar generation profile and that only nuclear energy is a drop-in replacement…A large body of academic work concludes that not only can modern power grids provide reliable power without 'baseload' generation, but in many markets (including Australia) the cheapest path forward is to use a

13 Australian Energy Council, *Submission 14*.

14 Engineers Australia, *Submission 170*.

15 Dr Matthew Stocks, Research Fellow, The Australian National University, *Proof Committee Hansard*, Canberra, 18 October 2019.

> portfolio of variable renewables with dispatchable energy sources.[16]

1.47 In summary, on the evidence, it is unlikely that firming in the form of nuclear will be needed. However, I support the technology assessment in recommendation 2 to analyse all claims.

iii) Emissions reduction outcomes

1.48 A dominant reason provided for support in lifting the moratorium on consideration of nuclear energy was that Australia needs to decarbonise its energy sector. This was even submitted by the Queensland Resources Council, who stated:

> Like the rest of the world, the challenge for Australia is to balance lowering emissions while maintaining our reliable and affordable energy supply. Just over half of Australia's net total emissions are from stationary energy—around 53 per cent—with Queensland's net total emissions at a similar level of 46 per cent. QRC recommends that any feasible opportunity to reduce a significant portion of Australia's emissions should be considered.[17]

1.49 Portrayal of nuclear's role in the Report as playing a major role in decarbonising efforts ignores the vast resources Australia has available to power renewable energy and emerging technology like hydrogen.

1.50 At paragraph 1.25, Mr Ian Hore-Lacy stated:

> That there is no real realistic decarbonisation prospect for Australia which does not involve nuclear.

1.51 This was contradicted by evidence submitted by Professor Andrew Blakers to the effect that renewables could deliver 100 per cent of Australia's energy decarbonisation needs. Blakers submitted:

> Energy balancing for a 50-100% renewable grid is straightforward using off-the-shelf techniques that are already widely used. These techniques comprise energy storage, demand management, and strong interconnection over large areas using high voltage transmission lines.[18]

1.52 Further, he stated that that current deployment rate of renewables is fast enough to reach 50 per cent renewable electricity by 2024 and 100 per cent by 2032.

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16 Mr Simon Holmes a Court, *Submission 258*.

17 Mr Ian Macfarlane, Chief Executive, Queensland Resources Council, *Proof Committee Hansard*, Brisbane, 30 September 2019.

18 Professor Andrew Blakers, *Submission 97*.

1.53 Dr Mark Diesendorf from the University of New South Wales also submitted a peer reviewed paper he co-authored titled: 'The feasibility of 100% renewable electricity systems: A response to critics', which stated:

> Electricity supply systems, operating on 100% renewable energy with the major proportion from variable renewables, are technically feasible, reliable and affordable for many countries and regions of the world.[19]

1.54 The Report's assertion that there is no realistic decarbonisation without nuclear is dubious and that it is needed to firm renewables. It is simply not reflective of the evidence.

1.55 Further discussion in relation to decarbonisation goals of the Australian economy is at Section J.1 below.

iv) Nuclear as a share of global energy generation

1.56 At paragraph 1.45, the Report stated:

> It is notable that nuclear energy represents approximately 11 per cent of the world's total energy mix, with countries that use nuclear energy using other energy sources including renewables.

1.57 The Report omits that in fact the share of nuclear energy as a portion of total energy capacity is shrinking due to rapid growth of renewable energy. Only serious intervention would reverse this trend. The International Energy Agency's 'Nuclear Energy in a Clean Energy System', report, which was cited throughout the inquiry, states that nuclear's:

> …share of global electricity supply has been declining in recent years. That has been driven by advanced economies, where nuclear fleets are ageing, additions of new capacity have dwindled to a trickle, and some plants built in the 1970s and 1980s have been retired.[20]

1.58 Professor Andrew Blakers explains the driving force behind this trend:

> You have to ask: why is it that nuclear is completely stagnant and renewables are now two-thirds of global net new generation capacity, and 100 per cent in Australia? The answer is very simple: renewables, like wind and solar, are much cheaper than any alternative, including nuclear.[21]

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19 Dr Mark Diessendorf, *Submission 86*, Attachment 1.

20 See https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system.

21 Professor Andrew Blakers, *Proof Committee Hansard*, Canberra, 18 October 2019.

1.59 To counter this, nuclear proponents throughout the inquiry point to the examples of China and India who do have some new nuclear facilities planned and in operation.

1.60 Whilst both are building moderate amounts of nuclear, they have much greater generation targets in renewables which further demonstrates the international decline of nuclear. India in particular has an impressive commitment. Mr Tim Buckley outlined the scale of India's ambition:

> Prime Minister Narendra Modi has a visionary ambition for India to install 523GWof renewable energy by 2030 as a way of dramatically reducing air pollution, reducing water scarcity risks, permanently reducing reliance on crippling fossil fuel imports, and hence improving energy security. This puts India on track to well exceed their Paris Agreement commitments, possibly achieving these commitments up to a decade ahead of schedule.[22]

1.61 In comparison, India has 21 nuclear reactors planned to be brought online by 2030. Equivalent to 15.7 GW.[23]

1.62 I support the recommendation by the Committee that seeks to clarify the various points of view on these matters. The committee has recommended that the Australian Nuclear Science and Technology Organisation (ANSTO) or another equivalent expert reviewer undertake a technology assessment and the Productivity Commission undertake an assessment of the viability of nuclear.

F) Community Engagement & Social License

1.63 It is clear that community engagement and social license is a prerequisite in establishing nuclear energy in Australia. RADM the Hon Kevin Scarce, AC, CSC Rtd. stated:

> The community consultation—getting and maintaining the social licence—is a critical issue. Everything that we saw overseas was, 'Don't underestimate how long that will take'. When you're talking about storing waste for a million years people have every right to be concerned and need to understand the technology.[24]

22 Institute of Energy Economics and Finance Studies, *Submission 103*.

23 See: http://world-nuclear-news.org/Articles/India-plans-expansion-of-nuclear-fleet-says-DEA-c

24 RADM the Hon Kevin Scarce, AC, CSC, Rtd, *Proof Committee Hansard*, Adelaide, 2 October 2019.

1.64 This would be especially necessary with SMRs. Whilst waste would be less than Generation 1 and 2 nuclear technologies, they would be deployed in greater numbers across numerous locations.[25]

1.65 At this time, a sufficient level of community engagement has not occurred. Essential and Roy Morgan Polls submitted to the inquiry have shown increasing levels of support for nuclear energy,[26] however, in those same polls when asked about situating a nuclear development close to their residence, both polls have a strong majority of respondents resistant to the idea. This community sentiment would need to significantly shift to enable any nuclear technology to be progressed.

1.66 The ANU Energy Change Institute citing the Symposium on the Nuclear Fuel Cycle submitted that education is one way to help build greater understanding and engagement in the community of nuclear energy, asserting that this will take time, transparency and extensive consultation.[27]

1.67 Associate Professor Peter Speck stated:

> The introduction of nuclear power into Australia must be accompanied by an intensive and completely transparent program to give Australians knowledge about every aspect of nuclear power. Such a program should be a high priority in planning for a nuclear future, and it should receive the significant resources it deserves, for decades into the future…The Commonwealth Government should take a leading role in building community engagement, with a view to arriving at a community consensus.[28]

1.68 In this process, it is important to learn from the mistakes of the past failed citizens' juries as part of the South Australia Nuclear Fuel Cycle Royal Commission 'Get to Know Nuclear' campaign.[29]

1.69 We must also learn from the experiences of Indigenous communities like the Adnyamathanha situated close to a uranium mine in the Flinders ranges whose representative, Mr. Couthard told the committee of their experience:

> In the midst of this discussion about nuclear energy, Adnyamathanha people, and Aboriginal people in South Australia, are very much afraid that we're going to be left with a dump site for our next generation. I think that's a big concern to

25 SMR Nuclear Technology Pty Ltd, *Submission 39*.

26 Bright New World, *Submission 168*.

27 ANU Energy Change Institute, *Submission 160*.

28 Associate Professor Peter Speck, *Submission 108*, p. [1].

29 South Australia, *Nuclear Fuel Cycle Royal Commission Report*, May 2016.

> put on the table as traditional owners are very much concerned about the fact that there are no guarantees in terms of this actually making an impact, a lasting impact, a beneficial impact.[30]

1.70 Effective community engagement leading to social license is possible. At paragraph 1.104, the Report highlighted the examples of overseas jurisdictions effectively doing so:

> 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.

1.71 Any future Australian government must be community focused and recognise the need to obtain social license first.

1.72 A future Australian Government should commission an independent community engagement program. However, it must have regard to technology neutrality and inform the community of all the options available.

1.73 The community, especially those situated close to proposed sites, should have all the information available to them as they will be required to make a complex and difficult decision on a controversial technology. Perhaps those communities would prefer a wind or solar farm located nearby.

I) National Consensus and Political Bipartisanship

1.74 The Committee heard from various groups and individuals about the importance of national consensus and political bipartisanship as a consideration of lifting the moratorium on nuclear energy.

1.75 The Report refers to and discusses this. However, the Report understates the importance of these needs and does not consider a viable solution to achieving both.

1.76 After several commissions, inquiries and a great deal of debate, the public is still divided as is the Committee.

1.77 A Roy Morgan Poll cited by Bright New World had a narrow majority of Australians supporting nuclear power (51 per cent) if it was used to reduce Australia's carbon emissions. However without reference to

30 Mr Dwayne Coulthard, Representative, Conservation Council of South Australia, *Proof Committee Hansard*, Adelaide, 2 October 2019.

reducing carbon emissions only 45 per cent of respondents say Australia should develop nuclear power.[31]

1.78 A different poll conducted by YouGov on behalf of the Australia Institute found that when asked about their preferred source of energy, 22 per cent placed nuclear in their top three, whilst 59 per cent placed it in their bottom three.[32]

1.79 Amongst the Australian public who submitted and presented to the inquiry in an independent capacity, there was also a lack of consensus.

1.80 The Minerals Council of Australia submitted:

> Political bipartisanship is required to both reflect and drive community engagement and form the basis for a national consensus.[33]

1.81 A lack of bipartisanship and national consensus can only be overcome if a future government seeks a clear mandate from the Australian people. A mandate can only be confirmed by plebiscite or federal election.

1.82 In response to the findings of the South Australian Royal Commission into the Nuclear Fuel Cycle, the South Australian Government similarly recognised the importance of a mandate, confirmed by popular vote. Stating that a move into nuclear would require:

> …bipartisanship and broad social consent, secured through a statewide referendum.[34]

1.83 Accordingly I sought amendments to the Report recommendation 3 which instead requires social license confirmed by plebiscite or federal election prior to the conditional approval of nuclear energy. This was ultimately rejected by the Committee. On the evidence, it is still necessary.

1.84 With the long development times for nuclear energy and the requisite preparation of the workforce and introduction of legislation and regulation to manage new nuclear facilities[35] this Government should convey its intent to the Australian people as soon as possible.

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31 Bright New World, *Submission 168*.

32 The Australia Institute, *Submission 167*.

33 Minerals Council of Australia, *Submission 266*.

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

35 See Australian Nuclear Science and Technology Organisation (ANSTO), *Committee Hansard*, Sydney, 29 August 2019.

J.1) Legislation for Net Zero

1.85 There needs to be a clear purpose for considering lifting the moratorium on nuclear energy. This can only be a goal of zero emissions.

1.86 The Report supports emissions reduction commitments and goals for nuclear generally. At paragraph 1.10 it states:

> Australia should be goal-oriented in its consideration of nuclear energy. This requires us to…consider the prospect of nuclear energy against broader goals for Australia's energy system – that is, to deliver affordable and reliable energy whilst fulfilling international emissions reduction obligations.

1.87 There is no doubt Australia needs to decarbonise its energy supply. The Committee heard from many parties both for and against nuclear that a core prerequisite for a future government was acceptance that nuclear energy could play a role in decarbonising the energy sector.

1.88 Specifically in order to meet the Paris Agreement's stated goal of limiting global warming to 1.5 degrees Celsius.

1.89 The Intergovernmental Panel on Climate Change's (IPCC) 'Global Warming of 1.5 ºC' Special Report shows that time is of the essence.[36] We need to decarbonise quickly.

1.90 The long development times of nuclear, canvassed in the Report as between ten and twenty years, mean it is ill-suited to the decarbonisation of the energy sector that is required. There is a risk that by focusing on future technologies like SMRs we may be leaving decarbonisation too late.

1.91 Lifting the moratorium and considering nuclear energy distracts from current and emerging technologies. It does not make sense when Australia has the potential to be an energy superpower with renewables and hydrogen.

1.92 The Paris Agreement requires Australia to increase its ambitions from our National Determined Contribution and develop a long term plan in line with a long term goal.

1.93 Even the Minerals Council of Australia stated that limiting warming to 1.5 degrees necessitates Australia reaching net zero emissions by 2050.[37]

1.94 Net zero targets have been adopted by all the States in Australia in either statute or policy as well as many of Australia's trading partners such as the United Kingdom, Japan and New Zealand. See table 1 below:

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36 Intergovernmental Panel on Climate Change, *Global Warming of 1.5 ºC Special Report*, 2018.

37 Minerals Council of Australia, *Submission 266*.

Table 1: International Net Zero Targets

International Net Zero Targets	
Country	**Status**
New Zealand	In Law
Norway	In Law
Sweden	In Law
France	In Law
United Kingdom	In Law
Portugal	Policy Position
Iceland	Policy Position
Ireland	Policy Position
Japan	Policy Position
Switzerland	Policy Position
European Union	Under Discussion
Germany	Under Discussion
The Netherlands	Under Discussion

Source: Countries' stated positions.

1.95 A recent Australia Institute survey of 1,424 respondents found almost two-thirds of Australian support a net zero target.[38]

1.96 Yet, the Federal Government currently lacks a legislated net zero target and no plan has been released. On the evidence, if a future government wishes to consider nuclear energy it must be in the context of decarbonisation in line with long term goal. This can only be a net zero target by 2050.

J.2) National Energy Policy

1.97 Australia does not currently have a national energy policy. This is not referenced in the Report and must be a prerequisite of lifting the moratorium.

1.98 Dr Ziggy Switkowski AO submitted that you cannot:

> …graft a long term commitment to nuclear energy onto a currently unconfirmed and unstable national energy policy.[39]

1.99 Ms Chloe Munro AO, Deputy Chair, Energy Forum, Australian Academy of Technology and Engineering reinforced this:

38 See https://www.tai.org.au/content/majority-support-national-net-zero-emissions-2050.

39 Dr Ziggy Switkowski, *Submission 41*.

> Contemplating lifting the moratorium would be more productive in the context of a holistic energy policy, which we don't entirely have at the moment.[40]

1.100 On 8 September 2018, the National Energy Guarantee, a national energy policy which would have provided Australia certainty and direction in its transition to low carbon electricity, was abandoned. It would have assisted any consideration of nuclear energy. The current Government has not signalled any intent to provide a new policy.

1.101 A key consideration for future government in settling the national energy policy is the regard for the energy policy direction of each State government. The Report at paragraph 1.115 states:

> 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.

1.102 The New South Wales Government has recently released the 'NSW Electricity Strategy'[41] which details the development of three renewable energy zones in New South Wales. The Victorian Government has committed to a target of 50 per cent renewables by 2030 and the South Australian Government has a target of 100 per cent renewables by 2030.

1.103 The difficulty in achieving congruence in direction was evident from the evidence. Queensland Liberal National Party MP Michael Hart on behalf of the Opposition submitted:

> The LNP is strongly committed to an energy policy that delivers safe, affordable, and reliable energy to consumers while fulfilling Australia's international emissions reductions obligations…We believe this can be achieved without lifting the moratorium on nuclear energy generation.[42]

1.104 He further stated that the Government should focus on supporting the development of renewables. I agree.

1.105 A national energy policy is an essential prerequisite to the consideration of lifting the moratorium on nuclear energy. This policy must take into account the direction of the States.

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40 Ms Chloe Munro, Deputy Chair, Energy Forum, Australian Academy of Technology and Engineering, *Proof Committee Hansard*, Melbourne, 1 October 2019.

41 See https://energy.nsw.gov.au/media/1926/download.

42 Mr Michael Hart MP, *Submission 132*.

1.106 Accordingly I made the following additional recommendation which was only supported by opposition members of the Committee.

Recommendation

The Committee recommends that the Australian Government legislate a Net Zero emissions target by 2050.

1.107 In respect to a National Energy Policy, I support the recommendation made by Labor members of the Committee in their dissenting report.

Ms Zali Steggall OAM MP
Member for Warringah

A

Appendix A – Summary of evidence

1.1 This summary of evidence is divided into the following sections:

- Background on nuclear energy
- Switkowski Review
- South Australian Royal Commission
- Australia's moratorium on nuclear energy
- Economic considerations
- Legal and regulatory frameworks
- Workforce capability requirements
- Environmental considerations
- Waste management
- Public health and safety
- Security and proliferation
- National consensus and community engagement

1.2 This report relies upon draft transcripts of the public hearings (known as 'proof Committee Hansard'). Errors or omissions are possible and readers are encouraged to check final transcripts when they become available on the Committee's website for verification.

Background: nuclear energy

1.3 Nuclear energy is derived from the process of atomic fission. Fission is a process whereby a heavy element in nuclear fuel (such as uranium) becomes unstable and breaks apart, and its particles collide with others, creating a further chain reaction. The fission reaction releases energy

inside a nuclear reactor, which can be harnessed and used to heat water and generate steam to drive turbines, which in turn generate electricity.[1]

1.4 Nuclear power has been an energy source overseas since the late 1950s,[2] and supplies around 11 per cent of the world's electricity, with almost 450 plants in operation and many more planned.[3]

Nuclear reactor designs by generation

1.5 The design of nuclear reactors has advanced over time. Designs are generally categorised by 'generation'.

- Generation I – early prototype reactors of the 1950s-1960s. No Generation I reactors are still operating.[4]
- Generation II – large-scale power stations, built from the 1960s-1970s. These represent most reactors operating today.[5]
- Generation III and III+ - evolutionary designs with better fuel efficiency and safety features, expected to have a longer useful life and reduced costs and timeframes for construction. Several are in use in Japan and South Korea and others are under construction or on order.[6]
- Generation IV – emerging designs under development. None are operational yet. Design elements will include greater safety and resistance to proliferation, better sustainability, less waste and economic competitiveness.[7]

Generation IV reactor designs

1.6 International collaboration on Generation IV reactors is taking place as part of the Generation IV International Forum (GIF), with fourteen member states supporting research and development for these advanced reactor designs.[8]

1 Nuclear Energy Agency, OECD, 'Nuclear Energy Today', 2nd edition, 2012, p. 15.
2 OECD Nuclear Energy Agency, 'Nuclear Energy Today', 2nd edition, 2012, p. 7.
3 Ian Hore-Lacy, 'Nuclear Energy in the 21st Century', 4th edition, 2018, p. 18.
4 John E Kelly, US Department of Energy, 'Generation IV International Forum', slides dated January 2014, p. 8; Ian Hore-Lacy, 'Nuclear Energy in the 21st Century', 4th edition, 2018, p. 42.
5 John E Kelly, US Department of Energy, 'Generation IV International Forum', slides dated January 2014, p. 8.
6 Ian Hore-Lacy, 'Nuclear Energy in the 21st Century', 4th edition, 2018, p. 42.
7 Generation IV International Forum, < https://www.gen-4.org/gif/jcms/c_9502/generation-iv-goals>, accessed 20 November 2019; OECD Nuclear Energy Agency, 'Nuclear Energy Today', 2nd edition, 2012, p. 23; Australian Nuclear Science and Technology Organisation (ANSTO), *Submission 166*, p. 4.
8 See Generation IV International Forum, < https://www.gen-4.org/gif/>, accessed 8 November 2019.

1.7 After considering almost 100 design concepts, the GIF selected six reactor designs for further research, ranging from small 20 MW to large 1,500 MW capacities).[9]

1.8 These designs are:

- Gas-cooled fast reactors;
- Lead-cooled fast reactors;
- Molten salt reactors;
- Sodium-cooled fast reactors;
- Supercritical water-cooled reactors; and
- Very high-temperature reactors.[10]

1.9 Australia, as a member of the GIF, is participating in work towards the molten salt reactor and the very high-temperature reactors.[11] Both of these reactor designs aim to provide efficient operation and a reduction in radioactive waste.[12]

Small modular reactor designs

1.10 Small modular reactors (SMRs) do not neatly fit into the above categories. Some forms of small reactors have been developed using Generation III and III+ technology, particularly for military applications. Newer commercial proposals for SMRs may be considered a subset of Generation IV.[13] These reactors are intended to be smaller, scalable reactors that can be produced more efficiently and added to each other to increase capacity over time.[14]

1.11 SMRs are generally defined to be nuclear power plants that generate less than 300 MWe.[15] While ANSTO describes its position on the adoption of nuclear power as 'agnostic',[16] its submission noted that SMRs could reduce the build costs for nuclear reactors by:

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9 See Generation IV International Forum, < https://www.gen-4.org/gif/>, accessed 20 November 2019.

10 See Generation IV International Forum, < https://www.gen-4.org/gif/>, accessed 20 November 2019.

11 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.

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

13 Friends of the Earth Australia, *Submission 36*, p. 2.

14 OECD Nuclear Energy Agency, 'Nuclear Energy Today', 2nd edition, 2012, p. 23.

15 Australian Nuclear Science and Technology Organisation (ANSTO), *Submission 166*, p. 5.

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

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

1.12 The World Nuclear Association states that, according to the International Atomic Energy Agency (IAEA), there are fifty SMR designs under development worldwide, three projects are nearing the demonstration stage, and that the first reactors may be commercially available in the next 10-15 years.[18]

Switkowski Review

1.13 In June 2006, the then-Prime Minister established a taskforce to 'undertake an objective, scientific and comprehensive review of uranium mining, value-added processing and the contribution of nuclear energy in Australia in the longer term'. This review would provide a factual base and framework to encourage community discussion and contribute to a constructive public debate on Australia's future energy needs.[19]

1.14 The Switkowski Review concluded that nuclear power was a viable option requiring serious consideration for inclusion in Australia's electricity market, to assist in meeting growing demand and to reduce greenhouse gas emissions.

1.15 The Review supported the expansion of Australian mining and export of uranium indicating that nuclear power could add $1.8 billion of value annually if all Australian uranium was processed domestically.

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

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

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

1.16 Given Australia's stable geological and political conditions, the Switkowski Review proposed a national repository for burial of low-level waste from all sources including a future nuclear power industry.

1.17 The Review assessed that the following matters would need to be addressed prior to establishing nuclear energy in Australia:

- community acceptance through informed discussion;
- skill shortages and commercial and technology barriers; and
- government policies, legal prohibitions and regulatory impediments restricting the growth of the industry.

1.18 The review stated that 'nuclear power, and renewable energy sources, are only likely to become competitive in Australia in a system where the costs of greenhouse gas emissions are explicitly recognised'.[20] It added that initial investment may require some form of government support or directive.

1.19 The review concluded that 'the earliest that nuclear electricity could be delivered to the grid would be 10 years, with 15 years more probable'.[21]

Government Response

1.20 In April 2007, to open the way for nuclear power in Australia, the then-Prime Minister announced that Australia would:

- establish a nuclear regulatory regime;
- remove any regulatory obstacles which might stand in the way of building nuclear power plants;
- apply to join the Generation IV International Forum, developing advanced reactor designs; and
- take steps to remove impediments to uranium mining.[22]

1.21 In June 2007, the emissions trading taskforce report proposed that Australia move to implement an emissions trading scheme.[23]

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

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

22 Prime Minister Hon John Howard, 'Uranium Mining and Nuclear Energy: A Way Forward for Australia', Media Release, 28 April 2007.

23 National Emissions Trading Taskforce, *Possible design for a national greenhouse gas emissions trading scheme: Final framework report on scheme design,* December 2007, at https://www.caf.gov.au/Documents/nett-final-report.pdf.

1.22 However, following the change of government in 2007 the implementation of an emissions trading scheme and the move towards nuclear power did not proceed.[24]

South Australian Royal Commission

1.23 In 2015 the Government of South Australia established a Nuclear Fuel Cycle Royal Commission to investigate the potential for increasing South Australia's participation in the nuclear fuel cycle in four key areas:

- exploration, extraction and milling of minerals containing radioactive materials;
- processing and manufacture of minerals and radioactive and nuclear materials;
- use of nuclear fuels for electricity generation; and
- facilities for the storage and disposal of radioactive and nuclear waste.[25]

1.24 The royal commission's report, presented in May 2016, outlined the 'feasibility, viability, risks and opportunities associated with a potential expansion of the nuclear fuel cycle from the perspectives of the environment, the economy and the community, including regional, remote and Aboriginal communities'.[26]

1.25 Key recommendations of the Royal Commission were that the South Australian Government:

- pursue removal at the federal level of prohibitions on nuclear power generation to allow it to contribute to a low-carbon future electricity system, if required;
- promote and collaborate on a comprehensive national energy policy that enables all technologies, including nuclear, to contribute to a reliable, low-cost, low-carbon electricity network;
- in collaboration with the Australian Government, commission expert monitoring and reporting on the commercialisation of new nuclear reactor designs; and
- pursue the opportunity to establish used nuclear fuel and intermediate level waste storage and disposal facilities in South Australia, including

24 https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/australia.aspx

25 South Australia, *Nuclear Fuel Cycle Royal Commission Report,* May 2016.

26 South Australia, *Nuclear Fuel Cycle Royal Commission Report,* May 2016, p. xi.

removing the state's legislative prohibition that would inhibit a thorough analysis and discussion of that proposal.[27]

South Australian Government response

1.26 Following the release of the Royal Commission report, the South Australian Government conducted a community engagement program between May and November 2016, which included constituting two 'Citizens' Juries', and holding meetings in 130 locations around the state.[28]

1.27 The SA Government then issued its response to the Royal Commission in November 2016, supporting nine of its 12 recommendations. These included the recommendations related to uranium mining and exploration, increased use of nuclear medicine, and monitoring the development of new nuclear reactor designs, as well as collaboration on a comprehensive national energy policy.[29]

1.28 Recommendations that were not supported included the removal of existing prohibitions on nuclear power generation in the state and the removal of restrictions on nuclear fuel cycle activities, citing the finding that nuclear power generation would not be cost-effective in the state.

1.29 The Government supported 'continued investigation' of the proposal to establish an international high-level waste storage facility in South Australia, while saying that this would require 'bipartisanship and broad social consent, secured through a statewide referendum'.[30]

1. Australia's moratorium on nuclear energy

Legal framework of the moratorium

1.30 Commonwealth law prohibits nuclear energy generation in Australia.

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

- A nuclear fuel fabrication plant;
- A nuclear power plant;

27 South Australia, *Nuclear Fuel Cycle Royal Commission Report,* May 2016, pp. xiv-xvi.

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

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

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

- An enrichment plant; and
- A reprocessing facility.[31]

1.32 The *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) also expressly prohibits the Minister from approving the 'construction or operation' of the same facilities.[32]

1.33 Additionally, a number of states and territories have legislation that prohibits nuclear power or restricts uranium mining.[33]

1.34 The federal prohibitions were introduced in late 1998[34] and have formed a longstanding bipartisan moratorium.[35]

Effects of the moratorium

1.35 Evidence was received explaining that the ban on nuclear power limits Australia's ability to research its suitability or its potential impact on electricity markets.

1.36 Dr Alex Wonhas from the Australian Energy Market Operator (AEMO) said that future energy planning does not currently include nuclear energy:

> One of AEMO's responsibilities is informing the design of Australia's future energy system through the preparation of the Integrated System Plan, or ISP in short. The ISP provides an integrated roadmap for the efficient development of the National Electricity Market over the next 20 years and beyond. …
>
> The ISP currently does not include an assessment of nuclear, as it is at the moment a technology that is not permitted in Australia. Should this change, AEMO will include nuclear in its ISP assessment. We expect the inclusion of nuclear in the ISP to make only make a small difference, if any, to what's the end of the outlook period. For nuclear investment to be the optimal choice for Australia it will have to demonstrate, among many other things, that it is more cost-effective compared to alternative technologies and that it is sufficiently flexible so it can be integrated in what we expect to be a highly dynamic future energy market.[36]

31 *Australian Radiation Protection and Nuclear Safety Act 1998* (Cth), s. 10.

32 *Environment Protection and Biodiversity Conservation Act 1999* (Cth), s. 140A.

33 Australian Workers' Union, *Submission 290*, pp. 13-14.

34 Bright New World, Submission 168, pp. 34-40.

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

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

1.37 The Commonwealth Scientific and Industrial Research Organisation (CSIRO) told the Committee that an effect of the moratorium was that public money cannot be spent on research and investigation into relevant topics surrounding nuclear power.[37]

1.38 Dr Jim Green (Friends of the Earth Australia) was sceptical that lifting the moratorium would result in benefits to Australia:

> The only thing that would actually change in Australia if the ban against nuclear power were repealed is that nuclear companies would descend on Canberra to try to gouge as much taxpayer money as they could possibly get from the federal government. That would be the one practical change…company representatives would be lined up outside ministerial offices trying to stitch together a package of direct and indirect taxpayer subsidies.[38]

Arguments for maintaining the moratorium

1.39 Reasons to retain the moratorium largely related to concerns about costs and unproven technologies, consequences such as nuclear accidents, fears of weapons proliferation and a lack of community support.

1.40 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.[39]

1.41 Mr Dave Sweeney from the Australian Conservation Foundation argued that lifting the moratorium was not necessary for the nuclear debate to take place; rather, that the ban had saved Australia significant costs:

> …the prohibition hasn't stopped debate or discussion. It hasn't stopped a whole range of dialogue and engagement around nuclear issues. But it has stopped us having a major cost burden,

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

38 Dr Jim Green, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 2.

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

> having more waste and having an imposed industry that leaves a massive intergenerational burden.[40]

1.42 Ms Brenda Huggett submitted that the moratorium should remain, particularly until any new technologies are proven:

> During these *Watch and Learn* years, there should absolutely be no lifting of our moratorium on the development of nuclear energy – a moratorium that has no doubt frustrated some, but has clearly satisfied an overwhelming majority of Australians as poll after poll has shown.[41]

1.43 Ms Elicia O'Reilly raised concerns about nuclear accidents as a reason to keep the moratorium. She highlighted the example of Fukushima, and said that 'the best way to guard against similar disasters occurring here is to retain the moratorium on nuclear power.[42]

1.44 The International Campaign to Abolish Nuclear Weapons Australia (ICAN) was concerned that 'moves towards nuclear power could be read as a proliferative signal to our neighbours', and recommended that Australia reject nuclear power.[43]

1.45 Mr Tim Buckley from the Institute of Energy Economics and Financial Analysis (IEEFA) told the Committee that:

> Any such discussion would unleash a massive level of community unrest. It would work directly against the goal of achieving bipartisan energy policy support, and that is what we need to unleash the tens of billions of dollars of capital that need to be invested in the coming decade to modernise, decarbonise and lower the cost of electricity for all Australians.[44]

1.46 Ms Noel Wauchope submitted that there was no support to lift the moratorium:

> There is no social licence to introduce nuclear power. There's no general movement for overturning the laws that have been passed, to protect Australians from this industry - its health and environmental hazards, its costs that are passed on to future generations. The push for nuclear comes from small sectors of Australian society, the industry itself, and from those in politics

40 Mr Dave Sweeney, *Proof Committee Hansard*, 1 October 2019, p. 11.

41 Ms Brenda Huggett, *Submission 236*, p. [2].

42 Ms Elicia O'Reilly, *Submission 247*, p. 2.

43 International Campaign to Abolish Nuclear Weapons Australia (ICAN), *Submission 157*, pp. 9-10.

44 Mr Timothy Buckley, Director, Energy Finance Studies, Institute of Energy Economics and Financial Analysis (IEEFA), *Proof Committee Hansard*, Sydney, 9 October 2019, p. 41.

> and in the defence sector, who see nuclear power as the pathway to nuclear weapons.

1.47 The submission continued:

> To get a national consensus in favour of introducing nuclear power will require a major propaganda effort. No wonder that the industry wants those laws repealed. That would allow them to launch a campaign for the hearts and minds of Australians.[45]

1.48 The Committee also received over 405 short submissions via Friends of the Earth Australia, stating a desire to retain the moratorium. The submissions stated that nuclear power is unpopular, dangerous and carries environmental, safety and security risks.[46]

Arguments for lifting the moratorium

1.49 Evidence in favour of lifting the moratorium suggested that removing the legislated bans would allow for a well-considered debate about a future nuclear industry.[47]

1.50 Dr Ziggy Switkowski said that the moratorium should be lifted:

> 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.[48]

1.51 SMR Nuclear Technology submitted that the moratorium was 'put into place at a time when there was no real appreciation of the contribution that modern, safe nuclear power plants could make to energy security, affordability and emissions reduction'.[49]

1.52 Dr Tom Biegler submitted that the moratorium is:

> …an expression of Australia's embedded cultural and political antipathy to nuclear energy.[50]

45 Ms Noel Wauchope, *Submission 72*, p. [5].

46 Sample of the Friends of the Earth campaign submission (405 received), *Submission 306*, p. [1].

47 Mr Logan Smith, *Submission 107*, p. [4]; Nuclear for Climate Australia, *Submission 135,* p. 30.

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

49 SMR Nuclear Technology, *Submission 39*, p. 14.

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

1.53 Dr Biegler added:

> The global context is that Australia is one of only around 15 countries with some kind of formal opposition to nuclear energy. In contrast, there are around 450 nuclear power stations operating in 31 countries, with a further 50 or so planned or under construction.[51]

1.54 Dr Switkowski was in favour of removing the ban to encourage modelling and assessment of the industry:

> In my opinion, at a minimum we should ensure that there aren't any obstacles to having nuclear technology in front of us and available to financiers and other organisations to model and compare with alternative scenarios. It should be in the mix, as it is in other countries, and it should be able to be analysed alongside all the other alternative platforms, and then the energy strategy can be optimised accordingly.[52]

1.55 Mr Tony Wood from the Grattan Institute said that the moratorium represents a 'significant barrier' to modelling being undertaken:

> …it does seem to be a little difficult to have a modelling discussion around nuclear, at least in this country. When I was involved with the Garnaut review, it was effectively 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, I think, a significant barrier, even though it may not be a legal barrier, to being able to have that conversation.[53]

1.56 StarCore Nuclear submitted that the moratorium prevents proper discourse and discourages investment:

> 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 for Small Modular Reactors (SMRs) at their operations, the conversation stops at the ban.[54]

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

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

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

54 StarCore Nuclear, *Submission 128*, p. 4.

1.57 Similarly, SMR Nuclear Technology Pty Ltd submitted that:

> The legislative prohibitions preclude any serious consideration of the merits of nuclear power generation in Australia. SMR vendors will not treat Australia as a potential market whilst the prohibitions remain. Although government reports have repeatedly endorsed the merits of "technology neutrality" in power system planning, the legislative prohibitions have prevented its accomplishment.[55]

1.58 The ANU Energy Change Institute advised that a national symposium of around 70 participants held in 2017 discussed the findings of the South Australian Royal Commission. In relation to the moratorium, the symposium's view was that:

> …legislated prohibition is inconsistent with widespread government practice of supporting technology neutrality, and is an inhibiting factor in the free and open discussion of options available to society.[56]

1.59 Down Under Nuclear Energy submitted that:

> Amending the legislation is not equivalent to mandating nuclear. It simply means that is will become possible for energy providers to consider nuclear as part of our energy mix. Without a change in legislation we cannot have an informed set of choices about our future and decisions cannot be made on either social benefit or commercial grounds. It is a basic principle in mathematics that decision making under constraints can never be better than unconstrained choice.[57]

1.60 The Australian Taxpayers Alliance (ATA) submitted that the moratorium should be lifted to encourage research and investment.[58] The ATA said:

> … this moratorium should be lifted regardless of whether the government is approached with a business case. Rapid innovations mean that the costs of nuclear power and hence the difficulties of establishing nuclear projects in Australia, will decrease over time with the removal of the moratorium supplying the catalyst for proposals and research in the longer-term... Although lifting the moratorium may not provide sufficient

55 SMR Nuclear Technology Pty Ltd, *Submission 39*, p. 14.
56 ANU Energy Change Institute, *Submission 160,* pp. [3-4].
57 Down Under Nuclear Energy, Submission 159, p. 4.
58 Australian Taxpayers' Alliance, *Submission 263*, p. 2.

> certainty for private investors by itself, it is a pre-condition for ensuring commercial certainty.[59]

1.61 The ATA added:

> The ATA further notes that nuclear power plants produce a fraction of the greenhouse gas emissions of solar or wind farms, according to the UN Intergovernmental Panel on Climate Change. It is therefore submitted that Australia's current and easily reversible moratorium on nuclear power is not only an act of economic vandalism, but of environmental vandalism which stymies innovations in the climate policy space.[60]

1.62 The Minerals Council of Australia submitted:

> Repealing the legislated ban on nuclear energy in the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is critical if Australia is to seriously embrace all technologies so our future energy mix is affordable, reliable and cleaner. Similarly, removing uranium mining and milling from the definition of nuclear actions in the EPBC Act and lifting the state-based prohibitions on uranium exploration and mining is critical to not just removing discriminations against uranium mining, but also as part of a broader recognition that Australia is joining the International Panel on Climate Change (IPCC) in acknowledging uranium-fuelled nuclear energy as a critical part of global efforts to reduce greenhouse emissions.[61]

1.63 Dr Donald Higson was strong in his assertion that the moratorium has contributed to Australia's 'energy crisis':

> These prohibitions have been significant contributors to our energy crisis. If there was ever any justification for them, it certainly does not exist today.[62]

The future of the moratorium

1.64 A number of submissions suggested that either a referendum or plebiscite should be conducted to ascertain the public's views as to whether

59 Australian Taxpayers' Alliance, *Submission 263*, p. 15.
60 Australian Taxpayers' Alliance, *Submission 263*, p. 2.
61 Minerals Council of Australia, *Submission 266*, p. 5.
62 Dr Donald Higson, *Submission 139*, p. [1].

Australia should move towards nuclear power or retain the current prohibitions.[63]

1.65 However, while most acknowledged the need for public support, a public vote was not universally supported.[64]

2. Economic considerations

1.66 The Committee was provided with costings and analysis based on procurement of 1000MWe nuclear reactors or, alternatively, procurement of small modular reactors (SMRs).

1.67 Mr Barrie Hill, for example, favoured a 1000MWe reactor:

> The standard reactor plant recommended for installation in Australia is the South Korean Advanced Power Reactor 1000MWe (APR1000) an evolutionary pressurised water reactor (PWR) which has been developed from the proven design of the Optimum Power Reactor 1000MWe (OPR1000).[65]

1.68 NuScale Power favoured its small modular reactors (SMRs):

> NuScale's plant has a significantly lower overnight capital cost and annual operating costs on a dollar per MW-hour basis significantly better than the current U.S. nuclear fleet average, and can be constructed in considerably less time compared to large nuclear plants. That's in part because of fully factory-fabricated elements of the modular design that takes safety-related fabrication work out of the field, lessening the risk to both cost and schedule.[66]

GenCost 2018 report's SMR costings

1.69 The GenCost 2018 report, jointly prepared by the CSIRO and the Australian Energy Market Operator (AEMO), forecast the future costs of

63 Mr Ian Fischer, *Submission 8*, p. [2]; Mr Rob Watson-Smith, *Submission 19*, p. [3]; Mr Gerard Van Hees, *Submission 40*, p. [1]; Mr Allen Biggins, *Submission 42*, p. [1]; Mr Kevin F Chilman, *Submission 92*, p. [1]; Mr Henry Gillard, *Submission 102*, p. 8.

64 Mr Craig Tamlin, *Submission 125*, p. 4; Ms Rosumund Krivanek and Ms Noel Wauchope, P*roof Committee Hansard*, Melbourne, 1 October 2019, p. 40.

65 Mr Barrie Hill, *Submission 60*, p. [2].

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

energy options. The report is available on the CSIRO's website.[67] The report stated that:

> The updated projections indicate that solar photovoltaic (PV) capital costs continue to fall at a faster rate than most other technologies and solar PV is projected to represent one of the largest contributors to electricity generation by 2050. Wind, batteries, pumped hydro and CCS [carbon capture and storage] are also expected to feature more strongly in the global electricity generation mix and consequently achieve cost reduction through increased deployment.[68]

1.70 The report compared small modular reactors with solar options between 2020 and 2050:

- Small modular reactors are assessed to cost $16,000 per kilowatt and this trend remains flat (unchanged) over the next thirty years to 2050.
- Solar thermal (with 8 hours storage) is shown to decrease from $5,000-$8,500 per kilowatt in 2020 to $2,000-$4,000 per kilowatt in 2050.
- Large scale solar photovoltaic is shown to decline from around $2,000 per kilowatt in 2020 to $600 per kilowatt in 2050.[69]

1.71 In relation to the flat trend predicted for nuclear generation technology capital cost, the GenCost 2018 report stated:

> The flat trend arises because, while nuclear is assigned a learning rate to recognise the potential for further improvements in the technology, they do not experience significant changes in costs due to the limited scope to double global cumulative capacity. In this sense, nuclear power is caught between having the existing deployment scale of a mature technology, but with the technological potential of an immature technology in terms of optimal technology design not being completely settled. Another factor which partially constrains nuclear deployment is that, besides economic drivers, its uptake is significantly influenced by government policy.[70]

1.72 Dr Alex Wonhas from AEMO provided the Committee with further explanation of the projections in the GenCost 2018 report, in particular the future capital costs of solar energy and small modular reactors:

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67 CSIRO, 'Annual Update Finds Renewables are the Cheapest New-Build Power', at https://www.csiro.au/en/News/News-releases/2018/Annual-update-finds-renewables-are-cheapest-new-build-power.

68 GenCost 2018, p. v.

69 GenCost 2018, pp. 15-18.

70 GenCost 2018, p. 16.

> What we endeavour to do is provide on an annual basis the best consensus view on capital cost. …there is typically an observation of decreasing capital costs; this is actually referred to as the learning effect. Where the installed capacity doubles we typically observe in the market a reduction in the capital cost of the equipment. Obviously, with the significant deployment of renewable energy resources, there is learning, and, therefore, those resources become more cost-effective, which has been observed over many decades now…
>
> The challenge at the moment with SMR reactor technology is that it is still very much in development. The actual deployment of the technology is relatively low, but once there is deployment I expect we will see some cost reduction based on that. But that's obviously an event that at the moment looks to be in the future.[71]

1.73 Dr Jim Green from Friends of the Earth Australia assessed that the estimates in the GenCost 2018 report are 'reasonable, but there's a wide degree of variance and a high degree of uncertainty'.[72]

1.74 Dr Jennifer Hayward from CSIRO told the Committee that the figure in the GenCost 2018 report was being reviewed:

> …based on stakeholder feedback, we're revising the scenarios… the modelling assumptions, and we're also modifying our methodologies. What we're expecting to see is a bit more variety in terms of the outcomes for SMR. So, instead of having a flat cost trajectory going out to 2050, we think that, given the changes that we're making because of the stakeholder feedback…that will actually see some cost reductions. But, yes, we are sticking with that number, because it is a first-of-a-kind plant. That's the assumption that we're sticking with.[73]

1.75 Dr Hayward said the figure of $16,000 had been sourced from the World Nuclear Association's website.[74]

1.76 Other submissions and witnesses did not agree with the costings published in the GenCost 2018 report.

1.77 Mr Ian Hore-Lacy from the Australasian Institute of Mining and Metallurgy said that some numbers in the GenCost 2018 report are 'astronomically high and unjustifiable'. He said:

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71 Dr Alex Wonhas, *Proof Committee Hansard*, 29 August 2019, p. 22.

72 Dr Jim Green, *Proof Committee Hansard*, 1 October 2019, p. 2.

73 Dr Jennifer Hayward, CSIRO, *Proof Committee Hansard*, 16 October 2019, p. 2.

74 Dr Jennifer Hayward, CSIRO, *Proof Committee Hansard*, 16 October 2019, p. 2.

> They must have been pulled out [of] thin air. There are plenty of numbers available in terms of costs of generation and so forth—that is, capital cost per kilowatt of setting up a nuclear power plant and the levelised cost of the energy which comes from it. I simply make the point that if you're looking at the LCOE be careful not to compare apples to oranges. The LCOE from a reliable, continuous supply—a dispatchable source such as nuclear, coal or gas—cannot be compared with those costs from solar and wind, because your system costs need to be added… Even if you were getting solar and wind at zero cost, it would still be more expensive by the time the consumer got it because of the system costs that are involved.[75]

1.78 The World Nuclear Association submitted:

> The joint AEMO CSIRO GenCost report which is apparently considered authoritative in Australia certainly cannot be considered as credible when it comes to nuclear costs. The latest edition excludes the technologically mature gigawatt-scale light-water and pressurized heavy water reactor designs – for which data are available – in order to focus on small modular reactors, for which prices are currently speculative. There is scant reasoning provided for this exclusion in the report and the supporting material. Australia has 13 major sites for coal electricity generation and those plants will have to [be] replaced sooner or later. Eleven of those sites house more than 1.3 gigawatts of power capacity and could be suitable for gigawatt-scale nuclear facilities.
>
> The report then assigns a surprisingly high estimated cost to SMRs of $16,000 AUD/kW, as well as assuming almost no learning rate. Confidence about the costs of as yet unbuilt reactor designs is naturally lower than in the (excluded) gigawatt-scale reactor segment. However, confidence is increasing as several prospective vendors undertake the necessary studies to advance through licensing processes and secure private investment. We can therefore say categorically that the figure of $16,000 AUD/kW is not in concordance with current international expectations.[76]

1.79 In response to the CSIRO's advice on the source of this figure being from the World Nuclear Association, Mr David Hess from that organisation said:

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75 Ian Hore-Lacy, *Proof Committee Hansard*, 1 October 2019, pp. 21-22.

76 World Nuclear Association, *Submission 259*, p. 7.

> The World Nuclear Association gets its cost data from other people who develop the projects—the vendors and the developers—so any data that we collect would be coming from there. But we can't be the ultimate authority for these kinds of projections. On our website we have an online information resource that is kept up to date as regularly as it can be with new information as it comes in. There is a possibility that the information used to be present as a data point in our extensive information collection, but it would have only been one value and, by the sound of things, it would have been an extreme value, because it's a very high capital cost estimate for nuclear projects.[77]

Friends of the Earth SMR and large reactor costings

1.80 Based on publicly available information, Friends of the Earth Australia (FoE) submitted the following analysis:

> A 2016 report by the South Australian Nuclear Fuel Cycle Royal Commission estimated levelized costs of electricity (LCOE) of US$161/MWh based on the US NuScale SMR design. A 2015 NuScale report estimated a LCOE of $98-$108/MWh. And in June 2018, NuScale said it is targeting a cost of just US$65/MWh for its first plant. No doubt NuScale's cost estimates will continue to drop precipitously … unless and until it actually builds an SMR plant.[78]

1.81 The submission continued:

> Lazard's most recent levelized-cost-of-energy analysis gives figures of US$112–189/MWh for new, large reactors; $29–56 for wind power; and $36–46 for utility-scale solar. If figures of US$60–65/MWh could be achieved with SMRs, the electricity they generate would be 2–3 times cheaper than that from large reactors but still more expensive than wind power and utility-scale solar.[79]

1.82 Dr Jim Green from FoE told the Committee that:

> Given the absence of any operating SMRs and the unpromising nature of the two under construction, or the two relevant ones under construction, the argument that SMRs are leading to cleaner, safer and more efficient energy production could only possibly be justified with reference to paper designs until the unproven claim is promoted by the nuclear industry. It ought to be obvious, and I'm sure it is obvious…that paper designs and

77 Mr David Hess, World Nuclear Association, *Proof Committee Hansard*, 22 October 2019, p. 2.

78 Friends of the Earth Australia, *Submission 36*, p. 16.

79 Friends of the Earth Australia, *Submission 36*, p. 17.

> corporate claims are no basis for public policy, especially given the history of the past decade.[80]

1.83 Dr Green also said:

> If SMRs were half as good as they're said to be, where is the private finance? It's not there. It's not there in the US or the UK or Canada. They're insisting on massive government subsidies, billions of dollars, and without that we won't even have any prototypes of these small reactors or these advanced reactors, let alone fleets of them generating vast amounts of low-carbon power. So we're in a holding pattern now where, unless governments are prepared to bet on these technologies…nothing is going to happen.[81]

Australian Nuclear Association and Nuclear for Climate Australia 1000MWe reactor costings

1.84 The Australian Nuclear Association's submission provided an estimated cost of larger nuclear power plants in Australia (1000MWe/1GWe), using a model from Energy Power Consulting:

> Costing for the nuclear power option was based on information provided by South Korean government agencies during an intensive study tour of that country's nuclear engineering industry. After adjusting the Korean costing information for the labour rates and general civil engineering costs currently seen on local major projects in Australia, the overnight cost of 1 GWe nuclear plant was A$6200/kWe which was used in the EPC model.[82]

1.85 Nuclear for Climate Australia's submission provided the same information and included further information on how the costings were calculated.[83]

1.86 The model uses an approach based on system levelised cost of energy. Mr Robert Parker of Nuclear for Climate Australia said:

> This model calculates the levelised cost of energy for each generation source, but, importantly, it then calculates the systemised levelised cost of energy for the whole NEM [National Energy Market] system. This incorporates costs from all generation sources, plus storage, devices and extra transmission

80 Dr Jim Green, *Proof Committee Hansard*, 1 October 2019, p. 1.

81 Dr Jim Green, *Proof Committee Hansard*, 1 October 2019, p. 12.

82 Australian Nuclear Association, *Submission 155*, p. 10.

83 Nuclear for Climate Australia, *Submission 135*, pp. 18-19.

> costs above and beyond those required to supply a current, more compact system. It also calculates the carbon abatement cost of a generation mix from a base reference cost. Models were run for a range of scenarios involving various amounts of nuclear energy, renewables and fossil fuels…In essence, we've found the systems based on renewables grew steadily more expensive than those incorporating nuclear energy as the emissions reductions intensified.[84]

1.87 Dr Alex Wonhas from AEMO said:

> …the best metric to look at in the long run is what we call 'total system cost' that takes into account the capital investment and the operating cost of a plant, and that is actually the metric that we are looking at when we do the analysis for the integrated system plan.[85]

Assessing the economics and business case for nuclear energy

1.88 The Committee heard many general views on the economics and business case relating to nuclear energy in Australia.

1.89 Dr Alex Wonhas from AEMO said that reliability and system security are two key considerations.

1.90 In relation to reliability, Dr Wonhas said:

> Reliability is what you have referred to as keeping the lights on, which means we have enough power available when consumers actually demand it. As we all know, renewables have a variable output that depends on the influence of weather—at least, I should say that some renewables do—and, as a result, we need what we call dispatchable resources within the Australian energy market. That can be a whole range of different plants. It is obviously the existing coal generation fleet and it is gas generators, which have the advantage of being quite flexible in their approach, but it can also be technologies set up that are now growing, such as pumped hydro or battery storage.[86]

1.91 On system security, Dr Wonhas said:

> The separate issue is what we call system security, which means that, at very short time scales, the system remains stable, in particular against potential disturbances. That is also an issue that

84 Mr Robert Parker, *Proof Committee Hansard*, 9 October 2019, p. 18.

85 Dr Alex Wonhas, *Proof Committee Hansard*, 29 August 2019, p. 25.

86 Dr Alex Wonhas, *Proof Committee Hansard*, 29 August 2019, p. 20.

> we look at very carefully when integrating renewables, because that requires a certain amount of what's called inertia, which basically keeps the frequency stable at 50 hertz, and maybe an additional injection of frequency through frequency ancillary services. What is also needed to integrate renewables is what is called a high short-circuit ratio and, in general, system strength.[87]

1.92 Dr Wonhas commented on the responsiveness of the energy system to changes in demand:

> There is a certain amount of energy that we expect renewables to deliver, which is obviously driven by the statistics of weather, which we will be looking at, but we will need dispatchable resources in the market and we also need resources that can actually respond relatively quickly to changes, which is quite important. Some generators are more able to do that than others. Take existing coal generators. They are typically slower and have less flexibility to respond, whereas a gas generator or, say, a pumped hydro system or a battery is much faster to respond.[88]

1.93 The Minerals Council of Australia submitted that:

> SMRs represent one of the cheapest new build 24/7 power supplies of any technology. In Australia, this would possibly make SMRs the cheapest zero emission power source capable of providing 24/7 energy. … the capital cost attributed to SMRs of $16,000/KW cannot be validated and appears to be at least 2-3 times that cited elsewhere. For example, NuScale estimates the capital cost of large-scale fabrication (which leads to lower costs) would be US$3,600/KW or A$5,140/KW.20 The Canadian SMR Roadmap also provided a range of estimates, with the average just under C$7,200/KW (A$7,500/KW).[89]

1.94 Ms Chloe Munro from the Australian Academy of Technology and Engineering said:

> In terms of the economics…the capital costs have been plummeting for both solar and wind. The calculation of the levelised costs of energy takes into account the capacity factor. Solar and wind may be generating only 30 or 40 per cent of the time, and that's taken into account in calculating the levelised cost of energy. In terms of reliability and security, yes, they need to be firmed—that is the technical term—in some other way. But again,

87 Dr Alex Wonhas, *Proof Committee Hansard*, 29 August 2019, p. 21.

88 Dr Alex Wonhas, *Proof Committee Hansard*, 29 August 2019, p. 21.

89 Minerals Council of Australia, *Submission 266*, p. 9.

> with the falling costs of storage and with potential deployment of large-scale storage like pumped hydro, renewables plus storage can deliver a much more reliable service. The question is whether that is then usefully backed up by other forms of generation—gas technology and potentially, in the future, nuclear. That's a relatively small residual piece that's left to be filled.[90]

1.95 The Australian Workers' Union supported trialling SMRs in Australia. The submission recommended:

> …a pilot program to assess the viability of Small Modular Reactors in the Australian economy, with a focus on providing energy to the heavy industrial using businesses in the economy. This should involve liaising with the US Department of Energy to assess the outcomes of the US Government's pilot project.[91]

1.96 On the other hand, a submission from Professor Steve Thomas and Mr Paul Dorfman (University of Greenwich) advised against SMRs. Their submission stated:

> SMRs have been widely promoted as potentially solving the problems associated with new large reactors, which have led to a sharp decline in the prospects for new large plant nuclear power orders. Their main somewhat implausible rationale is that building SMRs factories as modules, leaving just assembly on-site, will produce savings from use of production-line techniques that will more than counter-balance the lost scale economies of building large reactors.[92]

1.97 The submission continued:

> …the first demonstration plants are unlikely to be online before 2030. Whilst SMR demonstration plants will show whether the designs are technologically viable, it will take a further decade or more (only if production lines have been set up and large numbers of reactors have been pre-ordered and produced) before their economic viability is tested. Based on past experience with new nuclear technology, there is a high probability that this line of technology development will fail. At most, SMRs are [a] distant and very costly experiment, and Australia should focus on the very wide range of fully mature and commercially viable

90 Ms Chloe Munro, *Proof Committee Hansard*, 1 October 2019, p. 50.

91 Australian Workers' Union, *Submission 290*, p. 4.

92 Professor Thomas and Mr Dorfman, *Submission 277*, p. 1.

> renewable, energy management, distribution and storage technologies for reducing emissions.[93]

1.98 The submission anticipated financial risks:

> The poor record of existing designs and the unproven nature of SMRs means financing nuclear will be impossible via normal project finance and will require all major risks to fall on the public, either as tax-payers or electricity consumers.[94]

1.99 Environmental groups opposed the idea of introducing 1000MWe nuclear reactors in Australia:

> For Australia, the Australian Nuclear Association suggests South Korea as a potential supplier of reactor technology. However…the South Korean nuclear industry suffers from sustained allegations of endemic corruption. South Korea's four-reactor project in the UAE is said to be a welcome contrast to the vastly over-budget and long-delayed projects in western Europe and the US, but the UAE project is at least three years behind schedule (partly because of the corruption scandal involving South Korean manufacturers) and costs are reported to have increased from A$29.7 billion to A$47.3 billion (US$20 billion to US$32 billion). Remarkably, the South Korea/UAE reactor contract was accompanied by a secret military side-agreement.[95]

1.100 Ms Noel Wauchope also cited research from Carnegie Mellon University, concluding that the SMR industry would not be viable without 'several hundred billion dollars of direct and indirect subsidies'.[96]

1.101 Prof John Quiggin said:

> Having studied the subject extensively, I don't believe that nuclear power is economically feasible in the absence of a substantial carbon price…In this, I'm simply endorsing what the Switkowski inquiry concluded 12 years ago…if we are to proceed, the correct path is to implement a carbon price, starting at probably a level of $25 a tonne and rising gradually to a level of $50 a tonne, which in my view is the minimum necessary for nuclear power to compete against fossil based fuels. It will then be an open question whether nuclear power in fact succeeds in competition with renewables.[97]

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93 Professor Thomas and Mr Dorfman, *Submission 277*, p. 2.

94 Professor Thomas and Mr Dorfman, *Submission 277*, p. 2.

95 Nine environment groups and state conservation councils, *Submission 219*, pp. 4-5.

96 Ms Noel Wauchope, *Submission 72,* p. [3].

97 Prof John Quiggin, *Proof Committee Hansard*, 30 September 2019, p. 7.

1.102 Prof Quiggin said that small modular reactors may be feasible 'on paper' but added: 'I'd be surprised if they got a cost below $100 a megawatt hour.'[98]

1.103 Mr Tony Wood from the Grattan Institute assessed:

> So what we've seen is economic models that prove that some particular view of the world in the future will be the cheapest. If you look at almost all of those results, you find that the results are consistent with those who paid for the modelling.[99]

The mining industry

1.104 Processed uranium is a fuel source for nuclear energy. Some submissions and witnesses commented on the value of mining in Australia, in particular the extraction of uranium.

1.105 The Minerals Council of Australia submitted:

> The Australian uranium sector directly and indirectly employs around 3000 Australians and delivers more than $600 million in export income.[100]

1.106 The Australian Workers' Union submitted that:

> Australia is the largest global exporter of almost all raw materials and commodities for energy production yet perversely has the highest domestic electricity prices. Despite abundant reserves and large exports of coal, gas, uranium, and lithium, as well as natural endowments of wind, solar, hydro, thermal and wave technology – Australia is unable to satisfy its energy needs.[101]

1.107 Mr Ian Macfarlane from the Queensland Resources Council told the Committee that:

> In 2013, a Queensland government review into the recommencement of uranium mining in Queensland indicated the value of Queensland's major uranium deposits to be approximately $10 billion. Mining is a vital contributor to the economic growth of Queensland's regions. According to QRC's economic contribution survey in 2017-18, 77 per cent of direct employees of the Queensland resource industry live in regional Queensland, and 55 per cent of the direct and indirect jobs

98 Prof John Quiggin, *Proof Committee Hansard*, 30 September 2019, p. 8.

99 Mr Tony Wood, *Proof Committee Hansard*, 1 October 2019, p. 31.

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

101 Australian Workers' Union, *Submission 290*, p. 5.

> supported are in regional Queensland. Most importantly, mining jobs are typically highly skilled, high tech and high paying.

1.108 Mr Dave Sweeney of the Australian Conservation Foundation did not agree. He said:

> We certainly do have considerable uranium reserves—a third of the world's uranium reserves—but we are actually mining and exporting less each year, and that's simply in relation to the market demand and commodity price. It is measured in US dollars a pound. It was US$120 a pound pre Fukushima; it's US$30 a pound now. The basic rule of thumb is that it takes US$60 a pound for a greenfield mine site to be viable in Australia…We are seeing profit shrink, production shrink and value shrink, and the sector is being hit by external commodity forces. To say that the creation of some nuclear powered future in Australia will lead to a uranium renaissance and bonanza is simply fanciful.[102]

1.109 Associate Professor Gavin Mudd stated that:

> …uranium is being left behind and is largely being overtaken by lithium. Lithium has now almost triple the value of uranium, and that has given a dynamic to current energy globally and to the shift to renewables and is increasing the use of batteries. I think that's unlikely to change at all, and in some ways that's a very good direction for Australia to be heading in. There are certainly opportunities for Australia in energy exports and so on, but I think those relate to things such as lithium.[103]

3. Legal and regulatory frameworks

1.110 One essential element in considering any future nuclear energy industry in Australia is a suitable legal and regulatory framework.

1.111 The only Australian nuclear facility presently requiring regulation is the Commonwealth-owned research reactor at Lucas Heights, although states and territories have legislative and regulatory arrangements in place in relation to nuclear materials (such as medical supplies) and radiation within their jurisdictions. At the Commonwealth level, regulatory responsibilities and functions for aspects of nuclear security, safeguards and safety cut across the Health, Foreign Affairs and Trade, and Environment and Energy portfolios.

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102 Mr Dave Sweeney, *Proof Committee Hansard*, 1 October 2019, p. 13.

103 Associate Professor Gavin Mudd, *Proof Committee Hansard*, 1 October 2019, p. 15.

1.112 The 2006 UMPNER report stated:

> Australia currently has several Commonwealth regulatory entities as well as state and territory authorities. Safeguards and security are regulated by the Australian Safeguards and Non-Proliferation Office (ASNO) while health and safety is regulated by state and territory radiation protection authorities or, in the case of Commonwealth entities, by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Some of these regulatory functions could be consolidated.
>
> 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.
>
> For Australia to expand its role in the nuclear power industry it is essential that an appropriate and rigorous regulatory framework is established at an early stage. Adequate provision would need to be made for its implementation.[104]

1.113 CEO of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), Mr Carl-Magnus Larsson, advised the Committee on nuclear regulation in Australia:

> The aim of the regulatory activities, as for all other activities that we carry out at ARPANSA, is the protection of the health and safety of the workers, the public and the environment independent of any promoting interests. Our focus is also on the safety and security of the regulated facilities, with the aim of reducing the likelihood of accidents and mitigating their consequences, should they occur. We apply international best practice in our regulatory decision-making and we participate in the development and implementation of the international framework for safety together with our international partners. We also fulfil Australia's reporting obligations under certain international instruments such as the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. We are also the national competent authority

104 Department of the Prime Minister and Cabinet, *Uranium Mining, Processing and Nuclear Energy – Opportunities for Australia?*, 2006, p. 9.

> on the assistance and early notification conventions for radiological and nuclear emergencies.[105]

1.114 Mr Larsson said that regulatory arrangements for nuclear energy could depend upon who is operating the facilities:

> Looking at other countries with a federated constitution like Australia's, when they have embarked on a nuclear program they have made a choice to establish a federal regulator for all nuclear installations. So today we have federal regulation for all the nuclear installations, but all the nuclear installations are owned and operated by the Commonwealth, so that would be something that the regulator would have to consider. Changes would in that case have to be made to the ARPANS Act if we were to think about non-Commonwealth operated entities. Obviously, as the committee surely is fully aware, there are prohibitions in the ARPANS Act and in the EPBC Act but it is a much broader look at the regulatory structure that is needed in order to accommodate a nuclear power program.[106]

1.115 Mr Adriaan van der Merwe submitted that:

> Prior to the inclusion of nuclear energy in a country's energy mix, consideration also needs to be had to the status of energy and nuclear legislation and regulations on a commonwealth and state level, as well as the required expansion thereof to bring same in line with required international benchmarks. In Australia the interplay between commonwealth and state legislation will be particularly important, especially in light of international treaty obligations and the level to which those obligations are backed down into domestic law.[107]

1.116 Ms Robyn Glindemann from the Law Council of Australia (LCA) elaborated on the complications of legal and regulatory arrangements for nuclear energy in Australia's federal system:

> If you start from the point of the mining part of the energy, if we use our own uranium and actually have a secondary processing capability in this country to then put it into a nuclear energy reactor, the mineral resources themselves are the properties of the states; they're not the Commonwealth's, so the regime for getting the stuff out of the ground is governed by state law. There's a little overlay of Commonwealth law in terms of the EPBC Act and

105 Mr Carl-Magnus Larsson, *Proof Committee Hansard*, 29 August 2019, p. 9.

106 Mr Carl-Magnus Larsson, *Proof Committee Hansard*, 29 August 2019, p. 12.

107 Adriaan van der Merwe, *Submission 175*, p. 1.

> various other pieces of legislation, but the fundamental digging it out of the ground is governed by state mining legislation…So there are inherent differences in the regime from the very get-go. If we were to have a…legislative regime to cover the entire cycle from taking it out of the ground to processing to using it as fuel to waste, other than the boundaries with the current Commonwealth legislation…it is a patchwork quilt of state legislation that you'd have to manage. In terms of managing risk, it is simpler to have one legislative regime that is properly resourced in terms of compliance and enforcement to manage those risks rather than relying on the states to manage their own regimes in combination with the Commonwealth.[108]

1.117 ARPANSA advised the Committee that it hosted an International Atomic Energy Agency (IAEA) peer review of Australia's regulatory framework in 2018. The review noted that the legal framework for radiation and nuclear safety in Australia is 'complex' and suggested improvements, particularly to address inconsistencies in requirements and practices between jurisdictions. ARPANSA stated that:

> The observations by the IRRS team provide strong incentives to review the legal framework for radiation and nuclear safety, and efforts are underway through jurisdictional collaboration to make changes.[109]

1.118 ARPANSA noted that the ARPANS Act 'was developed with research reactors in mind', and while its general provisions could provide a regulatory framework for nuclear power reactors, there are 'areas that need to be strengthened, either in the ARPANS Act or in other existing legislation—or, alternatively, in new legislation'.[110] These include waste management, emergency preparedness and nuclear liability.

1.119 Ms Helen Cook, a legal adviser on civilian nuclear energy, submitted that if Australia were to introduce nuclear energy, 'a comprehensive review of Australia's existing legal and regulatory infrastructure would be needed', focusing on the following:

- the underlying policy objectives for, and role of the Federal Government in, the development of nuclear energy;
- overturning the primary legal impediments to nuclear energy (legislated prohibitions);

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

109 Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), *Submission 136,* p. 3.

110 ARPANSA, *Submission 136,* pp. 6-7.

- the need for any Federal actions to strengthen international and bilateral nuclear commitments, including in relation to third party liability for nuclear damage;
- the adequacy of the 'domestic legal infrastructure' including in relation to nuclear safeguards, security, safety, emergency preparedness, international obligations, and liability. This may result in the need to amend existing legislation, or promulgate 'new, consolidated and comprehensive legislation' for the civilian nuclear energy sector;
- 'domestic regulatory infrastructure' including licensing and information disclosure, and the suitability of the powers and responsibilities of the current regulatory agencies; and
- a roadmap for the implementation of all of the above.[111]

1.120 Resources Law International submitted that Australia is 'already well down the track in implementing international best practice' for a nuclear power program, but an 'up-to-date audit' on the efficacy of the current framework may be warranted.[112]

1.121 Ms Cook noted the need for 'a legal and regulatory regime that is tailor-made to our particular policies and circumstances'.[113] ARPANSA said that 'the building blocks already exist in Australia, but are not optimally linked or presented within a coherent framework'.[114] Dr Adi Patterson, CEO of ANSTO, said that Australia's regulatory construct is both 'robust and flexible, and that's a prerequisite, I think, to being successful in expanding a nuclear footprint in any country'.[115]

1.122 ARPANSA submitted that:

> It is ARPANSA's view that a single piece of national legislation encompassing, as a minimum, radiation and nuclear safety (including waste safety, transport safety, environmental protection, emergency preparedness and response, and security) should be a vision for a review and revision of the legal framework, whether a decision is taken to pursue nuclear power or not. This should accommodate different ownership/operator options.[116]

111 Ms Helen Cook, *Submission 158,* pp. 1-3.

112 Resources Law International, *Submission 156,* p. 4.

113 Ms Helen Cook, *Submission 158,* p. 3.

114 ARPANSA, *Submission 136,* p. 5.

115 Dr Adi Patterson, Chief Executive Officer (CEO), Australian Nuclear Science and Technology Organisation (ANSTO), *Committee Hansard*, Sydney, 29 August 2019, p. 15.

116 ARPANSA, *Submission 136,* p. 5.

1.123 Resources Law International noted that while the IAEA is not an international nuclear regulator, it does act as an advisory body and is mandated to help build capacity in its member states, including through publishing a number of 'invaluable' guidance documents to assist countries developing nuclear power for the first time.[117]

1.124 With regard to regulation arrangements, the LCA supported the UMPNER report's recommendation for a single national regulator for radiation safety, nuclear safety, security safeguards and environmental impact, in relation to all nuclear fuel cycle activities.[118]

1.125 ARPANSA expressed the 'firm view that, should nuclear power be introduced in Australia, it should be under Commonwealth regulation'. ARPANSA suggested that this would not entirely eliminate state and territory responsibilities, and that other nations with nuclear power in federal systems, such as Germany, Canada and the United States, could offer useful models for an appropriate framework for Australia.[119]

1.126 Resources Law International submitted that:

> …ARPANSA is an effective, national and independent regulatory authority for the purposes of developing an Australian nuclear power programme subject to two important provisos: first that ARPANSA would need to build additional resourcing to cope with an expanded work load and, second, that there should be direct representation by the community on its board of directors.[120]

1.127 LCA also recommended:

> …rationalisation of the uranium mining regulatory framework to ensure a consistent approach to environmental and radiation protection throughout the nuclear fuel cycle; and…a secure long-term commitment to compliance and enforcement of approvals issues for the energy cycle, and this includes a commitment by way of properly funded human resources within the relevant regulatory agencies.[121]

1.128 The Medical Association for the Prevention of War (MAPW) expressed concern that 'Australia is likely to under regulate the industry, with a resulting loss of safety culture and increased risk to the community'.[122] MAPW submitted detailed concerns about 'regulatory capture' in the

117 Resources Law International, *Submission 156,* pp. 3-4. See also ARPANSA, *Submission 136,* p. 5.

118 Law Council of Australia, *Submission 267,* p. 9.

119 ARPANSA, *Submission 136,* p. 6.

120 Resources Law International, *Submission 156,* p. 7.

121 Ms Robyn Glindemann, *Proof Committee Hansard,* 18 October 2019, p. 20.

122 Medical Association for the Prevention of War, *Submission 223,* p. 21.

nuclear industry internationally, citing the example of Japan, which it said 'became captive to the government and industry's goal of nuclear promotion at any cost, leading to a poor safety culture'.[123] It argued that the uranium mining industry in Australia was poorly regulated and subject to regulatory capture, suggesting that the same could be true of a nuclear power industry in this country.[124]

1.129 In this regard, Resources Law International submitted that:

> The IAEA advocates the institutional separation of the regulatory authority from agencies concerned with the promotion and utilisation of nuclear energy. This is also one of the fundamental safety principles embodied in the [Convention on Nuclear Safety] CNS. Therefore, national legislation should provide for an effective separation between the functions of the regulatory body, and those of any other body or organization concerned with the promotion or utilisation of nuclear energy.[125]

Liability and insurance

1.130 Matters relating to legal liability for nuclear incidents were also raised in some evidence given to the inquiry.

1.131 The Australia Institute commented that:

> Nuclear power is…uninsurable. The low-probability but high-cost risk of a nuclear event means that private insurance won't cover the full costs. In the US and in many other countries, operator liability is capped, meaning taxpayers and individuals end up subsidising the risk. If the industry was required to cover the full risk in insurance, it would not even be up for discussion. Even in Australia, without a nuclear industry, when you or I get insurance for our car, home or contents, there are explicit exclusions for nuclear events.[126]

1.132 The Australia Institute submitted that '[i]f developers of nuclear power stations were forced to insure the full costs of nuclear accidents, nuclear power would be completely uncompetitive'.[127] The submission stated that in the absence of private insurance coverage either the Government would need to provide indemnity—as it has in the case of ANSTO's Opal

123 Medical Association for the Prevention of War, *Submission 223,* p. 12.

124 Medical Association for the Prevention of War, *Submission 223,* pp. 21-22.

125 Resources Law International, *Submission 156,* p. 6.

126 Mr Tom Swann, *Proof Committee Hansard,* 18 October 2019, p. 18.

127 The Australia Institute, *Submission 167,* p. 31.

reactor—or the community would bear the risks of liability for nuclear incidents.[128]

1.133 Other submitters shared the view that the problem of insurance would either make nuclear energy economically unviable for operators, or place an unreasonable burden on taxpayers.[129]

1.134 The Australian Nuclear Science and Technology Organisation (ANSTO) stated that international law channels all liability for nuclear incidents to the operators of nuclear installations, and 'there are large amounts of nuclear insurance (in the billions of dollars) available in the global market', to cover this. ANSTO noted that there are gaps in commercial insurance coverage, and some governments therefore provide insurance to ensure the full coverage required by international Conventions.[130]

1.135 ANSTO noted that while the Government has provided a Deed of Indemnity to cover liability over its facilities, this may not be appropriate for private operators of nuclear energy facilities. Should such facilities be established in Australia, the Government may therefore need to enact nuclear liability legislation. ANSTO proposed that the Government may also consider ratifying the IAEA Convention on Supplementary Compensation,[131] 'so as to provide a further level of reassurance to potential international partners'.[132]

1.136 In relation to international liability arrangements for a nuclear accident, Ms Robyn Glindemann from LCA advised that:

> In terms of the international legal framework for liability post disasters, there are general principles of international environmental law which unfortunately are not well embedded…To the extent that a disaster in one jurisdiction affects another, there are broad legal principles, but I'm not aware of a formal, internationally agreed legal regime for who is liable for what post a disaster. That should be addressed, but it is not something that Australia could address by itself.[133]

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128 Mr Tom Swann, *Proof Committee Hansard,* 18 October 2019, p. 25.

129 See PaYUng Contracting, *Submission 91,* pp. 4-5; Citizens Climate Lobby Australia, *Submission 169,* pp. 3-4; Mr Ivan Quail, *Submission 253,* pp. 15-16; Mr Matthew Baird, *Submission 121*, p. 3.

130 Australian Nuclear Science and Technology Organisation (ANSTO), *Submission 166,* pp. 31-33.

131 Convention on Supplementary Compensation for Nuclear Damage, done at Vienna on 12 September 1997 under the auspices of the International Atomic Energy Agency, entered into force 15 April 2015.

132 ANSTO, *Submission 166,* p. 35.

133 Ms Robyn Glindemann, *Proof Committee Hansard,* 18 October 2019, p. 24.

4. Workforce capability requirements

Workforce capability requirements for a nuclear energy industry

1.137 Nuclear energy generation needs an adequately skilled workforce to develop, operate and regulate the industry.

1.138 In its submission, the Australian Nuclear Science and Technology Organisation (ANSTO) referred to the International Atomic Energy Agency's (IAEA) acknowledgement that 'it is unrealistic to expect that a Member State initiating a new nuclear power program would have sufficiently skilled personnel, with the required levels of competence, to implement that program.'[134] ANSTO further submitted that the IAEA would expect that in nations forming a nuclear workforce:

- a national system would be developed to build the human resource base;
- the first reactor project would be turnkey to leverage the knowledge and experience gained during the build from the provider;
- there will be recruitment of competent staff for the commissioning and operational phases of the program; and
- a loose partnership will be formed between the operator, vendor(s), regulatory bodies, established nuclear facilities, academic/educational institutions, and trade organisations.[135]

The current nuclear workforce capability in Australia

Existing workforce

1.139 The current Australian workforce is largely supporting ANSTO's research reactor at Lucas Heights. A number of professionals are also working in related fields.

1.140 Evidence to the inquiry regarded this workforce as a basis for Australia's capability to operate potentially expanded nuclear operations in the future.

1.141 Australian Young Generation in Nuclear (AusYGN) submitted that despite the absence of a nuclear power industry, the current and former research reactors at ANSTO's Lucas Heights campus demonstrate Australia's proven ability to operate safe nuclear facilities.[136]

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

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

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

1.142 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.[137]

1.143 Women in Nuclear Australia submitted that ANSTO, the Australian Safeguards and Non-Proliferation Office (ASNO) and the Australian Radiation Protection and Nuclear Safety Authority (ARPANSA) are well established bodies and could form a basis for a future regulatory body for a nuclear power industry.[138]

Current workforce training and development

1.144 Dr Ziggy Switkowski told the Committee that Australia's vocational and higher education sector is capable of quickly producing a trained workforce for a future Australian nuclear industry.[139] A number of universities in Australia currently offer relevant courses that may equip professionals for a future nuclear power industry:

- The Australian National University (ANU) offers a Masters course in nuclear physics,[140] established in 2007. The campus manages a particle accelerator facility with a strong experimental emphasis, and offers practical education in nuclear physics,[141] and includes nuclear reactors and the nuclear fuel cycle.[142]
- The University of New South Wales offers a Masters course in nuclear engineering,[143] established in 2013.[144]

1.145 Women in Nuclear Australia submitted that these academic programs are already contributing technical skills and knowledge into the Australian nuclear workforce.[145]

1.146 The ANU program has produced graduates who have gone on to employment in ASNO, ARPANSA, ANSTO, and also at the headquarters of the IAEA.[146]

137 SMR Nuclear Technology Pty Ltd, *Submission 39*, p. 12.
138 Women in Nuclear Australia Inc., *Submission 154*, pp. 11-12.
139 Dr Ziggy Switkowski AO, *Submission 41*, p. 2.
140 Women in Nuclear Australia Inc., *Submission 154*, p. 12
141 ANU School of Physics, *Submission 151*, p. [2].
142 SMR Nuclear Technology Pty Ltd, *Submission 39*, p. 12.
143 Women in Nuclear Australia Inc., *Submission 154*, p. 12.
144 SMR Nuclear Technology Pty Ltd, *Submission 39*, p. 12.
145 Women in Nuclear Australia Inc., *Submission 154*, p. 12.

1.147 SMR Nuclear Technology submitted that a key workforce prerequisite for a nuclear power program in Australia is an increased number of nuclear engineering courses.[147]

1.148 The ANU School of Physics suggested that its courses could be expanded in the future to include undergraduate nuclear engineering programs and other necessary training including technical skills and research programs.[148]

Moving towards a workforce capability for nuclear power

1.149 The Committee heard evidence nonetheless that the Australian nuclear workforce is not yet at a level that would be suitable to sustain a nuclear power industry.[149] A number of submissions observed that if Australia was to introduce nuclear power, there would be a need for more skilled workers to assist in developing the new industry.[150]

1.150 Mr Bernd Felsche said that the moratorium on nuclear energy meant that opportunities in Australia for employment in the nuclear sector are few, resulting in a lack of practicing nuclear engineers. He said some of the 'immediate demand' for nuclear engineers would likely need to be filled by skilled immigration or work-visas for short-term demand, particularly during plant construction.[151]

1.151 Resource Futures further noted that:

> There is clearly negligible current capacity to build or operate nuclear power in Australia beyond the non-nuclear components – site preparation, steam generation, transmission connection. Building these competencies would take many years and even then experienced middle and senior management would need to be sought from nuclear power capable countries until local capacity became available.[152]

1.152 SMR Nuclear Technology was optimistic about attracting a skilled workforce to Australia, and advised that:

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146 ANU School of Physics, *Submission 151*, p. [2].

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

148 ANU School of Physics, *Submission 151*, p. [2].

149 Ms Julia Garside, President, Australian Young Generation in Nuclear, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 2; Dr Philip White, *Submission 119*, p. [9]; Mr Bernd Felsche, *Submission 129*, p. [3]; ANSTO, *Submission 166*, p. 27; Dr David Jones, *Submission 249*, p. 7.

150 Dr Philip White, *Submission 119*, p. [9]; Mr Bernd Felsche, *Submission 129*, p. [4]; Women in Nuclear Australia Inc., *Submission 154*, p. 12; Mr Tom Bammann, *Submission 178*, p. 4; Resource Futures Pty Ltd, *Submission 238*, p. [3]; Dr David Jones, *Submission 249*, p. 7.

151 Mr Bernd Felsche, *Submission 129*, pp. [3-4].

152 Resource Futures Pty Ltd, *Submission 238*, p. [3].

> Australia is a very attractive place to live and there's no problem in attracting engineers from overseas to Australia. Our company is regularly contacted by people asking, 'Do you have any jobs for us?' We don't believe there's a problem in getting enough workforce for a nuclear power program.[153]

1.153 A submission from environmental groups noted the time needed to develop a specialised workforce as a disadvantage of nuclear power compared to alternative energy sources.[154]

1.154 The Committee heard 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.[155] 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.[156]

1.155 Dr White pointed to the example of the United Arab Emirates (UAE), submitting that despite placing orders for nuclear power plants in 2010, the UAE was only able to certify the first group of senior reactor operators in mid-2019, with 'additional training and procedural development' cited as necessary.[157]

1.156 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'.[158]

1.157 Similarly, AusYGN told the Committee that there is a current capability gap, but that one benefit of the lead times in enacting required legislative and regulatory changes, construction and commissioning of nuclear energy facilities would allow a window of opportunity to train up a capable workforce.[159]

1.158 Mr Tony Irwin from SMR Nuclear Technology said that the lead times present an opportunity to skill a workforce:

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153 Mr Tony Irwin, Technical Director, SMR Nuclear Technology Pty Ltd, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 20.

154 Joint signatory of fifty civil society organisations, *Submission 172*, p. [1].

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

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

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

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

159 Ms Julia Garside, President, Australian Young Generation in Nuclear, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 2.

> OPAL is a good example. I was reactor manager there, and what we would do with a nuclear power plant is appoint your operating staff at an early stage in the project so they can get involved with all the construction and commissioning. This is where you really gain all your experience. For OPAL what we did was employ young engineering graduates, obviously with no nuclear background at that time, and we trained them in nuclear during the time of the commissioning and early operation, which is where you really gain a huge amount of experience. Once a nuclear power plant is running, it's pretty boring. It sits there and just operates, so you get all your experience during its early operation.[160]

1.159 Mr Barrie Hill of Nuclear for Climate Australia told the Committee that in his experience, it takes around two years to suitably train qualified engineers to understand nuclear technology.[161] Mr Hill also pointed out that many of the required engineers for a nuclear workforce would not need specific nuclear experience:

> Not every person needs to be a nuclear engineer. We would need, based on the OPAL experience, probably about 10 people with intimate nuclear engineering experience... The majority of the workforce is our normal engineering workforce—civil engineers, electrical engineers, mechanical engineers for most of the plants. The whole construction group does not need to be nuclear engineers.[162]

1.160 Women in Nuclear Australia also highlighted Australia's experience in large construction projects such as shipbuilding and related Defence industries, and indicated that nuclear power plant construction could draw on this workforce.[163]

1.161 Mr Hill said that a lack of workforce capability in Australia is 'a complete myth'[164], and that examples such as liquid national gas and iron ore

160 Mr Tony Irwin, Technical Director, SMR Nuclear Technology Pty Ltd, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 20.

161 Mr Barrie Hill, Associate, Nuclear for Climate Australia, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 20.

162 Mr Barrie Hill, Associate, Nuclear for Climate Australia, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 20.

163 Women in Nuclear Australia Inc., *Submission 154*, p. 12.

164 Mr Barrie Hill, Associate, Nuclear for Climate Australia, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 20.

projects point to Australia's ability to quickly mobilise a necessary workforce.[165] Mr Hill argued that a key barrier is finance:

> If you put the money in the bank for me tomorrow, I'd have a 200-person team working on a nuclear power station within three months. We have experienced engineers, we have experienced scientists. Most of the engineers who worked for me at ANSTO, for instance, are nuclear trained and are now working on projects all over Australia. They could be easily pulled in.[166]

1.162 Mr Tony Irwin from SMR Nuclear Technology said that lifting the moratorium would likely result in an expansion of available university courses.[167] AusYGN agreed, submitting that the development of nuclear power in Australia would present 'significant opportunity for employment and education for young professionals.'[168]

1.163 AusYGN also noted the need for young entrants to the nuclear workforce in Australia to facilitate intergenerational knowledge transfer, as the industry consists of an ageing workforce.[169]

1.164 In her submission, Ms Noel Wauchope noted that around one third of nuclear professionals are over 55 years of age. The submission stated:

> The uncertainty about the industry's future means that there's a cloud over this industry as far as a career path is concerned. To develop a nuclear industry in Australia would require huge expenditure in training and tertiary education - large public investment would be needed.[170]

1.165 ANSTO told the Committee that if Australia was to opt to introduce nuclear power, 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.[171]

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165 Mr Barrie Hill, Associate, Nuclear for Climate Australia, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 20.

166 Mr Barrie Hill, Associate, Nuclear for Climate Australia, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 20.

167 Mr Tony Irwin, Technical Director, SMR Nuclear Technology Pty Ltd, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 20.

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

169 Ms Julia Garside, President, Australian Young Generation in Nuclear, *Proof Committee Hansard*, Sydney, 9 October 2019, p. 2.

170 Ms Noel Wauchope, *Submission 72*, p. [4].

171 ANSTO, *Submission 166*, p. 27

1.166 ANSTO also noted that there would be a need to develop a framework to train the nuclear workforce for eventual decommissioning of plants; however, these skills would not be required for some time.[172]

1.167 Mr Bernd Felsche submitted that prospective nuclear engineers may be able to seek practical experience overseas.[173]

1.168 The Australian Academy of Technology and Engineering recommended pursuing international partnerships in nuclear education, research and development to further enhance workforce skills.[174]

1.169 With regard to regulation, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) advised the Committee that it is not currently able to provide of the all necessary skills and competencies to the scale required for a national nuclear power program.[175] The agency indicated that it would require a significant increase to its resourcing, involving two elements:

- establishment of a new resourcing and competence baseline to handle the establishment of a nuclear power program; and
- a scalable element that is proportionate to the size of the nuclear power program.[176]

1.170 ARPANSA said it would need to recruit experts able to address the safety aspects across the nuclear supply chain, along with people to manage issues such as community engagement, communications and organisational psychology.[177] Additionally, a long-term education, training and research program would be required in order to support capability.[178]

1.171 ARPANSA's submission stated:

> 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.[179]

172 ANSTO, *Submission 166*, p. 28.

173 Mr Bernd Felsche, *Submission 129*, p. [3].

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

175 Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), *Submission 136*, p. 6.

176 ARPANSA, *Submission 136*, p. 6.

177 ARPANSA, *Submission 136*, p. 6.

178 ARPANSA, *Submission 136*, p. 6.

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

5. Environmental considerations

1.172 The Committee heard that nuclear power may offer benefits in terms of assisting efforts to reduce emissions,[180] and may offer advantages in terms of air quality[181] and a smaller footprint.[182]

1.173 On the other hand, environmental concerns about nuclear energy raised in the evidence included radioactive waste,[183] mine site rehabilitation[184] and water usage.[185]

1.174 At present, there are no available impact statements to outline the likely effects of nuclear power on Australia's environment. The Australian Nuclear Association submitted that the current moratorium in the *Environment Protection and Biodiversity Conservation Act 1999* prevents an Environmental Impact Statement from being prepared and assessed in Australia.[186]

Nuclear as a potential method to reduce carbon emissions

1.175 Reducing emissions is a key aspect of the Australian Government's climate change plan to achieve internationally agreed targets.[187]

1.176 The Australian Nuclear Association submitted that:

> The carbon emissions for the whole nuclear fuel cycle are very low and of the order of 40 g CO2/kWh. 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

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

181 Nuclear for Climate Australia, *Submission 135*, p. 7.

182 World Nuclear Association, *Submission 259*, p. 3.

183 Sample of Friends of the Earth campaign submission (405 received), *Submission 306*, p. [1].

184 Associate Professor Gavin Mudd, *Submission 225*, p. [11].

185 Sample of the Australian Conservation Foundation campaign submission (5,104 received), *Submission 296*, p. 1.

186 Australian Nuclear Association Inc., *Submission 155*, p. 1.

187 Department of the Environment and Energy, 'Government and international initiatives', https://www.environment.gov.au/climate-change/government, accessed 8 November 2019.

> nuclear energy are able to achieve very low carbon emissions from electricity generation.[188]

1.177 Mr Ian Hore-Lacy from the Australasian Institute of Mining and Metallurgy said that there is 'no real realistic decarbonisation prospect for Australia which does not involve nuclear'.[189] He said:

> You need a continuous, reliable supply on a considerable scale. If we also want decarbonisation then that points to nuclear rather than coal or gas. Building renewables at the rate we have been is simply saying that we're basically going to depend on gas to fill the gap, which has its own carbon footprint, especially if there's any methane leakage. You need only three per cent methane leakage and you have the same global warming potential as burning coal.[190]

1.178 Nuclear for Climate Australia also saw nuclear power as the only option to meet global emissions reduction targets:

> Keeping the existing nuclear fleet in operation and adding new capacity can help the world reach its climate goal. Only by rapidly expanding nuclear energy together with renewables and other low carbon sources can we still deliver on the Paris agreement commitments.[191]

1.179 Nuclear for Climate added that nuclear nations in Europe had achieved rapid reductions in emissions from power generation. It highlighted that France, 'which produces approximately three quarters of its electricity from nuclear, has the lowest per capita emissions of the seven largest industrialized countries (G7)'.[192]

1.180 Bright New World noted that the Intergovernmental Panel on Climate Change (IPCC) classifies nuclear as a 'mitigation technology', in terms of reducing greenhouse emissions, and said that nuclear power is 'comparable to renewable energy technologies such as wind and solar PV.'[193]

1.181 Associate Professor Peter Speck and Dr Henry Askin were both supportive of nuclear power as a method to reduce emissions and as an alternative to coal:

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

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

190 Ian Hore-Lacy, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 22.

191 Nuclear for Climate Australia, *Submission 135*, p. 5.

192 Nuclear for Climate Australia, *Submission 135*, p. 5.

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

> With proper management, nuclear power will have little negative environmental impact, and potentially positive impact by reducing carbon emissions.[194]
>
> Because coal is abundant and cheap it fuels the largest part of Australia's baseload electricity generating capacity. This is highly unsatisfactory as coal releases far more carbon dioxide than other fossil fuels per unit of useful energy…Nuclear generation is a zero emission option which could initially augment and eventually supplant combustion technology in providing base load generating capacity.[195]

1.182 Associate Professor Speck cautioned that as nuclear power carries a 'perception of adverse environmental impact', careful management would be required.[196]

1.183 Others were less convinced that nuclear energy offered a true low-carbon alternative. Dr Philip White submitted that:

> There is a tendency for nuclear proponents to equate environmental impacts of nuclear power plants with CO2 emissions during the electricity generation mode and to conclude that nuclear power is good for the environment because it has zero CO2 emissions.
>
> …it would take considerably more than a decade before the first nuclear power plant came on line. In the meantime, we would have obstructed the development of a reliable, affordable and low greenhouse gas emissions (GHG) electricity system based on renewable energy. Instead, we would have propped up a high GHG emissions system based on coal. So, even though nuclear power plants don't emit much CO2 during the electricity generation phase…the delay in moving to a low GHG emission system makes them a very bad choice from an environmental perspective.[197]

1.184 The Medical Association for the Prevention of War said:

> A critical consideration in relation to nuclear power is the carbon emissions generated by the whole nuclear fuel chain, which are repeatedly overlooked by nuclear proponents. The mining,

194 Associate Professor Peter Speck, *Submission 108*, p. [1].

195 Dr Henry Askin, *Submission 113*, p. 2.

196 Associate Professor Peter Speck, *Submission 108*, p. [1].

197 Dr Philip White, Submission 119, pp. [6-7].

milling, fuel fabrication, enrichment, reactor construction, decommissioning and waste management all use fossil fuels.[198]

1.185 Ms Elizabeth Dangerfield submitted that:

- …nuclear reactors, even modular ones, take [such] a long time to be approved and built that global warming is likely to be well over 1.5°C before the first reactors come online,
- this would only be an advantage if coal fired power stations in Australia were shut down soon,
- we need to contribute to a worldwide reduction in CO_2 emissions so we would still need to stop exporting our coal and natural gas to other countries,
- Mining, processing and transport of fuel for nuclear power stations produces CO_2 emissions as well as environmental and social impacts such as pollution, land degradation and erosion of Aboriginal customs and rights,
- we could achieve the same results with less cost through renewable energy.[199]

1.186 EcoEnviro submitted:

> Whilst many nuclear power plants around the world have a strong safety record, there are a string of recorded incidents of failure of plants around the world… the impacts to the environment from the mining, transport and utilisation of uranium for nuclear generation are avoidable. Cheaper, cleaner options of generation are now available to us on utility-scale wind and solar projects. … Perhaps a better idea would be to lead the world in renewable energy and new battery storage technologies, rather than heading back down a path that the rest of the world has decided to leave behind.[200]

Air pollution

1.187 Evidence was also received regarding how nuclear power could result in less air pollution than other methods of electricity generation.

1.188 Nuclear for Climate Australia explained that uranium is an 'energy dense fuel', and that less uranium is required per unit of energy produced than the amount of coal that would be required for the same energy output:

198 Medical Association for the Prevention of War, *Submission 223*, p. 16.

199 Ms Elizabeth Dangerfield, *Submission 185*, p. 5.

200 EcoEnviro, *Submission 6*, pp. 1-3.

> …while a 1000 MWe coal plant would consume about 2.6 million tonnes of coal per year, the equivalent nuclear plant would consume only 25 tonnes of uranium.[201]

1.189 Nuclear for Climate added that less fuel usage results in less transport to supply fuel, and the refuelling needs of a nuclear plant keep pollution to a minimum:

> Partial refuelling takes place every 18 to 24 months. This means that a nuclear power plant releases very little air pollution and there are very limited truck movements to supply fuel. Most nuclear plant has an operating lifetime of up to 60 years.[202]

1.190 The Australian Nuclear Science and Technology Organisation (ANSTO) submitted that regulations in the industry result in careful checks and balances to keep pollution levels as low as possible:

> …the nuclear industry is subject to strict regulations and licensing conditions regarding emissions and discharges. Nuclear power plants, and, more broadly all nuclear facilities, are mandated to collect and analyse environmental samples and gaseous discharges to ensure that their environmental impacts are minimised.[203]

Reduced environmental footprint

1.191 The Committee was told that nuclear energy has fewer impacts on the environment than other methods of energy generation, given that it requires less land and fuel per unit of energy produced.

1.192 The World Nuclear Association submitted that:

> Nuclear plants leave more space for nature. They require far less fuel than their coal or gas equivalents, requiring less extraction and transport infrastructure. They also take up only a small fraction of the space needed for wind and solar farms. A 3.2 GW nuclear power plant on 430 acres produces the same amount of electricity as 130,000acres of solar panels or 250,000 acres of onshore wind farms.[204]

1.193 Women in Nuclear submitted that small modular reactors and Generation IV reactors, in particular, provide:

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201 Nuclear for Climate Australia, *Submission 135*, p. 7.

202 Nuclear for Climate Australia, *Submission 135*, p. 7.

203 Australian Nuclear Science and Technology Organisation (ANSTO), *Submission 166*, p. 19.

204 World Nuclear Association, *Submission 259*, p. 3.

> highly capable, scalable power solutions…able to service cities through to small remote towns with a reliable power supply on a reduced footprint in comparison to other energy forms, therefore allowing precious land to be salvaged for agriculture, industry, population grown or for wildlife and green areas.[205]

1.194 StarCore Nuclear also compared the land area required to reach the same level of electrical output between different energy production methods, and concluded that the 'environmental risk of not using nuclear power is far greater than the use of nuclear power.' According to StarCore, despite there being over 439 reactors worldwide, they have had a 'largely benign effect on the environment'.[206]

Radioactive waste

1.195 ANSTO submitted that waste is an 'important consideration' in discussing the environmental impacts of nuclear energy generation.[207]

1.196 In terms of waste impacting the environment, the Australian Academy of Science pointed out that nuclear waste is stored in containers and not released into the air, unlike 'gaseous emissions'.[208]

1.197 However, the Committee also received evidence from many concerned individuals saying that hazardous waste would 'pose a direct human and environmental threat for many thousands of years and impose a profound inter-generational burden.'[209]

1.198 Radioactive waste is discussed further below.

Mining sites

1.199 Mr Dave Sweeney from the Australian Conservation Foundation told the Committee that mine rehabilitation was costly and, to date, largely unsuccessful:

> If we look at this country's fledgling engagement with the nuclear industry, we have profound and adverse environmental impacts at existing and former uranium mine sites. Rio Tinto are currently spending in the order of $1 billion and facing enormous challenges to rehabilitate the Ranger mine site in Kakadu. The public purse will be hit with a new cost—the figures spoken about are in the range of $200 million to $250 million extra—in public dollars to

205 Women in Nuclear Australia Inc., *Submission 154*, p. 4.

206 StarCore Nuclear, *Submission 128*, p. [10].

207 ANSTO, *Submission 166*, p. 19.

208 Australian Academy of Science, *Submission 304*, p. [2].

209 Sample of Friends of the Earth campaign submission (405 received), *Submission 306*, p. [1].

> clean up the former Rum Jungle site in the Northern Territory. There is a legacy of leaking tailings dams, underperforming mines and badly or non-remediated sites at every uranium operation.[210]

1.200 Associate Professor Gavin Mudd also commented on the rehabilitation efforts at uranium mine sites in Australia:

> Australia has not demonstrated successful long-term uranium mine rehabilitation at any site. In other words, all sites still exhibit various problems ranging from local impacts or risks to severe risks to adjacent streams and land use restrictions. Perhaps most alarmingly, there remains a complete lack of agreed standards as to define an acceptable standard of rehabilitation – such as gamma radiation, radon & progeny, water quality, ecosystem re-establishment, erosion – but most critically the time frame over which site monitoring and maintenance needs to occur.[211]

1.201 The Queensland Resources Council's view was that Australia is a world leader in mine rehabilitation. Mr Ian Macfarlane, Chief Executive, told the Committee:

> Australia has the ability to supply uranium that is mined under the most stringent environmental standards in the world, where the land is repatriated or rehabilitated under the strictest laws in the world.[212]

1.202 Women in Nuclear Australia submitted that the 'environmental impact of uranium mining is no different to the environmental impact of mining other heavy metals, such as rare earths and other elements used in solar panels or wind turbines.'[213]

1.203 Its submission cited research that found solar and wind facilities require up to 15 times more concrete, 90 times more aluminium, and 50 times more iron, copper and glass than fossil fuels or nuclear energy. The submission concluded that 'the environmental consequences from mining for nuclear energy, therefore, are substantially less than other forms of energy generation.'[214]

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210 Mr Dave Sweeney, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 10.

211 Associate Professor Gavin Mudd, *Submission 225*, p. [11].

212 Mr Ian Macfarlane, *Proof Committee Hansard*, Brisbane, 30 September 2019, p. 4.

213 Women in Nuclear Inc., *Submission 154*, p. 7.

214 Women in Nuclear Inc., *Submission 154*, p. 7.

Water usage

1.204 More than 5,000 submissions received from individuals via the Australian Conservation Foundation expressed concern that nuclear power consumes too much water.[215]

1.205 Women in Nuclear Australia commented on water usage:

> While large amounts of water are used for cooling, 99% of this water is returned to the environment, only a few degrees warmer and free of contaminants as the cooling water is circulated through heat exchanges and is never exposed to radioactive material.[216]

1.206 Its submission suggested that reactors located in coastal regions could desalinate seawater for both their own use and to provide drinking water to populations:

> The freshwater usage requirements of a nuclear plant are slightly larger than that of a conventional fossil fuel plant but are not large enough to discount nuclear energy due to this factor alone. In addition, due to the small amounts of fuel used for nuclear energy compared to gas or coal, there is greater flexibility in the location of nuclear reactors. Hence reactors on the coast could desalinate water to cool themselves (or provide drinking water to communities) whilst at the same time generating electricity.[217]

1.207 Nevertheless, the Australian Academy of Science suggested that the water needs of nuclear energy generation may make it an unsuitable technology given the Australian environment. It further submitted that extreme weather events pose 'significant threats'[218], and noted a number of resultant issues:

> Nuclear power can also be disrupted by water scarcity and rising water temperatures, resulting in safety issues including flooding, loss of power, loss of communication, blockage of evacuation routes, and equipment malfunction.[219]

1.208 The Australia Institute submitted:

> All thermal generation uses water, but the water requirements of nuclear power stations are 20-83% higher compared to fossil fuel-based power stations. Open loop nuclear power stations withdraw water from an inland water body and circulate it, discharging the

215 Sample of the Australian Conservation Foundation campaign submission (5, 104 received), *Submission 296*, p. 1.

216 Women in Nuclear Australia Inc., *Submission 154*, p. 7.

217 Women in Nuclear Australia Inc., *Submission 154*, p. 9.

218 Australian Academy of Science, *Submission 304*, pp. [5-6].

219 Australian Academy of Science, *Submission 304*, p. [5].

> warmer circulated water back into the original water body. This can lead to thermal pollution by overheating the local ecosystem, affecting fish and aquatic life. Other nuclear power stations are more water efficient but still require vast quantities of water.
>
> Reliance on water for cooling increases vulnerability to extreme heat. Multiple heatwave-related nuclear power plant shut downs occurred in France in the 2019 summer, as the waters surrounding the plants become too warm to provide a cooling function.[220]

1.209 ANSTO provided the following comments on nuclear reactors and water usage:

> Water usage by nuclear power plants is high, and second only to that required by the agricultural sector. Water is a requirement for cooling; however, the majority of water used in power reactors around the world is derived from the sea, which is returned to the environment only a few degrees warmer and with minimal loss due to evaporation.[221]

1.210 ANSTO advised that 'as an average, water use for the OPAL Cooling Towers with the reactor operating at 20 MWth is 30 m3 per hour'.[222]

Comparison with other energy sources

1.211 Many submissions and witnesses compared nuclear power to other energy sources, in terms of environmental outcomes.

Renewables

1.212 Mr Terry Vanden Bergh was concerned about the land area needed for large scale solar farms, along with the environmental cost of producing panels and batteries:

> …few people consider the implications of solar on a mass scale if it was widely adopted. When the sun is not shining they are not producing. Large surfaces areas will need to be covered to support our growing population, not to mention the environmental impact producing and recycling of these systems will have on the environment. Now that's before even considering all the mining of rare earth elements that will need to occur to produce the batteries required to store surplus energy for use at night. If we then take

220 Australia Institute, *Submission 167*, p. 33.

221 ANSTO, *Submission 166*, p. 18.

222 ANSTO, *Submission 166*, p. 40.

> into account the lifespan of the batteries and panels then it becomes a very wasteful alternative and environmentally costly.[223]

1.213 Mr Dallas Lane submitted that:

> The environmental impact of solar panel and battery manufacture is a problem where toxic waste generally ends up in land fill forever…There is the further short lifetime of batteries and solar panels and the problem of recycling, whereas existing nuclear reactors have demonstrated they can operate for more than 50 years with little maintenance.[224]

1.214 StarCore Nuclear also indicated that there are environmental costs in pursuing renewable energy:

> …environmental groups conveniently ignore the cost of mining the minerals needed to make PV panels, including rare elements such as gallium, indium and germanium as a necessary component of the PV technology. These elements are very rare and at this stage there is no commercial method for their recycling. Recycling of PV panels is a looming issue that has yet to be addressed and heavy metals such as cadmium are known to leach into the environment from them.[225]

1.215 SMR Nuclear Technology further submitted that an additional impact, in the form of noise, pointed to nuclear as a better option, stating that 'wind turbines produce significant noise which has an environmental impact and limits their siting. The noise of nuclear cannot generally be heard outside the plant boundary'.[226]

1.216 Not all submissions and witnesses agreed with the above views. For example, the Electrical Trades Union submitted:

> Rather than fuel higher carbon emissions and unnecessary radioactive risk, the Australia Government can and should do better. Our shared energy future is renewable, not radioactive and our Government must plan for and support a fair and just transition for energy workers, their communities and the Australian people. The Government needs to focus its efforts on establishing and implementing an actual energy policy based on the science, technical and engineering expertise available to it. Australia needs to embrace the fastest growing global energy sector and become a driver of clean energy thinking and

223 Mr Terry Vanden Bergh, *Submission 187*, p. [4].

224 Mr Dallas Lane, *Submission 138*, p. [3].

225 StarCore Nuclear, *Submission 128*, pp. [6-7].

226 SMR Nuclear Technology Pty Ltd, *Submission 39*, p. 8.

> technology. Renewable energy is affordable, low risk, clean, and popular. Nuclear is simply not.[227]

Coal

1.217 Some evidence received commented that nuclear energy is preferable to coal-fired energy due to reduced environmental impacts.

1.218 The Australian Academy of Science pointed out that burning coal to produce electricity releases radioactive elements into the environment, as opposed to nuclear power, where waste products are contained. These materials include uranium, thorium and radium; as well as admium, lead, mercury, selenium and thallium.[228]

1.219 The Academy further submitted that some 10-21 million tonnes of coal ash are produced each year in Australia and around 400 million tonnes are stored in unprotected sites. These sites 'do not adhere to regulations', management standards fall 'below global best practices', and a number of contamination events have occurred.[229]

1.220 StarCore Nuclear mentioned that air pollution from coal fired power plants is not limited to carbon emissions:

> …despite the technology to contain other fine particulates they emit heavy metals such as cadmium and mercury. Mercury is of particular concern because there is no lower threshold limit below which mercury does not cause damage to human health. Similarly, there are few controls on the ash dumps from coal fired power stations which collectively contain more uranium than has ever been mined as fuel for nuclear power.[230]

6. Waste management

1.221 According to the Australian Nuclear Science and Technology Organisation (ANSTO), radioactive waste 'encompasses any material that either is intrinsically radioactive or that has been contaminated by radioactivity, and that is identified as having no further use.'[231]

1.222 Around 90 per cent of radioactive waste is classified as low-level waste, and comprises items such as paper, rags, tools, clothing and filters, mostly

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227 Electrical Trades Union, *Submission 164*, p. 3.

228 Australian Academy of Science, *Submission 304*, p. [2].

229 Australian Academy of Science, *Submission 304*, p. [2].

230 StarCore Nuclear, *Submission 128*, p. [8].

231 Australian Nuclear Science and Technology Organisation (ANSTO), *Submission 166*, p. 9.

generated in medical and industrial settings. Despite its large volume, only around one per cent of the radioactivity of all radioactive waste is generated by low-level waste.[232]

1.223 Intermediate-level waste has a higher radioactivity, accounting for seven per cent of the volume and four per cent of the radioactivity of all radioactive waste. This waste usually consists of resins, chemical sludges, metal fuel cladding and contaminated materials left behind following the decommissioning of a nuclear reactor. Intermediate-level waste requires a level of shielding.[233]

1.224 High-level waste results from nuclear energy generation within a reactor, and generally comprises used fuel and other waste products. Only three per cent of the volume of worldwide radioactive waste is high-level waste, however it comprises 95 per cent of total radioactivity of this waste.[234]

1.225 Australia produces and stores both low and intermediate-level waste, but at present neither stores nor produces high-level nuclear waste.[235]

Current radioactive waste management in Australia

1.226 Australian Government policy in relation to radioactive waste is set out in the Australian Radioactive Waste Management Framework. The Framework provides principles and long-term goals to form the basis of Australia's national approach to radioactive waste policy making, and ensures that Australia's domestic arrangements align with its international obligations.[236]

1.227 Ms Samantha Chard from the Department of Industry, Innovation and Science advised that Australia produces around 40 cubic metres of low-level waste and five cubic metres of intermediate-level waste annually. Most is stored at the ANSTO facility at Lucas Heights, but there are over 100 locations around Australia holding waste.[237]

1.228 ANSTO CEO Dr Adi Patterson said that nuclear waste 'is rightly a public concern and rightly something that has to be done correctly'. He noted

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

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

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

235 ANSTO, *Submission 166*, pp. 9-10.

236 Department of Industry, Innovation and Science, 'Australian Radioactive Waste Management Framework', https://www.industry.gov.au/sites/default/files/2019-04/australian_radioactive_waste_management_framework.pdf>, April 2018, p. 2, accessed 8 November 2019.

237 Ms Samantha Chard, General Manager, National Radioactive Waste Management Facility Task Force, Department of Industry, Innovation and Science, *Proof Committee Hansard*, Sydney, 20 September 2019, p. 3.

that spent fuel from its research reactor is currently sent to France for reprocessing, with the re-usable elements recycled into French fuel. The residual waste is returned to Australia and stored in special containers at Lucas Heights.[238]

1.229 Ms Chard explained that introducing nuclear power to Australia would lead to additional amounts and types of waste:

> Australia currently doesn't produce any high-level radioactive waste. So approximately two energy reactors operating over 50 years would double Australia's inventory of radioactive waste and produce a new type of radioactive waste that we currently don't have any arrangements to store.[239]

1.230 Dr Henry Askin told the Committee that compared to fossil fuels, nuclear power generation produces only small quantities of waste. He did, however, point out that a 'credible' permanent waste solution would need to be implemented in order for nuclear power to be accepted by the general public.[240]

Views about radioactive waste

1.231 Mr David Sweeney of the Australian Conservation Foundation voiced concerns that nuclear energy is not 'clean' energy because of long-lived radioactive waste:

> There is also this talk of nuclear being clean. It is absolutely unacceptable, not proper and actually inconceivably to say that about an energy source that generates three years of reliable electricity—low carbon, granted—in a reactor and then, when those fuel rods are no longer reliable, has them taken out, because they're then spent nuclear fuel, and they're a radioactive waste management issue for up to 100,000 years. Now, that's not a good rate of return—three years of cold drinks, cool beers and warm showers and 100,000 years of needing to be isolated. That's a massive impost on the future. So it's not clean, cheap and safe, and it's not necessary.[241]

238 Dr Adi Patterson, *Proof Committee Hansard*, 29 August 2019, p. 16.

239 Ms Samantha Chard, General Manager, National Radioactive Waste Management Facility Task Force, Department of Industry, Innovation and Science, *Proof Committee Hansard*, Sydney, 20 September 2019, p. 4.

240 Dr Henry Askin, *Submission 113*, p. 3.

241 Mr Dave Sweeney, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 10.

1.232 However, StarCore Nuclear explained that public focus on the length of time these substances remain radioactive may be misplaced, as the more hazardous wastes are those with shorter half-lives:

> Central to the nuclear waste debate is that there is a focus on products produced in the fission process that are long lived (have long half-lives). In reality those nuclides with long half-life have less of an effect on human health than those with short half-lives, since they release a small number of radioactive particles. Those with short half-lives such as iodine and caesium which decay quickly, produce a relatively higher number of particles and exit the environment quickly, are of more concern but for periods of about 3 months (not 3,000 years!).[242]

1.233 Women in Nuclear agreed, submitting that:

> Unlike other toxic wastes, the principle [*sic*] hazard associated with nuclear waste is radioactivity, which diminishes over time. Used nuclear fuel loses 99.9% of its radioactivity in the first 40 years, making it easier to handle and manage.[243]

1.234 The Maritime Union of Australia submitted that public anxiety about nuclear waste continues to hinder efforts to find storage solutions for Australia's current needs, and that a nuclear power industry would increase this waste concern. The union pointed out that '[t]he attempts of successive federal governments to construct a nuclear waste facility have been thwarted by persistent community campaigns and legal actions'.[244]

Required waste management for a future nuclear power industry

1.235 The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) submitted that if Australia established a nuclear power industry, new arrangements would need to be considered for the treatment of spent fuel and permanent storage of waste.[245] This would include reconsidering the framework for radioactive waste management in Australia; and consideration of a disposal facility for spent nuclear fuel.[246]

242 StarCore Nuclear, *Submission 128*, p. [7].

243 Women in Nuclear Australia, *Submission 154*, p. 4.

244 Maritime Union of Australia, *Submission 237*, p. 7.

245 Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), *Submission 136*, p. 8.

246 ARPANSA, *Submission 136*, p. 8.

1.236 ARPANSA explained that:

> Changed arrangements including final management and disposal of spent fuel in Australia would require new facilities and a separate site selection process; it is not within scope for the ongoing site selection process for a NRWMF [National Radioactive Waste Management Framework].[247]

1.237 Dr Ziggy Switkowski described current arrangements for high-level nuclear waste storage in some detail, concluding that:

> In effect, that is your high-level waste repository: concrete silos queued up on an open field, where people walk and mow the grass. If you touch the silos they feel vaguely warm, so you know there's something going on. You don't want to linger there for hours or days, but you can certainly walk around. It's been like that for decades, awaiting a more permanent subterranean storage. In the meantime, it's not mysterious and it's not dangerous. You'd have to make a very, very big effort to somehow or other penetrate or compromise the storage. It's inefficient and it's probably not a good use of real estate, but that's what happens around the industry, around the world. So, although communities are easily unsettled at the notion of very long-lived radioactive waste, the way in which it is managed and prepared for subterranean storage is in fact quite simple and, thus far, has proven to be very effective.[248]

1.238 ARPANSA also explained that alternate policies for the transport of waste would need to be considered:

> A nuclear power program will see a substantial shift to the status quo of transported radioactive waste with increased transportation over potentially new transport routes, and introduction of new types of wastes not currently transported. Transport of radioactive material is a matter of considerable public concern.[249]

1.239 Nuclear for Climate Australia did not see it as difficult for Australia to change its processes to accommodate waste from nuclear energy generation. The group believed that the current regulatory rules covering radioactive waste disposal in Australia could be easily adapted to include high-level waste:

> An Australian Code for Disposal Facilities for Solid Radioactive Waste, ARPANSA 2018] is for low and intermediate level waste.

247 ARPANSA, *Submission 136*, p. 8.

248 Dr Ziggy Switkowski AO, *Proof Committee Hansard*, Sydney, 20 September 2019, p. 31.

249 ARPANSA, *Submission 136*, p. 8.

> This Code could readily be modified to cover disposal facilities for high level waste. The Australian Code is based on the International Atomic Energy Agency General Safety Guide No. GSG-1 Classification of Radioactive Waste (IAEA 2009) which itself covers high level waste.[250]

1.240 Women in Nuclear highlighted that the nuclear industry is not waste-heavy:

> The volume of waste generated from nuclear energy is significantly less than the volumes generated from other forms of energy. More than 95% of a used fuel assembly is recyclable, which also greatly reduces the lifetime of the waste.[251]

1.241 Mr Ian Hore-Lacy from the Australasian Institute of Mining and Metallurgy commented on nuclear waste storage abroad, stating that 'nuclear waste is the most boring aspect of the industry, bar none. The waste is handled. It's well funded. It's extremely safe. It's small in volume.'[252]

Permanent storage facilities for radioactive waste

The National Radioactive Waste Management Facility

1.242 The Australian Government has been working for some years to establish a 'single, safe, purpose-built radioactive waste management facility' in this country.[253]

1.243 The ANU Energy Change Institute submitted that Australia's current arrangements are unsuitable in the long-term and that the facility must be established:

> The current national radioactive waste arrangements are unsustainable in the long term, and the need for a national low-level waste disposal and intermediate-level waste storage facility is clear. Australia has the capability to construct and operate in the long term, a national facility for its own radioactive waste.[254]

250 Nuclear for Climate Australia, *Submission 135*, p. 11.

251 Women in Nuclear Australia, *Submission 154*, p. 4.

252 Mr Ian Hore-Lacy, Senior Adviser Nuclear, Australasian Institute of Mining and Metallurgy, *Proof Committee Hansard*, Sydney, 20 September 2019, p. 31.

253 Department of Industry, Innovation and Science, 'Managing radioactive waste', <https://www.industry.gov.au/strategies-for-the-future/managing-radioactive-waste>, accessed 7 November 2019.

254 ANU Energy Change Institute, *Submission 160*, p. [2].

1.244 The Government's National Radioactive Waste Management Facility Taskforce is considering sites in South Australia,[255] but the planned facility is only intended for low- and intermediate-level radioactive waste, and would not be suitable for high-level waste from nuclear power generation.[256]

1.245 ARPANSA explained that under the legislative framework for this facility:

> …any site for establishing a National Radioactive Waste Management Facility (NRWMF) must be volunteered and subject to a comprehensive process of community consultation. A NRWMF cannot be established unless it meets environmental and regulatory approvals under the ARPANS Act, the EPBC Act and the Safeguards Act.[257]

1.246 The Australian Government is negotiating with communities in South Australia about siting the proposed National Radioactive Waste Management Facility. The Department of Industry, Innovation and Science submitted that:

> Consultations with the communities have been based on the premise that the proposed facility would primarily support the Australian nuclear medicine industry – not a nuclear energy industry. The facility has not been designed for the disposal or temporary storage of high level waste that would result from the nuclear energy cycle. A different type of facility, likely a deep geological one, will be needed for permanent disposal of high level waste.'[258]

1.247 The Committee heard evidence that the negotiations were difficult, and that the communities may not be in favour of the facility. Mr Dave Sweeney from the Australian Conservation Foundation said that:

> Right now, communities in South Australia are taking legal action because they feel disenfranchised about consultation about waste siting.[259]

1.248 A joint submission to the inquiry made by a number of environmental groups and conservation councils said of the plans in South Australia:

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255 Department of Industry, Innovation and Science, 'Managing radioactive waste', <https://www.industry.gov.au/strategies-for-the-future/managing-radioactive-waste>, accessed 7 November 2019.

256 Department of Industry, Innovation and Science, *Submission 211*, p. 1

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

258 Department of Industry, Innovation and Science, *Submission 211*, p. 1.

259 Mr Dave Sweeney, *Proof Committee Hansard*, 1 October 2019, p. 10.

> The current push to establish a national radioactive waste repository and store in SA is strongly contested and aspects of the proposal are currently subject to legal challenges and a Human Rights Commission complaint, initiated by Traditional Owners of the targeted sites.[260]

1.249 Prior consultation undertaken by the South Australian Nuclear Fuel Cycle Royal Commission had also showed that community acceptance was not high, with a 'citizens' jury' convened in 2016 rejecting the construction of a high-level waste repository in the state.[261]

1.250 With regard to the site selection in South Australia, the Committee heard that Indigenous groups may have particular concerns. Mr Dwayne Coulthard from the South Australian Conservation Council told the Committee:

> …we are currently in discussion with the federal government in regard to a nuclear waste facility here in South Australia. There were two preferred nominated sites, those being Kimba and Hawker—Wallerberdina and Barndioota. In the midst of this discussion about nuclear energy, Adnyamathanha people, and Aboriginal people in South Australia, are very much afraid that we're going to be left with a dump site for our next generation.[262]

1.251 Mr Coulthard added:

> We, the people, feel like any destruction to our land is a destruction to our culture, because you can't separate the two. You can't say, 'This little patch of land here is not going to be impacted.' It will have an impact.[263]

1.252 The Australian Human Rights Commission also noted that different parts of the community have alternate views about radioactive waste management:

> Agreement on selecting a site for a waste management facility has proven to be contentious in Australia. This is often due to the divergent positions of many groups, including Indigenous peoples.[264]

1.253 The Commission advised that Article 29(2) of the United Nations Declaration on the Rights of Indigenous Peoples states that 'no storage of

260 Submission by nine national environment groups and state conservation councils, *Submission 219*, p. 36.

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

262 Mr Dwayne Coulthard, *Proof Committee Hansard*, 2 October 2019, p. 2.

263 Mr Dwayne Coulthard, *Proof Committee Hansard*, 2 October 2019, p. 4.

264 Australian Human Rights Commission, *Submission 161*, p. 3.

hazardous materials shall take place on Indigenous lands without their free, prior and informed consent.'[265]

1.254 The Commission added:

> Furthermore, beyond the phases involved for site selection, radioactive waste management facilities will have a long-term impact on the surrounding community, potentially over generations, due to the long half-life of radioactive material. The social, environmental, economic and political context will change over this time which is likely to impact on the nature of Indigenous people's consent. As the site selection process and advanced stages progress, there is potential for Indigenous peoples' consent to change during each phase.[266]

1.255 The Commission submitted that in order for Indigenous people to make informed consent, adequate resourcing to representative groups needs to be provided to ensure appropriate and informed consultation.[267]

1.256 Nuclear for Climate Australia did not consider that completion of the national facility was a necessary prerequisite for commencing a nuclear energy industry:

> Such a central facility for managing and disposing of low and intermediate level waste would be beneficial to the operation of a nuclear power plant but is not essential. If in the unlikely event that the national radioactive waste management facility is not operational by the time a nuclear power plant is operational, then waste from the nuclear power plant would be stored in an interim storage facility like the other radioactive waste already existing in Australia.[268]

A future high-level waste repository

1.257 The Australia Institute commented that worldwide, there are not yet any operating high-level radioactive waste facilities:

> No country has successfully built a deep repository for high-level radioactive waste. Many countries have plans to develop such a repository and one is under construction in Finland. But there is no current example of an operating HLW [high-level waste] repository.[269]

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265 Australian Human Rights Commission, *Submission 161*, p. 4.

266 Australian Human Rights Commission, *Submission 161*, p. 9.

267 Australian Human Rights Commission, *Submission 161*, p. 9.

268 Nuclear for Climate Australia, *Submission 135*, p. 11.

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

1.258 The World Nuclear Association advised that the Finnish facility is due to start accepting high-level waste in 2023.[270]

1.259 Dr Philip White submitted:

> Much is made of Finland's SNF [spent nuclear fuel] disposal program. Of all nuclear nations, its program is the furthest advanced for the disposal of SNF from nuclear power plants. Nevertheless, although a licence has been issued for a repository, no spent fuel has been disposed of yet. It is important to realise that obtaining approval for a geological repository does not prove that SNF and HLW high-level waste can be safely disposed of. It just proves that certain procedural hurdles have been cleared. Given the very long half-lives of some of the radionuclides involved, we will not know whether the project was successful for thousands of years.[271]

1.260 StarCore Nuclear, however, submitted that the Finnish facility would be safe, stating that the project:

> …has had its safety aspects studied very intensely over many years by experts and peer reviewed and even in the most pessimistic scenario, the most highly exposed person would receive an annual radiation dose equivalent to eating several bananas.[272]

1.261 The Committee heard that Australia is suited to hosting an appropriate high-level waste storage repository, owing to stable geology and hydrological conditions.[273]

1.262 Despite this, a number of conservation councils and environmental groups submitted that the high costs of such a repository would be of concern:

> Estimated construction costs for high-level nuclear waste repositories are in the tens of billions of dollars and cost estimates have increased dramatically.[274]

1.263 Their joint submission further stated that:

> Operation of waste repositories adds many billions more to the costs. The US government estimates that to build a high-level

270 World Nuclear Association, *Submission 259*, p. 1.

271 Dr Philip White, *Submission 119*, p. [1].

272 StarCore Nuclear, *Submission 128*, p. [7]. See also section 7 for information about the Banana Equivalent Dose index for understanding radiation exposure.

273 Nuclear for Climate Australia, *Submission 135*, p. 12; Women in Nuclear Australia, *Submission 154*, p. 4; ANU Energy Change Institute, *Submission 160*, p. [2].

274 Submission by nine national environment groups and state conservation councils, *Submission 219*, p. 38.

> nuclear waste repository and operate it for 150 years would cost US$96.2 billion (in 2007 dollars) (A$143 billion), a 67% increase on the 2001 estimate.
>
> The South Australian Nuclear Fuel Royal Commission estimated a similar figure: A$145 billion over 120 years for construction, operation and decommissioning of a high-level nuclear waste repository.[275]

1.264 Nevertheless, waste storage could represent a potential economic benefit for Australia. Dr Ziggy Switkowski AO told the Committee that 'stewardship of the world's nuclear waste may yet prove to be a significant commercial opportunity for Australia'.[276]

1.265 Similarly, the ANU Energy Change institute said:

> …the greatest economic impact of participation in the NFC [nuclear fuel cycle] would be from the storage and disposal of international nuclear waste.[277]

1.266 ANU Energy Change Institute submitted that in addition:

> …waste storage would have significant non-proliferation benefits, by removing the rationale for national reprocessing programs for used fuel management reasons, and by removing national accumulations of used fuel which would otherwise be available for reprocessing in the future.[278]

1.267 Regardless of perceived or actual economic benefit and the suitability of the Australian geography for a repository, some submitters argued that previous experience pointed to likely ongoing resistance to a high-level waste repository in Australia.

1.268 Dr White shared his concerns that gaining public acceptance of disposal sites for spent nuclear fuel (SNF) and high-level waste (HLW) would be difficult:

> In Australia, the history of attempts to gain approval for storage and disposal sites for low and intermediate level radioactive waste has been traumatic and unsuccessful to date, while attempts to persuade the public to accept international SNF and HLW have been a total failure. There is no reason to believe finding a site for disposal of Australian SNF and HLW would be any easier.[279]

275 Submission by nine national environment groups and state conservation councils, *Submission 219*, p. 39.

276 Dr Ziggy Switkowski AO, *Submission 41*, p. 2.

277 ANU Energy Change Institute, *Submission 160*, p. [2].

278 ANU Energy Change Institute, *Submission 160*, p. [2].

279 Dr Philip White, *Submission 119*, p. [2].

1.269 Similarly, The Australia Institute highlighted the difficulties in establishing such a facility:

> There have been many proposals and considerable controversy in Australia over the issue of nuclear waste dumps, for various levels of waste, including HLW, resulting in bitter political fights between and within jurisdictions, and staunch community and legal opposition.[280]

Emerging nuclear technologies and waste

1.270 The Committee received some evidence that emerging reactor technologies offer benefits including reduced waste when compared with older models.

1.271 ANSTO said that Generation IV reactors are more fuel efficient and produce less waste than previous designs.[281]

1.272 Similarly, the Australian Academy of Science advised that some small modular reactors produce less waste due to their higher burn rates, and that SMRs running on thorium as a fuel source produce waste of lower radioactivity.[282]

1.273 Mr James Fleay from Down Under Nuclear Energy (DUNE) commented that waste from the nuclear power industry is comparatively small. He drew comparisons between the volumes of waste produced in nuclear energy generation, with the volumes produced by renewables such as wind or solar:

> I'm not sure how many solar panels there are in Australia, but I would suggest that it's probably in the tens of millions. Globally, it would be more than that. There is a well-known issue that is coming at nations with renewable energy—and it's not insurmountable, but it is being ignored by industry presently—on what to do with solar panels when they get to the end of their 20-year life. At the moment there is no viable recycling pathway for that. Any viable recycling pathway, not only for solar panels but also for wind turbines, requires an enormous amount of energy to reconstitute those components. It may be worth it in time, but the energy needs to come from somewhere. The point is that solar panels and wind turbines currently go into landfill and the cost of that waste stream is not thoroughly acknowledged. We would say

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

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

282 Australian Academy of Science, *Submission 304*, p. [1].

that on a comparative basis the waste streams from nuclear are quite small compared to zero-emissions alternatives.[283]

7. Public health and safety

1.274 The Committee received evidence from many submitters and witnesses opposed to nuclear energy expressing concern about health risks from radiation exposure, and the safety risks posed by nuclear power including potentially catastrophic accidents.

Understanding radiation

1.275 Radiation is energy, travelling as waves or particles.[284] Radiation occurs naturally in the atmosphere and soil, in building materials and in food and drink. People also receive radiation exposure from sources such as X-rays and medical treatments, industrial processes and items such as smoke detectors and digital devices.

1.276 Nuclear energy generation involves the use of radioactive substances throughout the fuel cycle. When discussing nuclear energy, concern about radiation usually refers to ionising radiation, which has the potential to affect normal biological processes.[285]

1.277 Mr Terry Ryan submitted that a useful way to understand different levels of radiation exposure is to consider the Banana Equivalent Dose (BED) measure, developed by the University of California. Bananas contain a small amount of radiation (due to their potassium content), and Mr Ryan provided the table at Figure 1 below comparing various background, medical and nuclear power related exposure levels.[286]

283 Mr James Fleay, Chief Executive Officer, Down Under Nuclear Energy, *Proof Committee Hansard*, Perth, 3 October 2019, p. 6.

284 Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 'Glossary of terms', < https://www.arpansa.gov.au/understanding-radiation/what-is-radiation/radiation/glossary>, accessed 31 October 2019.

285 International Atomic Energy Agency (IAEA), 'Radiation in Everyday Life', <https://www.iaea.org/Publications/Factsheets/English/radlife>, accessed 31 October 2019.

286 Mr Terry Ryan, *Submission 14*, p. 3.

Figure 1 Banana Equivalent Doses (BED) of various forms of radiation exposure

Radiation source	B.E.D
Background radiation in everyday life	
Living one day	100
Flying from Brisbane to Perth	400
Living in a concrete, stone or brick building for one year	700
Six months of an average food intake (or twenty-two bananas per day)	4,000
Modern technology exposures to radiation	
Airport security scan	2.5
Dental x-ray	50
Mammogram	400
Full body CT scan	100,000
Radiation exposures from nuclear power	
Living within 80 km of a nuclear power station	0.9
Average radiation dose within 16 km of the 3 Mile Island accident	800
Visiting Fukushima for 1 hour, 3 km from the reactors 2 months after the accident	1,000
Average dose of Chernobyl residents after 1986 accident	3,500,000
Non-fatal dose for temporary radiation sickness	10,000,000
Fatal dose of radiation leading to death within two weeks	100,000,000

Source *Mr Terry Ryan, Submission 14, p. 3.*

1.278 Mr Ryan advised that the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) estimates that the average annual Australian radiation exposure is equivalent to around 15,000 BEDs.[287]

Public health risks of nuclear power

1.279 Mr Martin Jane submitted that public health was improved by the use of nuclear power, due to reduced reliance on fossil fuels and avoiding their associated health burdens. Mr Jane pointed to over 3,000 deaths per year in Australia that result from the burning of fossil fuels and associated respiratory illnesses, and stated that:

> Nuclear power plants produce no pollution or release any radiation during normal operation… It is estimated by NASA's Goddard Institute that nuclear power plants have saved over 2 million lives by displacing fossil fuel pollution that would have been used instead. If we were to replace fossil fuel generators and

287 Mr Terry Ryan, *Submission 14*, p. 3.

> automation with electricity produced from nuclear power, we would decrease negative health outcomes in Australia.[288]

1.280 However, Dr Peter Tait from the Public Health Association of Australia (PHAA) told the Committee that the use of nuclear power is 'not acceptable from a health perspective', given alternative energy sources that avoid the risks associated with nuclear power.[289]

1.281 Associate Professor Gavin Mudd spoke about the health aspects of uranium mining, and said that renewables are a safer option:

> If you look at the work that has been done internationally through UNSCEAR, the United Nations Scientific Committee on the Effects of Atomic Radiation, when they've looked at these sorts of global dose estimates of the nuclear chain, uranium mining is always very significant in those calculations. That is dominated by the fact that they are assuming exposure only from tailing, so they're not even accounting for waste rock or open cuts and things like that. In terms of relative risk… we also have to look at the different choices of power, and the more I look at these things… I choose renewables any day. I believe they're much safer. The overall public safety, public health costs are much lower. That's even accounting for the radioactivity involved with rare earth mining, which I'm happy to go into if you want me to. But overall I see renewables as much safer.[290]

1.282 Dr Ingrid Johnston from PHAA commented on the health impacts of nuclear accidents:

> Along with the immediate and longer-term physical health issues, psychological and social effects are found. Severe healthcare problems are created by evacuation and long-term displacement, especially for the most vulnerable people such as the elderly and those in hospital. Public health responses required after the Fukushima disaster included the evacuation of 150,000 people; stable iodine prophylaxis to reduce the uptake of radioactive iodine by the thyroid; morgue management for radioactive dead bodies; protection of food and drinking water supply, including monitoring intake of contaminated food and water; monitoring of radioactivity and estimations of exposure; a massive

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288 Mr Martin Jane, *Submission 88*, p. [2]. See also Down Under Nuclear Energy (DUNE), *Submission 159,* p. 12.

289 Dr Peter Tait, Public Health Association of Australia, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 24.

290 Associate Professor Gavin Mudd, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 19.

> decontamination exercise through disposal of contaminated soil and wastes; and public communication around risks.[291]

1.283 SMR Nuclear Technology cited a statement from the UK Tyndall Centre for Climate Change, suggesting that safety risks for nuclear power and renewables are within a similar range:

> In 2013, the UK Tyndall Centre for Climate Change, in a report for Friends of the Earth, found that:
>
> "… overall the safety risks associated with nuclear power appear to be more in line with lifecycle impacts from renewable energy technologies and significantly lower than for coal and natural gas per MWh of supplied energy".[292]

1.284 Professor M V Ramana noted the ongoing problem of radiation exposure, as it relates to waste products from the nuclear industry. In his review of the technical and social problems of nuclear waste, he emphasised that waste remains harmful for as long as it remains radioactive, and that in storing this waste, humans are contending with an unprecedented issue:

> Since radiation is hazardous to health, even at low levels, exposure to these wastes will be harmful to people and other living organisms as long as the wastes remain radioactive. Thus, they have to be isolated from human contact for periods of time that are longer than anatomically modern *Homo sapiens* have been around on the planet.[293]

1.285 Environmental groups submitted:

> The Committee will likely receive submissions stating or implying that there is a threshold below which exposure to ionizing radiation is harmless. Such views are at odds with expert scientific opinion, including:
>
> - The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) states in a 2010 report that "the current balance of available evidence tends to favour a non-threshold response for the mutational component of radiation-associated cancer induction at low doses and low dose rates."
> - The 2006 report of the US National Academy of Sciences' Committee on the Biological Effects of Ionising Radiation (BEIR) states that "the risk of cancer proceeds in a linear fashion

291 Dr Ingrid Johnston, Public Health Association of Australia, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 19.

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

293 MV Ramana, *Submission 95*, Attachment 1, p. 3.

> at lower doses without a threshold and … the smallest dose has the potential to cause a small increase in risk to humans."[294]

1.286 The Australian Nuclear Science and Technology Organisation (ANSTO) submitted that experience has shown that managing waste and spent fuel can be done safely, highlighting its 60 years of efficient waste management[295] and the 25,000 international shipments of used fuel moved without incident.[296]

Health risks for the nuclear workforce

1.287 Some submitters raised concerns about health impacts for workers in the nuclear industry.

1.288 Dr Margaret Beavis from the Medical Association for the Prevention of War (MPAW) said that 'nuclear industry workers also have higher rates of leukaemia and solid cancers'. She also remarked that there had been inadequate monitoring of affected populations following the accidents at Chernobyl and Fukushima, which resulted in significantly understated health impacts.[297]

1.289 Dr Tilman Ruff from the International Campaign to Abolish Nuclear Weapons Australia (ICAN) told the Committee that it is not possible to separate nuclear power from the associated health risk of contamination.[298] Dr Ruff said:

> …there is very clear evidence, from the normal operation of nuclear facilities and from every stage of the nuclear chain along the way, that there are routine emissions and that there are health and environmental costs involved for the workers and for downwind and nearby communities.[299]

1.290 However, the 2016 South Australian Royal Commission into the Nuclear Fuel Cycle concluded that any radiation exposure for workers would be within acceptable limits:

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294 Environment groups and state conservation councils, *Submission 219*, p. 52.

295 Australian Nuclear Science and Technology Organisation (ANSTO), *Submission 166*, p. 12.

296 ANSTO, *Submission 166*, p. 13.

297 Dr Margaret Beavis, Vice-President, Medical Association for the Prevention of War, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 6.

298 Dr Tilman Ruff, International Campaign to Abolish Nuclear Weapons, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 13.

299 Dr Tilman Ruff, International Campaign to Abolish Nuclear Weapons, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 13.

> Data from modern nuclear fuel cycle facilities demonstrates they operate well within the applicable regulatory limits for workers, the public and the environment.[300]

1.291 The Minerals Council of Australia submitted that according to the 2019 Australian National Radiation Dose Register (ANRDR), those working with uranium receive relatively low annual doses of radiation, less than the doses received by airline crews and significantly below the recommended maximum dosages.[301]

Health risks for nearby communities

1.292 The Committee also heard evidence that some studies show increased health risks for people in communities near nuclear power stations.

1.293 The Medical Association for the Prevention of War (MAPW) explained that:

- a German study conducted over 25 years demonstrated that children faced double the risk of leukaemia if living within five kilometres of a nuclear power station, and that their risks remained elevated extending beyond 50 kilometres from a plant.[302]
- A further study conducted in France found similarly increased levels of risk.[303]
- A Swiss study examined the risks of cancer for children living in areas of the nation with higher radiation levels and found 64 per cent more cancers and more than double the risk of leukaemia.[304]

1.294 MAPW also advised that a 2007 analysis supported by the US Department of Energy considered all available, reliable data worldwide, and concluded that there is a 'statistically significant increase in leukaemia for children living near nuclear power plants.'[305]

1.295 Dr Philip White submitted that it is not possible to directly attribute a person's cancer to radiation exposure, but pointed out that studies show that cancer is more likely in those who have been exposed.[306]

1.296 ANSTO, however, did not share this level of concern about the health risks to the community. ANSTO submitted that nuclear power is safe,

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

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

302 Medical Association for the Prevention of War, *Submission 223*, p. 8.

303 Medical Association for the Prevention of War, *Submission 223*, p. 8.

304 Dr Margaret Beavis, Vice-President, Medical Association for the Prevention of War, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 6.

305 Medical Association for the Prevention of War, *Submission 223*, p. 8.

306 Dr Philip White, *Submission 119*, pp. [4-5].

'outperforming other established electricity generation technologies in human health outcomes.'[307]

1.297 Regarding the incidence of cancer resulting from exposure during nuclear accidents, ANSTO cited the example of Chernobyl and stated that increased cancer incidence in the community, related to the accident, had not been established.[308] It submitted that UNSCEAR believed that the effects of the accident on nearby populations were psychosocial rather than negative physical health outcomes.[309]

1.298 Similarly, the Committee was advised that no radiation related illness or deaths have been attributed to the accident in 2011 at Fukushima.[310]

Safety risks of nuclear power

1.299 With regard to nuclear safety, proponents of nuclear power pointed to the low rate of incident compared to the output in terms of energy, while those against nuclear power were generally concerned with the significant consequences should an accident occur.

1.300 The Minerals Council of Australia discussed the historical safety of nuclear power:

> With more than 17,000 cumulative reactor years over the past six decades, nuclear energy generation has resulted in fewer accidents and many fewer deaths and worker injuries than other energy generation sources.[311]

1.301 Down Under Nuclear Energy (DUNE) concurred, highlighting that nuclear power is the safest form of energy generation in terms of the number of deaths per unit produced.[312]

1.302 ARPANSA CEO Mr Carl-Magnus Larsson said that safety 'begins with understanding that accidents can occur' and depends upon technological and human factors.[313]

1.303 Professor Lyndon Edwards from ANSTO further contended that historic accidents and the acceptance of risk has resulted in a safer nuclear industry:

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

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

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

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

311 Minerals Council of Australia, *Submission 266*, p. 13.

312 Down Under Nuclear Energy (DUNE), *Submission 159*, p. 12.

313 Mr Carl-Magnus Larsson, Chief Executive Officer (CEO), Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), *Committee Hansard*, Sydney, 29 August 2019, p. 13.

> …we all accept that in the aviation industry accidents happen. We accept that risk all of the time when we fly. We also accept that every accident makes the industry safer. That means that, when we fly, we accept the risk. Incidents have gone down. Deaths have gone down. It's got better and better. Philosophically, for the nuclear industry, it's presented the other way around: every accident seems to make nuclear less safe, when actually it makes it safer. This is how continuous improvement happens.[314]

1.304 Mr Logan Smith explained to the Committee he saw the common opinion of 'nuclear is dangerous' as an invalid argument, comparing safety within the nuclear industry to safety regulations in other sectors of the economy:

> One of the things that comes up—and it's come up a few times today—is that nuclear is dangerous, and I don't consider this a valid argument. I've worked in mining, I've worked in gas and I'm currently working in construction, and, I can tell you right now, in all of those industries every day there are hazards that, if left unchecked, will kill you—hazards like arc flash, confined space, pressurised equipment, BLEVE, suspended loads falling from heights…hydrofluoric acid… However, such risks in industry are managed. We have engineering controls, preventative maintenance, isolation procedures, safe work method statements, barricading and exclusion zones. Radiation protection is just one facet of the overall ethos of working safely in the workplace.[315]

1.305 Mr Michael Wright (Electrical Trades Union) said:

> Inherently electricity itself is dangerous. You can't see it, you can't smell it and you can't touch it…when all is going well in nuclear, as it usually does, the risks are lower than for comparable generation…The risk of catastrophic damage in which, ordinarily, there will be no survivors in a power plant is the risk that we talk about when we talk about the risk. It is true that there is risk involved in all areas of electricity generation, but again we see the catastrophic risk as being too great in nuclear energy.[316]

314 Professor Lyndon Edwards, National Director, Australian Generation IV International Forum Research, Australian Nuclear Science and Technology Organisation (ANSTO), *Committee Hansard*, Sydney, 29 August 2019, p. 14.

315 Mr Logan Smith, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 41.

316 Mr Michael Wright, Electrical Trades Union, *Proof Committee Hansard*, 9 October 2019, p. 36.

1.306 PHAA submitted that:

> The nuclear fuel process is unsafe - there are direct health and environmental consequences from radioactive leaks, and there is potential contamination at all stages of the process.[317]

1.307 Dr Margaret Beavis from the Medical Association for the Prevention of War said that safety issues are relevant at all stages of the nuclear fuel cycle, not only during power generation at reactor sites. She told the Committee:

> …uranium is a key component of nuclear power generation. BHP's Olympic Dam mine in South Australia is exempt from many legislative and regulatory controls. BHP has a record of mine tailings dam failures—most notably, their mine in Brazil in 2015, which destroyed a village and killed 19 people… In June this year, after pressure from investor stakeholders after the dam failures, BHP released a global assessment of all its tailings facilities—where all its mining waste is piled up… five are listed as 'extreme risk'. Extreme risk—and this is an estimate from BHP's own engineers—is a potential loss of life of at least 100 workers. It also means that environmental rehabilitation of the site would be impossible.
>
> Of these five extreme risk sites, one is in the USA, and that mine has been closed. The remaining four extreme risk tailings facilities…are all in Australia. Three out of four are at Olympic Dam. These extreme risk tailings facilities represent a complete failure of regulation of worker safety and also of environmental safety. Yet this year BHP applied to build another tailings facility, and it is highly likely that they will be able to build another one.[318]

Nuclear accidents

1.308 Many critics of nuclear power pointed to three major reactor accidents as evidence of the risks to public health and safety: those at Three Mile Island (1979, USA), Chernobyl (1986, Ukraine, former USSR) and Fukushima (2011, Japan).

1.309 Dr Philip White, for example, submitted that:

> In the Japanese case, a myth of nuclear safety was deliberately propagated by nuclear proponents. Indeed, the belief in absolute safety permeated the nuclear industry itself, including the

317 Public Health Association of Australia, *Submission 141*, p. [2].

318 Dr Margaret Beavis, Vice-President, Medical Association for the Prevention of War, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 6.

> regulators. Anything that challenged this myth was covered up. This included failing to acknowledge or take measures to address known safety risks for fear that to do so would frighten the public and give ammunition to nuclear critics. That is, of course, in addition to the desire to avoid additional expense. This safety myth and this reluctance to address safety problems was one of the root causes of the 2011 Fukushima Daiichi nuclear accident. … The 1986 Chernobyl disaster was dismissed by the nuclear establishment as a problem specific to Soviet type reactors, but the Fukushima Daiichi nuclear accident proved that optimism to be misplaced.[319]

1.310 Others, however, disputed the relevance of these examples when considering a nuclear energy industry in Australia. Bright New World submitted that radiation exposure to the community from the Three Mile Island accident was 'equivalent to a chest x-ray'.[320] ANSTO submitted that there had been no established increase in cancer risk in communities surrounding Chernobyl,[321] and it was noted that there were no recorded deaths from radiation in the Fukushima disaster.[322]

1.311 ANSTO submitted that in all three accidents, poor safety culture, operational, design and emergency response flaws were contributing factors.[323]

New technology and passive safety

1.312 The Committee heard evidence that new reactor technologies would include design aspects that make them safer than the current fleet of reactors used throughout the world.

1.313 SMR Nuclear Technology asserted that emerging small modular reactors would be much safer than traditional nuclear reactors:

> Modern SMR designs have now become a game-changer for nuclear safety. Although traditional reactors are safe, SMRs take safety to a new level of "walk-away safety". For example, the NuScale SMR does not require any operator action, backup electrical supplies or water supplies and would have survived even the Fukushima accident. The passive safety systems enable

319 Dr Philip White, *Submission 119*, pp. [3]-[4].

320 Bright New World, *Submission 168*, p. 15.

321 ANSTO, *Submission 166*, p. 15. However see Dr Donald Higson, *Submission 139*, Attachment 1, p. [2], stating that around 4,000 cases of thyroid cancer are attributed to the accident.

322 Ian Hore-Lacy, 'Nuclear Energy in the 21st Century', 4th edition, 2018, p. 99.

323 ANSTO, *Submission 166*, p. 16.

> the reactor to be cooled indefinitely without attention - "indefinite cooling time".[324]

1.314 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.[325]

1.315 Down Under Nuclear Energy (DUNE) submitted that critics of nuclear energy are erring by comparing historical accidents to current and emerging reactor technologies:

> If we are serious, we need to discuss risk of accidents with current generation reactors or what is known as Gen III and Gen IV. These include small modular reactors. It is as silly to look at risk in terms of problems with second generation reactors designed in the 1960's as it is to look at airline safety with reference to the Hindenburg zeppelin disaster.
>
> In essence, current and coming reactors are completely contained and have passive safety systems. This means that in case of an accident such as an earthquake or monster tsunami the reactors [*sic*] cooling system functions without any external intervention or the need for external power.
>
> In the case of more advanced designs and small modular reactors a meltdown is virtually impossible. Most of these achieve the nuclear triple crown – no power, no additional water and no operator action required to achieve indefinite cooling.[326]

1.316 Mr Tristan Prasser pointed out that the older technologies that have suffered accidents in the past are no longer available for would-be nuclear nations to purchase:

> The reality is that designs connected to previous nuclear power plant accidents are no longer on the market and thus out-of-scope for consideration. Newer advanced reactor designs (such as Small Modular Reactors (SMRs)) that are coming online or in development are inherently safe as they are designed to operate on the laws of physics rather than use 'active' safety mechanisms.

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

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

326 Down Under Nuclear Energy (DUNE), *Submission 159*, p. 12.

> This makes the possibility of a Chernobyl-style meltdown significantly reduced or simply physically impossible.[327]

1.317 ANSTO, discussing new Generation IV technology reactors, agreed that the designs are 'inherently safe' and could be considered 'walk-away safe' by nuclear regulators.[328] CEO Dr Adi Paterson told the Committee that new technology was resulting in safer reactors:

> There's a subset of small modular reactors that are under development around the world which are based on a more rigorous safety case, which is called passive safety. It's an oversimplification, and I really don't want to oversimplify a complex matter, but the principle of passive safety is that, basically, the laws of physics and how fluids move and how cooling can be effected are the primary drivers of the safety case. You are not dependent on human intervention in order to achieve the safety objective and the safety envelope of passively safe small modular reactors.[329]

The role of the regulator

1.318 The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is the Australian Government's nuclear safety regulator and chief authority on radiation protection.[330] As discussed above, ARPANSA told the Committee that it would need further resourcing to achieve the necessary competencies and programs to regulate a national nuclear power industry.

1.319 Dr Margaret Beavis of the Medical Association for the Prevention of War was concerned that safety culture was deficient in Australia:

> Here in Australia it is self-evident that there is an enormous problem with the safety culture at ANSTO. For many years, there have been repeated accidents and worker exposures, with repeated reprimands and breaches from the regulator, ARPANSA. There have been repeated allegations of management bullying and blaming individual workers.
>
> There have also been numerous near misses. An independent inquiry last year made 85 recommendations to improve safety. Clearly, at ANSTO a safety culture is missing. One has to ask if the

327 Mr Tristan Prasser, *Submission 274*, p. 2,

328 ANSTO, *Submission 166*, pp. 4-5.

329 Dr Adi Paterson, Chief Executive Officer, ANSTO, *Committee Hansard*, Sydney, 29 August 2019, p. 10.

330 Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), *Submission 136*, p. 1.

> ANSTO board and senior management understand the critical need for a safety culture. If a small government funded research reactor can't operate safely, what hope is there for the safe operation of a large reactor?[331]

1.320 ARPANSA's view was that increased numbers of radiation incidents reflected increased reporting rather than more occurrences.[332] ARPANSA and ANSTO advised the Committee that they were working to address the recommendations made in the 2018 safety review referred to by Dr Beavis.[333] Further, ANSTO submitted that over the past twenty years, only five safety incidents had been reported where a person received a radiation dose in excess of the statutory limit, and that only one of those persons displayed physical symptoms.[334]

8. Security and non-proliferation

1.321 The Committee was told that there are a number of security implications associated with operating nuclear power reactors in Australia. These implications include:

- risks of sabotage on facilities;
- risks of theft of nuclear materials from facilities; and
- wider implications for possible nuclear weapons proliferation.[335]

Current safeguards in Australia

1.322 The key agency governing nuclear security in Australia is the Australian Safeguards and Non-Proliferation Office (ASNO). 'Safeguards' refers to the 'total system for accounting for nuclear materials', and constitutes the measures taken to ensure non-proliferation commitments are fulfilled.[336]

1.323 ASNO's responsibilities include:

- the application of nuclear safeguards in Australia;

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331 Dr Margaret Beavis, Vice-President, Medical Association for the Prevention of War, *Proof Committee Hansard*, Melbourne, 1 October 2019, p. 6.

332 ARPANSA press release, 'Radiation safety incidents in Australia', 1 August 2019, <https://www.arpansa.gov.au/news/radiation-safety-incidents-australia>, accessed 5 November 2019.

333 Mr Carl-Magnus Larsson, CEO, ARPANSA, *Committee Hansard*, Sydney, 29 August 2019, p. 9; ANSTO, *Supplementary Submission 166.1*, Answer to Questions on Notice, p. [1].

334 ANSTO, *Supplementary Submission 166.1*, Answer to Questions on Notice, p. [2].

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

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

- the physical protection and security of nuclear items in Australia;
- the operation of Australia's bilateral safeguards agreements; and
- contribution to the operation and development of International Atomic Energy Agency (IAEA) safeguards and the strengthening of the international nuclear non-proliferation regime.[337]

1.324 The *Nuclear Non-Proliferation (Safeguards) Act* 1987 (Cth) (Safeguards Act), administered by ASNO, applies to 'all nuclear facilities and all nuclear material in Australia'. The Act provides the framework for ASNO to prevent 'acts of theft or sabotage', and also gives effect to Australia's obligations under various treaties and agreements.[338]

1.325 Within Australia, ASNO is responsible for issuing various permits to industry in respect of nuclear materials. While the legislative moratorium would need to be lifted to permit a nuclear power industry to be established in Australia, ASNO noted that the Safeguards Act does not prohibit the granting of a permit to establish or operate a nuclear power reactor.[339]

1.326 ASNO further advised that the construction of nuclear power reactors in Australia would not 'substantially affect the application of IAEA safeguards in Australia' but would increase IAEA inspections and reporting. ASNO stated that if Australia were to establish a nuclear energy industry, further responsibilities for the regulator would need to be determined.[340]

1.327 The International Campaign to Abolish Nuclear Weapons Australia (ICAN) listed a number of problems it had identified with the current safeguards regime:

- under-resourcing;
- national sovereignty, commercial confidentiality and secrecy;
- accounting discrepancies due to conflicting assumptions and measurement issues surrounding fissile materials; and

337 Department of Foreign Affairs, Defence and Trade, 'About the Australian Safeguards and Non-Proliferation Office', <https://dfat.gov.au/international-relations/security/asno/Pages/about-the-australian-safeguards-and-non-proliferation-office.aspx>, accessed 12 November 2019.

338 ASNO, *Submission 153*, p. [1].

339 ASNO, *Submission 153*, p. [1].

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

- breakdown of safeguards in time of conflict.[341]

1.328 Additionally ICAN explained that the IAEA safeguards only begin at the stage of uranium enrichment, that the IAEA has 'no mandate' to prevent the misuse of nuclear facilities and materials, and countries may invoke their right to pull out of the Nuclear Non-Proliferation Treaty and develop a weapons capability, as North Korea has done.[342]

Security and proliferation considerations for a future Australian nuclear power industry

Risk of nuclear sabotage

1.329 Some evidence received described nuclear power plants as targets[343], posing a major threat to Australian security.[344] Examples included physical attacks on infrastructure[345], the possibility of insider attacks[346], and cyber attacks.[347]

1.330 The Medical Association for the Prevention of War (MAPW) submitted that 'a major coolant loss caused by accident or malice could cause a massive release of radioactive isotopes into the surrounding environment, with profound consequences in terms of morbidity, mortality, social disruption, tourism and agriculture...'.[348]

1.331 MAPW noted the importance of proper planning and risk assessment to mitigate the threat of 'deliberate attacks on infrastructure'. The submission added:

> …to date there have been no major incidents involving terrorism at nuclear facilities but multiple attempts and minor incursions, including involving the research reactor in Sydney.[349]

1.332 The MAPW submission noted reports that nuclear facilities face near-daily cyber-attacks.[350] Dr Philip White also discussed cyber security, explaining

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341 International Campaign to Abolish Nuclear Weapons Australia (ICAN), *Submission 157,* pp. 7-8.

342 ICAN, *Submission 157,* pp. 7-8.

343 Sample of Friends of the Earth campaign submission (405) received, *Submission 306*, p. [1].

344 Ms Julia Greenhill, *Submission 124,* p. [1]; Electrical Trades Union, *Submission 164*, p. 7; Sample of the Australian Conservation Foundation campaign submission (5,104 received), *Submission 296*, p. [1].

345 Medical Association for the Prevention of War, *Submission 223*, p. 14.

346 Medical Association for the Prevention of War, *Submission 223*, p. 15.

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

348 Medical Association for the Prevention of War, *Submission 223*, p. 14.

349 Medical Association for the Prevention of War, *Submission 223*, p. 14.

350 Medical Association for the Prevention of War, *Submission 223*, p. 15.

that it can be 'compromised by the use of third-party contractors who conduct maintenance activities, as well as contractors who update software and hardware and conduct monitoring.'[351]

1.333 Dr White also submitted that nuclear facilities are 'not failsafe against cyber-intrusions'[352], and went on to warn that:

> …a conventional military attack or a cyber attack would result in a direct cost to the nuclear facility due to physical damage and loss of output, but the greater concern is the potential for such an attack to precipitate a catastrophic accident.[353]

1.334 The 2006 Switkowski Review found that:

> While proliferation of nuclear weapons remains a critical global issue, increased Australian involvement in the nuclear fuel cycle would not change the risks; nor would Australia's energy grid become more vulnerable to terrorist attack.[354]

1.335 MAPW noted that the US Nuclear Regulatory Commission (NRC) considers nuclear power plants as 'difficult targets due to them being low lying and the reactor core being a small target'.[355]

1.336 ASNO noted that the IAEA provides advice and assistance to states to establish appropriate security infrastructure and to respond to cyber threats.[356]

Risk of nuclear theft

1.337 Dr John Kalish from ASNO said that one of the main threats associated with nuclear security is the potential theft of nuclear material.[357]

1.338 Dr Kalish assured the Committee that ASNO uses a risk-based approach to 'prevent and mitigate' such threats. He said that Australia's arrangements are based on the current 'nuclear footprint' and would need to be amended if Australia introduced nuclear power.[358]

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351 Dr Philip White, *Submission 119*, p. [10].

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

353 Dr Philip White, *Submission 119*, p. [10].

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

355 Medical Association for the Prevention of War, *Submission 223*, p. 14.

356 ASNO, *Submission 153*, p. [2]. See also Medical Association for the Prevention of War, *Submission 223*, p. 15.

357 Dr John Kalish, Assistant Secretary, Australian Safeguards and Non-Proliferation Office, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 40.

358 Dr John Kalish, Assistant Secretary, Australian Safeguards and Non-Proliferation Office, *Proof Committee Hansard*, Canberra, 18 October 2019, p. 40.

1.339 Dr Kalish suggested that locating a nuclear reactor underground provides 'additional capacity to safeguard material and reduces the likelihood of theft'.[359]

1.340 A joint submission by a number of environment groups and conservation councils highlighted IAEA reporting that showed a total of 424 confirmed incidents of 'unauthorised possession and related criminal activities' in the period from January 1993 to December 2013.[360]

1.341 Fuelling a nuclear power industry would require the movement of significant amounts of nuclear materials, both new and used. ASNO submitted that nuclear material is 'most vulnerable during transport'.[361] In his submission, Mr David Jones noted that a nuclear power industry would result in more fuel in transit, and warned of a 'consequent risk of domestic or international terrorist groups obtaining access to radioactive nuclear material and using it in attacks on the Australian population'.[362]

Proliferation issues

1.342 Some evidence to the inquiry noted a link between nuclear power and nuclear weapons.[363]

1.343 The Nuclear Non-Proliferation Treaty (NPT)[364] is the key international agreement regulating the use of nuclear technology. Under the NPT, non-nuclear-weapon States parties commit themselves not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, while nuclear-weapon States parties commit not to assist, encourage or induce others to manufacture or acquire them.[365]

1.344 The IAEA is entrusted with verifying states' compliance with the NPT and other non-proliferation agreements, including through its inspection system.[366]

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

360 Submission by nine national environment groups and state conservation councils, *Submission 219*, p. 57.

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

362 Mr David Jones, *Submission 249*, p. 7.

363 International Campaign to Abolish Nuclear Weapons Australia (ICAN), *Submission 157*, p. 2; Medical Association for the Prevention of War, *Submission 223*, p. [1].

364 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).

365 International Atomic Energy Agency, 'Non-Proliferation Treaty', <https://www.iaea.org/topics/non-proliferation-treaty>, accessed 11 November 2019.

366 International Atomic Energy Agency, 'Safeguards legal framework', <https://www.iaea.org/topics/safeguards-legal-framework>, accessed 11 November 2019.

1.345 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.[367]

1.346 Further, ICAN submitted:

> …any moves towards nuclear power could be read as a proliferative signal to our neighbours. In other words, if Australia were to adopt nuclear power, other states in our region might seek this technology to lower the barriers to a weapons capability – even if there was no such agenda in Australia.[368]

1.347 The Medical Association for the Prevention of War submitted that:

> There are clear historical and current links between the nuclear power industry and nuclear weapons proliferation. Any proposal for Australia to acquire nuclear power is likely to fuel suspicion as to our motives … and this could in turn promote regional nuclear weapons proliferation.[369]

1.348 The Electrical Trades Union submitted that 'nations in our region may view Australian nuclear aspirations with suspicion and concern'.[370]

1.349 ICAN provided a list of nations aligning nuclear energy and weapons programs:

> There is a long history of nation-states using civil nuclear programs as cover for weapons programs – five of the ten countries that have produced nuclear weapons did so under cover of a civil program (South Africa, Pakistan, India, Israel and North Korea) and power reactors have been used to produce plutonium for weapons in most or all of the other five nation-states.[371]

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

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

369 Medical Association for the Prevention of War, *Submission 223*, p. [1].

370 Electrical Trades Union, *Submission 164*, p. 7.

371 ICAN, *Submission 157*, p. 1.

1.350 MAPW added France and the UK to this list, stating these nations 'have used civilian reactors to supply plutonium for their nuclear weapons.'[372]

1.351 MAPW also noted a German survey regarding the driving force behind acquiring nuclear energy:

> The German Institute for Economic Research recently surveyed the 674 nuclear power plants that have ever been built. They found that an examination of economic history confirmed that electricity has primarily been used as a coproduct of nuclear power generation. The driving force was military developments and interests, primarily generating weapons-grade plutonium and, especially in the U.S. in the 1950s, developing pressurized water reactor technology to drive submarines.[373]

1.352 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'.[374]

1.353 SMR Nuclear Technology submitted that:

> Australia was one of the first countries to sign and ratify the 1970 *Treaty on the Non-Proliferation of Nuclear Weapons (NPT)* confirming Australia's position as a nation that will not acquire nuclear weapons. In addition to the safeguards agreement required by the NPT, in 1997 Australia was the first country to sign the *IAEA Safeguards Additional Protocol* giving inspectors rights of access to any site.[375]

Emerging nuclear technologies and required safeguards

1.354 The Committee was told that new reactor technologies, including small modular reactors (SMR), have design features that may lower their security and proliferation risks.[376] ASNO submitted that 'establishing the appropriate security and safeguards arrangements in Australia to meet international standards is readily achievable'.[377]

372 Medical Association for the Prevention of War, *Submission 223*, p. 4.

373 Medical Association for the Prevention of War, *Submission 223*, pp. 4-5.

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

375 SMR Nuclear Technology Pty Ltd, *Submission 39*, pp. 2-3.

376 ASNO, *Submission 153*, p. [3].

377 ASNO, *Submission 153*, p. [3].

1.355 Dr John Kalish from ASNO said that small modular reactors offer a level of 'proliferation resistance.'[378] He advised that SMRs would use smaller quantities of fuel making theft less attractive. He added:

> If the fuel assemblies are modular and they are put into the system and maintained there for many years, there is less movement and exchange of material, so again proliferation sensitivity is reduced and in fact nuclear security is also potentially increased in that situation…
>
> There are a range of other aspects. There is also a suggestion that the small modular reactors would involve what's called high burn-up. So the fuel would remain in the reactor for a long period of time. That reduces the utility of that spent fuel for reprocessing in the production of a plutonium 239 device, because more of the material within the reactor forms a non-fissile form of plutonium, plutonium 240.[379]

1.356 Thorium fuel reactors are another example of an emerging technology which may reduce the risk of proliferation. A number of submitters explained that the thorium process does not produce fissile material suitable for nuclear weapons production.[380]

1.357 On the other hand, ANSTO cautioned that the production of uranium-233 during the thorium fuel cycle 'presents a potential proliferation risk that would require similar safeguards to those that are established for the current uranium fuel cycle'.[381] ICAN submitted that:

> …the proliferation risks associated with thorium are comparable to the risks associated with conventional uranium reactor technology.[382]

1.358 Further, ICAN claimed that other emerging technologies, such as 'integral fast reactors', 'molten salt reactors' and other small modular reactors, were also able to produce fissile material for nuclear weapons.[383]

1.359 Dr Kalish said that locating facilities in remote areas posed challenges for security, as the ability for appropriate armed or police forces to intervene

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

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

380 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.

381 ANSTO, *Submission 166,* p. 7.

382 ICAN, *Submission 157*, p. 3.

383 ICAN, *Submission 157*, pp. 4-5.

in the event of an incident may be reduced, and as remote locations may present opportunities for easier intrusions.[384]

9. National consensus and community engagement

1.360 Many submitters to the inquiry discussed the importance of community acceptance to any successful establishment of nuclear energy in Australia. One submission summarised that 'the single biggest challenge for this inquiry will be to gain public support'.[385]

1.361 Dr Ziggy Switkowski said:

> 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.[386]

1.362 During the inquiry, the Committee's attention was drawn to a number of surveys of public opinion in relation to nuclear power, with varying results. A Roy Morgan survey on Australian Attitudes to Global Warming was conducted in September 2019. Key findings published on 7 October 2019 included that:

- 51% of respondents believed Australia should develop nuclear power to reduce Australia's carbon dioxide emissions, a rise of 16% since 2011. 34% opposed nuclear power in Australia and 15% were undecided.
- When the question was asked without the reference to reducing carbon emissions, 45% were in favour of nuclear power and 40% against.
- 58% of respondents would oppose a nuclear power plant being built in their area (down 17% since 2011).
- Support for nuclear power in Australia was distinguished by gender, with 65% of men and 38% of women in favour.[387]

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

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

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

387 Roy Morgan, 'A narrow majority of Australians want to develop nuclear power to reduce carbon dioxide emissions', *Finding No.8144,* 7 October 2019, https://www.roymorgan.com/findings/8144-nuclear-power-in-australia-september-2019-201910070349.

1.363 The Australia Institute submitted the findings of its 2019 *Climate of the Nation* report:

> nuclear power remains greatly divisive in Australia. Asked about their preferred source of energy, 22% placed nuclear in their top three and 11% placed it first, a small increase over the previous year. Yet even more placed it last (34%) and most (59%) placed it in their bottom three, making nuclear about as unpopular as coal.[388]

1.364 Dr Switkowski and others believed the 2011 Fukushima disaster had reversed a previously growing level of support for nuclear power in the Australian community.[389]

1.365 The Committee received evidence that public sentiment had shifted on this issue, and that the majority of the Australian community today was unlikely to oppose the introduction of nuclear energy. Mr James Graham, for example, submitted:

> Most Australians understand Australia's narrowing energy options and the challenge these present. They would be accepting of nuclear energy provided it is safely and responsibly implemented, with any potential for proliferation eliminated.[390]

1.366 Nuclear for Climate Australia submitted that community presentations conducted by the Australian Nuclear Association were hearing a change:

> The issues being raised by the public at these presentations are evolving. Two or three years ago they were reactor safety, radiation and cancer. These days a level of real interest exists in actually how nuclear energy can meet both our economic and environmental needs. Positivity is replacing anxiety.[391]

1.367 The Minerals Council of Australia submitted that:

> Nuclear power's safety record demolishes the argument that nuclear energy should be banned because it is dangerous. Its public acceptance in communities around the world where it has operated for decades negates the argument that it should be banned because communities do not accept it. Despite two decades of legal prohibition, nuclear energy commands net

388 The Australia Institute, *Submission 167,* p. 36 (footnote omitted).

389 Dr Ziggy Switkowski, *Proof Committee Hansard,* 29 August 2019, p. 3. See also Mr Gershon Nimbalker, *Submission 109,* p.[1]; Dr Phillip White, *Submission 119,* p. [2]; Dr Donald Higson, *Submission 139,* p. [3].

390 Mr James Graham, *Submission 104,* p. 10.

391 Nuclear for Climate Australia, *Submission 135,* p. 29. See also VIMY Resources, *Submission 251,* p. 4; Australian Taxpayers' Alliance, *Submission 263,* p. 11.

> positive support in Australia in the most recent polls, shattering the argument that the public is not ready for it to be legal.[392]

1.368 However, the Committee also received many expressions of strong continued opposition to nuclear energy in Australia. These included a 'Civil Society Statement on Domestic Nuclear Power' opposing nuclear energy, endorsed by 55 non-governmental organisations including environmental, union, church-based and professional groups.[393]

1.369 In addition, campaigns conducted by two non-government organisations generated 5636 form letters and short submissions from individuals to the inquiry.[394] These comprised:

- 4535 identical letters from supporters of the Australian Conservation Foundation (ACF);
- 569 copies of the ACF letter with additional or amended text included by the submitters;
- 337 identical letters from supporters of Friends of the Earth (FoE);
- 68 copies of the FoE letter with additional or amended text included by the submitters; and
- 127 short submissions received via the 'DoGooder' campaign website. All but a handful of these expressed opposition to the introduction of nuclear energy in Australia.

1.370 One point repeatedly made to the Committee by those both for and against nuclear power was that bipartisan political support would be necessary to gain community acceptance.[395] Mr Anthony Wood emphasised the importance of meeting 'as fellow Australians seeking solutions to our perceived problems and willing to judge proposals on their merits', rather than 'as antagonists trying to overwhelm opposition to some preconceived solution developed in the party room'.[396]

1.371 Nuclear for Climate Australia believed that '[t]he chances for a bi-partisan approach may be enhanced by the use of community forums where short term political opportunism can be defused'.[397]

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392 Minerals Council of Australia, *Submission 266*, p. 5.

393 *Submission 172.*

394 See *Submission 282*, *Submission 296* and *Submission 306*.

395 See, for example, Mr Michael Angwin, *Submission 50,* p. [6]; Mr Ronald James, *Submission 89,* p. 11; Dr Phillip White, *Submission 119,* pp. [8-9]; Nuclear for Climate Australia, *Submission 135,* p. 31; Dr Ian Burston, *Submission 215*, p. 1; 1Medical Association for the Prevention of War, *Submission 223,* p. 18; Mr Trevor Robotham, *Proof Committee Hansard,* 1 October 2019, p.46; Mr Barry Murphy, *Proof Committee Hansard,* 9 October 2019, p. 55.

396 Mr Anthony Wood, *Submission 116,* p. [3].

397 Nuclear for Climate Australia, *Submission 135,* p. 30.

Public education and community consultation

1.372 The Committee received evidence recommending public education and further discussion of the issues related to energy.

1.373 For example, Mr Anthony Wood submitted that '[o]n global warming we heed the advice of the experts. On reactor accidents we listen to anecdotal evidence often by the media which is usually designed to impress rather than inform'. He recommended more public education about radiation and nuclear issues, including in schools.[398] Mr Geoff Russell argued that once modern science was understood, '[p]ublic angst will drop to a realistic level and risks associated with nuclear power will be seen for what they are; far lower than those of air travel or bacon, for example'.[399]

1.374 Dr John Patterson commented on the citizen jury sessions held following the South Australian Royal Commission. He said:

> I attended as an observer two of the citizen jury sessions. …afterwards I spoke to a few of the delegates, and the message that came back from the general public was that they were confused. I spoke to, in particular, a couple of ladies there who said, 'For every argument that the experts put on one side, there's a counterargument on the other side, and we don't know who to believe.' So I leave that to you regarding the discussions on social licence, which are very important, I understand. Somehow we need to communicate to the general public and try to remove some of this confusion that I experienced after those citizen juries.[400]

1.375 Nuclear for Climate Australia submitted that:

> The lessons learned from the South Australian Nuclear Fuel Cycle Royal Commission with community engagement must not be repeated. Rushing to a "Citizens Jury" that lasted over a few weekends was a mistake. Understanding and assimilating the benefits of nuclear energy takes time and people need to become familiar with the issues.[401]

1.376 Nuclear for Climate Australia recommended that community consultations needed to focus on the key issues of environmental impact, reprocessing and disposal of waste, electricity prices, training and employment opportunities, and safety concerns.[402]

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398 Mr Anthony Wood, *Submission 116,* pp. [4-5].

399 Mr Geoff Russell, *Submission 93,* p. 3.

400 Dr John Patterson, *Proof Committee Hansard*, 2 October 2019, p. 6.

401 Nuclear for Climate Australia, *Submission 135,* p. 30.

402 Nuclear for Climate Australia, *Submission 135,* p. 31.

1.377 The ANU Energy Change Institute submitted the findings of a national symposium of around 70 participants held in 2017 to discuss the outcomes of the South Australian Royal Commission. The symposium assessed that 'a social licence to operate will not be achieved quickly. It will take time, transparency and extensive consultation'. The symposium concluded that 'distributed fairness and procedural fairness were critical to building trust and acceptance', as was confidence in government to be able to manage the personal and environmental risks associated with nuclear energy.[403]

1.378 The symposium recommended:

> that expertise in the humanities and social sciences be engaged to study the evolution and determining factors for public opinion on nuclear issues in Australia. This could be facilitated by engaging the Australian Academy of the Humanities (AAH) and the Academy of Social Sciences in Australia (ASSA) to propose jointly with the cosponsors of the Symposium, an [Australian Council of Learned Academies] ACOLA research project on the [nuclear fuel cycle] social license to operate…[404]

1.379 Mr Ronald James offered a recommendation to 'develop and deliver extensive Australia-wide community awareness and consultative programs to "bring the community" on the journey.[405] Mr James expanded on his views in this regard at a public hearing of the Committee:

> A major public awareness program will be the deciding factor to enable the successful introduction of nuclear energy into Australia…I believe the first things that need to be done, assuming those prerequisites are acknowledged, are to undertake a comprehensive public education and awareness program about the benefits of nuclear energy in the 21st century and to amend the *Australian Radiation Protection and Nuclear Safety Act 1998* and the *Environment Protection and Biodiversity Conservation Act 1999* to permit the development of nuclear power. Since these acts were proclaimed the issue of climate change has gained massive momentum, and this legislation is now grossly out of date and counterproductive. We need to develop a plan for long-term sustainability of energy supply that identifies where we are now, where we want to be in 2050 and how we get there.[406]

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

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

405 Mr Ronald James, *Submission 89,* p. 18.

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

1.380 Some views advised caution or expressed scepticism about public education. For example, Ms Noel Wauchope offered a view on public education programs:

> …those who are pro-nuclear believe that the only experts we need to listen to are engineers, nuclear engineers, chemists that relate to the nuclear industry—people who are already involved in the nuclear industry…I feel that if there were an education program it would happen the way it's happening in America. The nuclear lobby would set up little groups in universities, give the universities plenty of funding and promote the story that only nuclear engineers know what it's all about.[407]

1.381 Mr David Jones argued that both in Australia and globally, the nuclear industry has 'a poor record of community engagement', and added that:

> The nuclear power industry and its protagonists typically characterise opposition to nuclear power generation as "uninformed", "emotional" and "ideological".
>
> The reality is that community opposition to nuclear power generation is generally both well-informed and based on sound rational objections.[408]

1.382 Mr Michael Angwin noted the importance of focusing on trust, stating that '[t]here is a rational basis for nuclear fear and it cannot be overcome by the wider and wiser collection and dissemination of facts…Nuclear fear can only be addressed by building trust and then nurturing it'.[409] Mr Angwin added that a trust-based strategy must be based on behaviour rather than narrative, respect people's fears and concerns, and acknowledge that sufficient community support may or may not be forthcoming.[410]

1.383 The South Australian Government reflected on its experience:

> The Royal Commission emphasised the critical importance of social consent to the adoption of any new nuclear activity (including nuclear power) finding that:
>
> > Efforts over recent decades internationally to develop nuclear projects by focusing on technical considerations without an equal or even greater emphasis on systematic engagement with the community have commonly failed.

407 Ms Noel Wauchope, *Proof Committee Hansard*, 1 October 2019, p. 38.

408 Mr David Jones, *Submission 249,* p. 6.

409 Mr Michael Angwin, *Submission 50,* p. [1].

410 Mr Michael Angwin, *Submission 50,* pp. [5], [7-8].

> Further, the Royal Commission's report identified several key characteristics of successful processes that had sought community consent for new types of nuclear facilities. These characteristics included:
>
> - Transparency of decision making;
> - Willingness to accept long community engagement timeframes;
> - Early and deep engagement with local communities to build knowledge and understanding; and
> - Availability of scientific evidence and where necessary, multiple corroborating bodies of evidence to demonstrate the effectiveness of steps taken to address risks.[411]

1.384 Ms Chloe Munro from the Australian Academy of Technology and Engineering suggested that the Government's approach to wind farms could provide a useful model for community consultation:

> As a part of the package for settling the review of the Renewable Energy Target, the Australian government established the National Wind Farm Commission. I think that has been very successful in terms of the quality of community engagement that the commissioner has embarked on. There were a number of communities that had concerns or some open complaints. The commissioner was very diligent in visiting those communities and resolving those issues. He was very firm in his findings and also reported on the quality of engagement by the industry and made recommendations on how that could be improved. I think that's had enormous benefit for the acceptability of wind generation in the communities. Not all communities are necessarily going to be settled in that view, but the intensity of that process, I think, has been very helpful. It strikes me that, if Australia were to pursue nuclear power, some equivalent function of a nuclear power commissioner who could lead that community engagement and deal very directly with local concerns would be a very helpful approach.[412]

1.385 Mr Gershon Nimbalker submitted, however, that 'marketing spin and government sponsored efforts' would be counter-productive, and instead proposed that governments '[w]ork with effective grassroots campaigners to get the message across', and focus on 'authentic and credible stories' from people who live with or near nuclear power.[413]

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411 Government of South Australia, *Submission 297,* p. 5.

412 Ms Chloe Munro, *Proof Committee Hansard*, 1 October 2019, p. 48.

413 Mr Gershon Nimbalker, *Submission 109,* p. [1].

1.386 Although opposed to the introduction of nuclear energy in Australia and believing it would be divisive, Dr Phillip White offered the following view:

> One tool… could be to foster deliberative forums which enable ordinary citizens to objectively consider Australia's climate and energy options. The process could begin at the local level and build on these local discussions towards state-based and/or national forums. Politicians should listen carefully and respectfully to the considered opinions that emerge and studiously resist the temptation to use them for partisan purposes.
>
> Nuclear energy could be one of the options that is discussed. Participants need to be given the opportunity to weigh up the merits and demerits of all the alternatives. The concern is not that ordinary citizens would not make sound judgements in a free and open deliberative process. Rather, it is that politicians and bureaucrats would try to rig the process to achieve a predetermined outcome.[414]

1.387 Professor John Quiggin submitted that the only way to achieve national consensus in support of nuclear power is to achieve 'unequivocal acceptance of mainstream climate science', and the adoption by government of 'radically more ambitious goals' to reduce CO2 emissions.[415]

1.388 Dr Heiko Timmers proposed that Australia may in the next twenty years focus on nuclear measures other than establishing a nuclear power capacity, such as sustained export of yellowcake (uranium), contributing to international research and establishing a successful spent fuel repository, as part of 'taking ethical and environmental responsibility for the planet and helping to limit carbon-dioxide emissions'. Such measures 'may generate an increased confidence among Australia's citizens that nuclear technologies can be managed safely and that they can be good for the nation'.[416]

Indigenous land

1.389 The Committee received evidence relating to Indigenous Australians' relationship with the land, and the importance of their consent in relation to decisions about nuclear facilities. This mainly focused on proposals to establish nuclear waste disposal facilities, as discussed above.

414 Dr Phillip White, *Submission 119,* pp. [8-9].

415 Professor John Quiggin, *Submission 16,* p. 3.

416 Dr Heiko Timmers, *Submission 63,* p. 3.

1.390 Associate Professor Peter Speck said:

> Indigenous Australians… are… not terribly trusting of governments, and, given that a lot of nuclear assets are likely to be sited in out-of-the-way places, the Indigenous Australian view is one that I believe should be carefully considered, and there should be a great deal of respectful consultation undergone with Indigenous Australians and the broader population.[417]

1.391 The Australian Human Rights Commission (AHRC) provided a submission about Australia's obligations under international human rights law to ensure the consent of Indigenous peoples for radioactive waste management facilities. In this context, the AHRC elaborated on the meaning of the human rights principle of 'free, prior and informed consent':

> It is much stronger than an obligation simply to provide information or 'consult' with Indigenous peoples. Obtaining free, prior and informed consent entails a process of ongoing discussion and engagement with Indigenous peoples. Furthermore, processes of engagement must be able to accommodate the complexities and inter-relatedness of Indigenous societies and a wide range of issues and players. The process must therefore be managed on a case-by-case basis and not through a 'one-size-fits-all' model of consultation. [418]

1.392 More generally, Mr Dwayne Coulthard from the South Australian Conservation Council told the Committee that:

> A lot of these uranium deposits and a lot of the stuff that you find in uranium are very much associated with sacred stories and sacred sites. A lot of the minerals and such that you would find associated with sacred sites are very much connected with the stories that the old people would tell…So any discussion about creating a nuclear energy reactor, small or large—it would obviously happen on Aboriginal land, so that would obviously have to be taken into consideration, because it's a long legacy to leave.[419]

1.393 Councillor Dominic Wy Kanak requested that:

> …the Committee apply an Aboriginal First Nations Indigenous 'Sovereignty' lens to all the Committee's Terms of Reference for this Inquiry…and seek as a fundamental prerequisite the views

417 Professor Peter Speck, *Proof Committee Hansard,* 2 October 2019, p. 26.

418 Australian Human Rights Commission, *Submission 161,* p. 6 (footnote omitted).

419 Mr Dwayne Coulthard, *Proof Committee Hansard*, 2 October 2019, pp. 1-2.

> and Approval of the First Nations Peoples of Australia. As Custodians, Descendants of Our Commonwealth's First Nations Peoples should decide if there should be any change to the moratoriums currently preventing an expansion of the nuclear industry in Australia.[420]

1.394 Cr Wy Kanak expressed the view that without First Nations consensus, the national consensus required for nuclear energy 'is void'.[421] He noted the long history of opposition to nuclear facilities by Australia's Aboriginal people, and inadequate consultation in relation to past nuclear testing and activities on Indigenous land, and requested that the Government dispense with proposals for nuclear energy and instead focus on how to move to a 100 per cent renewable energy market.[422]

1.395 The Committee heard from Aboriginal women representing the Australian Nuclear Free Alliance, including Ms Shelly Haseldine, who said:

> I was fortunate enough to grow up on my father and grandmother's country, on the far west coast of South Australia, in Ceduna…My grandmother's strong desire to keep the land as it is has inspired me to follow in her footsteps and protect our beautiful country and our cultural way of life. Through my grandmother's experiences I have grown up witnessing the after-effects of the nuclear bomb test at Maralinga and Emu Field. I am currently undergoing tests for thyroid issues, and so is my nanna. As a young Aboriginal woman, I have seen and familiarised myself with how the government has continuously ignored Indigenous and wider community calls to stop uranium mining and nuclear usage, which both threaten all of our futures.[423]

1.396 Mr Coulthard also spoke about the shadow cast by past nuclear activities on Australia's Indigenous communities:

> The atomic testing was back in the fifties, and they're still talking about it today in regard to the impacts it had. It remains very much a contentious issue for the communities, especially as the interface that we've dealt with it through is mining. There hasn't been any real discussion within Aboriginal communities, and what this actually means would need to be explained quite clearly. But, like I said, the previous history certainly left a bad taste…

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420 Cr Dominic Wy Kanak, *Submission 22,* p. [1].

421 Cr Dominic Wy Kanak, *Submission 22,* p. [1].

422 Cr Dominic Wy Kanak, *Submission 22,* p. [3].

423 Ms Shelly Haseldine, *Proof Committee Hansard,* 18 October 2019, p. 21.

> especially in South Australia, which, as I hear, is one of the leaders in renewable energy. Yet here we are talking about a nuclear reactor or creating nuclear energy here in Australia.[424]

1.397 Mr Coulthard commented on how nuclear energy should be discussed with Indigenous communities:

> I can't speak on behalf of all Aboriginal people here in South Australia. I'll only speak on behalf of, I guess, my own experience engaging with communities where English could be a second, third or even fourth language for some people in our state…
>
> One of our biggest things is that you have to find a way to explain the process without being so verbal. So I would strongly encourage that a lot of visual presentations are used and diagrams to take it away from these technical terms…That language won't necessarily be accessible or won't be readily understood by certain communities…It's actually quite technical and quite scientific. So my suggestion would be to contact the local community. Get a community spokesperson or engagement officer that can help you facilitate any kind of discussions, because, like I said, this is a very technical aspect that can really just fly over a community's head if they're not given their own opportunity to engage with that information in a way that's done by them, for them. So empowering community to be part a of this process rather than just participants and actually being engaged in a way that really makes them feel like they're being spoken with, not to or on behalf of. They're actually leading the conversation.[425]

1.398 Professor Hans Bachor from the Australian Academy of Science said:

> The Indigenous communities must be engaged respectfully and any form of tension must be avoided. This includes ensuring Indigenous communities are involved in the decision-making process, avoiding tactics that result in division between Indigenous communities and avoiding exerting pressure on traditional owners, including legal threats.[426]

424 Mr Dwayne Coulthard, *Proof Committee Hansard*, 2 October 2019, p. 2.

425 Mr Dwayne Coulthard, *Proof Committee Hansard*, 2 October 2019, p. 2.

426 Professor Hans Bachor, *Proof Committee Hansard,* 18 October 2019, p. 33.

B

Appendix B - Submissions

Submissions

1	Mr Gavin Brown
2	Mr Jonathon Peter
3	Ms Glenda Maxwell
4	Mr Paul Savi
5	Mr Stuart Allinson
6	EcoEnviro Pty Ltd
7	Professor Derek Abbott
8	Mr Ian Fischer
9	Mr David Gates
10	Mr Paul Myers
11	Professor Keith Thompson
12	Mr Barry Murphy
13	Mr Peter Briggs
14	Mr Terry Ryan
15	Mr Denys Smith
16	Professor John Quiggin
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17 Mr Terje Petersen
18 Mr Allen Tripp
19 Mr Rob Watson-Smith
20 Dr Matthew Gustafson
21 Mr John Hallam
22 Cr Dominic Wy Kanak
23 Mr Ian Bennett
24 Mr Stephen Brown
25 Mr Greig Meyer
26 Mr John Drake
27 Mr Alan Hewett
28 Mr Robert Gishubl
29 ThorCon US
30 Mr Richard Legar and Ms Lyn Allenn
31 Mr Geoff Billard
32 Ms Trish Frail
33 Mr Bruce McDonald
34 Mr Dale Hess
35 Mr Goronwy Price
36 Friends of the Earth Australia
37 Dr Geoffrey Hudson
38 Mr Eric Gribble
39 SMR Nuclear Technology Pty Ltd
40 Mr Gerard Van Hees
41 Dr Ziggy Switkowski AO
42 Mr Allen Biggins
43 Dr Susan Tregeagle
44 Ms Helen Smith

45	Mr Gregory Wolfe
46	Mr David Allen
47	Mrs Jacqualine McCarroll
48	Mr Mark Fitzsimmons
49	Ms Peggy Fisher
50	Mr Michael Angwin
51	Ms Claudia Tregoning
52	Ms Jenny Lovric
53	Mr Clif Barker
54	Hydricity Systems
55	Mr Stuart McConville
56	Dr Tom Biegler
57	Mr Fred Tropp-Asher
58	Mrs Carmel Laycock
59	Mr Arnaud Coquillard
60	Mr Barrie Hill
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66	Mr Sandor von Kontz
67	Australian Petroleum International Exploration and Development
68	Mr Chris Mills

69	Dr Richard Barnes
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73	American Nuclear Society
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75	Ms Heidi Hardisty
76	Ms Angela Rossen
77	Ms Valerie Fricker-Hampton
78	Ms Jan Whittome
79	Unions Shoalhaven
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90	Ms Leonie Stubbs
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93	Mr Geoff Russell

94	Mr Naveesh Reddy Kondakalla
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127	Mr Charles Pope
128	StarCore Nuclear (Canada)
129	Mr Bernd Felsche
130	Mr James Stewart

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131 Queensland Resources Council

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132 Mr Michael Hart MP

133 Dr Elizabeth Flann

134 Submarine Institute of Australia

135 Nuclear For Climate Australia

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136 Australian Radiation Protection and Nuclear Safety Agency

137 Mr John Huntley

138 Mr Dallas Lane

139 Dr Donald Higson

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140 CSIRO

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141 Public Health Association of Australia (PHAA)

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142 Dr David Sadedin

143 Clean Energy Council

144 Nuclear Economics Consulting Group

145 Professor John Fletcher, Dr Edward Obbard and Dr Patrick Burr

146 Mr Geoff Bailey

147 Mr Neil Smith

148 The Terra Verde Group

149 Mr John Wise

150 Mr Christopher Skinner

151 Australian National University

152	Ms Frieda Thompson
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185	Ms Elizabeth Dangerfield
186	Mr Colin Macgregor
187	Mr Terry Vanden Bergh
188	Mr Rob Hinds
189	Ms J Corcoran
190	Miss Bronwyn Kemp
191	Mr Tom Bond
192	Name Withheld
193	Dr Tanya Karlson
194	Ms Tracey Anton
195	Mr Digby Jacobs
196	Mr John Newlands
197	Mr Trevor Robotham
198	Mr Adam Corrie
199	Flibe Energy, Inc.
200	Dr John Patterson

201	Dr John Graham OAM
202	Mr Brian Monaghan
203	Miss Khuslah Juggeewon
204	Australasian Institute of Mining and Metallurgy
205	Ms Lisa McKenna
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225	Associate Professor Gavin Mudd
226	Mr Mnemosyne Giles
227	Dr Simon Ward and Dr Robyn Delaney
228	Ms Judy Blyth
229	South East MP Engagement Group
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234	Energy Policy Institute of Australia
235	Mr Robert Laird
236	Ms Brenda Huggett
237	Maritime Union of Australia
238	Resource Futures Pty Ltd
239	Unions Tasmania
240	Ms Gemma Ruting
241	Australian Young Generation in Nuclear
242	Name Withheld
243	Mr Paul Cahill
244	Mr Simon Coburn and Mr Chris Case

245	Roger Merridew
246	Australian Energy Market Operator (AEMO)
247	Ms Elicia O'Reilly
248	Ms Barbara Hartley
249	Mr David Jones
250	Austrian Embassy Canberra
251	VIMY Resources
252	Mr Aaron Oakley
253	Mr Ivan Quail
254	Mr Ian Turnbull
255	University of Technology Sydney and OntarioTech University
256	Mr Paul Langley
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285	Ms Kaye Guth
286	Nautilus Generators
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287	Ms Debra John
288	Kairos Power
289	South Australian Nuclear Energy Systems (SANES)
290	Australian Workers' Union (AWU)
291	Mr Damian Heran
292	Ms Mirka Heran
293	P & M Wilson

294	Ms Jacqueline Fox
295	Dr Jonathan Koomey Ph.D
296	Sample of the Australian Conservation Foundation campaign submission 5,104 received
297	Government of South Australia
298	R. Admiral Andrew Robertson RAN (Rtd)
299	Miss Shaantay Quiroz Jesus
300	Mr Alister Hertel
301	Mr Allan Williams
302	Mr Clem Grieger
303	Mr Michael Shellenberger
304	Australian Academy of Science
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306	Sample of Friends of the Earth campaign submission 405 received
307	Natural Resources Canada
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308	Department of the Environment and Energy
309	Dr Matthew Stocks

*Readers are advised to check this list against the list of submissions on the Committee's website.

C

Appendix C - Exhibits

Exhibits

1. Booklet – *Roadmap to Nowhere – the myth of powering the nation with renewable energy* by Mike Conley and Tim Maloney December 2019 (related to submission 112)
2. Australian Nuclear Association – Slides of presentation given to the Committee on 28 August 2019
3. Charles Pope – Book is entitled *Living with Radiation: How to be a Nuclear Greenie.* (related to submission 127)
4. Australian Nuclear Association chart Australia's carbon emissions sources
5. Climate Future – IPCC Global emissions pathway characteristics
6. DVD disks "Moltex Energy" and "Desalination"
7. 'Hinkley Point Nuclear Plant Building Costs Rise by up to £2.9bn'
8. 'Nuclear Power: Still Not Viable Without Subsidies'
9. 'Sun in the Box would Store Renewable Energy for the Grid'
10. 'Let's Change the Power that Changes the World'
11. 'NuScale: Power for all Humankind'
12. 'Nuclear Industry – Policy Position Statement'
13. 'International Energy Outlook 2019 – with Projections to 2050'
14. 'European Electricity Sector Decarbonisation Under Different Levels of Foresight'

15. ‘Nuclear Energy Mission’ - Electricité de France

16. ‘Radioactive Waste Management in Switzerland’ - Embassy of Switzerland

17. ‘Rosatom SMR energy solution’ - State Atomic Energy Corporation of Russia

D

Appendix D – Public Hearings

Thursday, 29 August 2019 - Sydney

Private capacity

Dr Ziggy Switkowski AO

Australian Energy Market Commission

Ms Suzanne Falvi, Executive General Manager, Security and Reliability

Dr Tim Nelson, Executive General Manager, Strategy and Economic Analysis

Australian Energy Market Operator

Mr Tony Chappel, Chief External Affairs Officer

Dr Alex Wonhas, Chief System Design and Engineering Officer

Australian Energy Regulator

Mr Mark Feather, General Manager, Policy and Performance

Ms Michelle Groves, Chief Executive Officer

Australian Nuclear Science and Technology Organisation

Professor Lyndon Edwards, National Director Australian Generation IV International Forum Research

Mr Steven McIntosh, Senior Manager, Government and International Affairs, Office of the Chief Executive Officer

Dr Adrian (Adi) Paterson, Chief Executive Officer

Australian Radiation Protection and Nuclear Safety Agency

Mr Carl-Magnus Larsson, Chief Executive Officer

Mr James Scott, Chief Regulatory Office

Monday, 30 September 2019 - Brisbane

Private capacity

Mr David Gates

Mr Ronald James

Professor John Quiggin

Mr Steven Robertson

Mr Desmond Scahill

Mr Jonathan Shaw

Mr Adrian Stephan

Queensland Resources Council

Mr Ian Macfarlane, Chief Executive

Tuesday, 1 October 2019 - Melbourne

Private capacity

Mr Adam Corrie

Ms Rosamund Krivanek

Associate Professor Gavin Mudd

Mr Trevor Robotham

Mr Logan Smith

Ms Noel Wauchope

Mr John Wise

Australian Academy of Technology and Engineering

Ms Chloe Munro, Deputy Chair, Energy Forum

Australian Conservation Foundation

Mr Dave Sweeney, Policy Analyst and Nuclear Campaigner

Australasian Institute of Mining and Metallurgy

Mr Stephen Durkin, Chief Executive Officer

Mr Ian Hore-Lacy, Fellow

Friends of the Earth Australia

Dr Jim Green, President and National Nuclear Campaigner

Grattan Institute

Mr Tony Wood, Energy Program Director

International Campaign to Abolish Nuclear Weapons

Dr Tilman Ruff, Founding Chair and Committee Member

Medical Association for Prevention of War

Dr Margaret Beavis, Vice-President

Melbourne Energy Institute

Mr Michael Brear, Director

Wednesday, 2 October 2019 – Adelaide

Private capacity

Professor Derek Abbott

Dr John Patterson

RADM Kevin Scarce AC CSC RAN (Rtd)

Associate Professor Peter Speck

Conservation Council of South Australia

Mr Dwayne Coulthard, Representative

Bright New World

Mr Dayne Eckermann, General Manager

Dr Benjamin Heard, Founder

Thursday, 3 October 2019 – Perth

Private capacity

Dr Ian Duncan

Cameco Australia Pty Ltd

Mr Simon Williamson, General Manager

Citizens Climate Lobby

Mr Humphrey Boogaerdt, Member

Mr Ivan Quail, Member

Conservation Council WA

Ms Mia Pepper, Nuclear Free Steering Committee Monitor

Down Under Nuclear Energy

Mr James Fleay, Chief Executive Officer

Nuclear Now Alliance Australia

Dr Stuart Hatch, Founder

Wednesday, 9 October 2019 – Sydney

Private capacity

Dr John Graham

Dr Donald Higson

Mr Roderick Hislop

Miss Bronwyn Kemp

Mr Robert Laird

Mr Colin Macgregor

Mr Barry Murphy

Australian Nuclear Association

Dr John Harries, Secretary

Dr Mark Ho, President

Australian Taxpayers Alliance

Mr Satyajeet Marar, Director of Policy

Australian Young Generation in Nuclear

Ms Julia Garside, President

Mr Julian Milthorpe, Vice President

Australian Workers Union

Mr Misha Zelinsky, Assistant National Secretary

Climate Future

Mr Richard Weller, Convenor

Electrical Trades Union of Australia

Mr Michael Wright, National Assistant Secretary

Energy Policy Institute of Australia

Mr Robert Pritchard, Executive Director

Professor Stephen Wilson, Board Member

Institute of Energy Economics and Financial Analysis

Mr Timothy Buckley, Director, Energy Finance Studies, Australasia

Nelson Parade Action Group

Mr Mario Raciti, Member

Nuclear for Climate Australia

Mr Barrie Hill, Associate

Mr Robert Parker, Founder

SMR Nuclear Technology Pty Ltd

Mr Tony Irwin, Technical Director

Women in Nuclear Australia Inc

Ms Pamela Ameglio, Executive Committee Member

Mrs Patricia Gadd, Committee Member

Wednesday, 16 October 2019 - Canberra

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Jane Coram, Director, Land and Water

Dr Jennifer Hayward, Senior Research Scientist

Dr Dirk Mallants, Senior Principal Research Scientist

Mr John Phalen, Chief Research Consultant, Science Strategy

Geoscience Australia

Mrs Marina Costelloe, Acting Branch Head, Mineral Systems

Dr Andrew Cross, Senior Commodity Specialist

Mr Andrew Feitz, Section Leader

Friday, 18 October – Canberra

Private capacity

Professor Andrew Blakers

Mr Simon Holmes à Court

Dr Ian Liley

Professor Ian Lowe

Mr Roger Merridew

Ms Elizabeth PO'

Mr Terry Ryan

Mr Bill Stefaniak, AM, RFD

Associate Professor Heiko Timmers

Australian Academy of Science

Mr Christopher Anderson, Director Science Policy

Professor Hans Bachor AM, Secretary for Education and Public Awareness

Australian International Thermonuclear Experimental Reactor Forum

Dr Richard Garrett, Member

Associate Professor Matthew Hole, Chair

Australian Nuclear Free Alliance

Ms Patricia (Trish) Frail, Community Member

Mrs Suezanne Haseldine, Co-president

Ms Shelly Haseldine, Junior Member

Ms June Norman, Committee Member

Department of Foreign Affairs and Trade

Dr Stephan Bayer, Director, Nuclear Security Section, Australian Safeguards and Non-Proliferation Office

Dr John Kalish, Assistant Secretary, Australian Safeguards and Non-Proliferation Office

Mr Jeff Robinson, Assistant Secretary, Arms Control and Counter-Proliferation Branch, International Security Division

Engineers Australia

Mr Tony Irwin, Chairman, Sydney Division Nuclear Engineering Panel

Mr Steven Rodgers, Senior Policy Adviser

Law Council of Australia

Ms Robyn Glindemann, Chair, Australian Environment and Planning Law Group, Legal Practice Section

Dr Leonie Kelleher OAM, Deputy Chair, Australian Environment and Planning Law Group, Legal Practice Section

Minerals Council of Australia

Mr Patrick Gibbons, Principal Adviser, Energy, Coal and Uranium

Mr Daniel Zavattiero, General Manager, State and Territory Relationships

People for Nuclear Disarmament

Mr John Hallam, Nuclear Weapons Campaigner

Public Health Association of Australia

Mr Ingrid Johnston, Senior Policy Officer

Dr Peter Tait, Convener, Ecology and Environment Special Interest Group

The Australia Institute

Mr Richard Merzian, Climate and Energy Program Director

Mr Tom Swann, Senior Researcher, Climate and Energy Program

The Australian National University

Professor Tim Senden, Director Research School of Physics

Dr Matthew Stocks, Research Fellow

Professor Andrew Stuchbery, Head, Department of Nuclear Physics and Australian National University 'energy Change Institute

Tuesday, 22 October 2019 – Canberra

Private capacity

Mr Stephen Thomas

World Nuclear Association

Dr Jonathan Cobb, Senior Communication Manager

Mr Philippe Costes, Senior Adviser, Staff Director of the Economics and Law Working Groups

Mr David Hess, Policy Analyst

Ms Charlotta Sanders, Staff Director of the Waste Management and Decommissioning, Sustainable Used Fuel Management, and Radiological Protection Working Groups

Wednesday, 23 October 2019 – Canberra

Department of Industry, Innovation and Science

Ms Samantha Chard, General Manager National Radioactive Waste Management Facility Taskforce

Mr Jason Russo, General Manager, Resources Strategy Branch Resources Division

Mr David Thurtell, Manager, Resources Economics, Office of the Chief Economist

Department of the Environment and Energy

Mr Sean Sullivan, Acting Deputy Secretary, Energy

Mr Tim Wyndham, Assistant Secretary, Energy Security Branch

Thursday, 24 October 2019 – Canberra

Private capacity

Professor M.V. Ramana

*Readers are advised to check this list against the witnesses listed in public hearing transcripts (Committee Hansard) available on the Committee's website.