PARLIAMENT OF VICTORIA

LEGISLATIVE COUNCIL
Environment and Planning Committee

Inquiry into nuclear prohibition

Parliament of Victoria
Legislative Council Environment and Planning Committee

Ordered to be published

VICTORIAN GOVERNMENT PRINTER
November 2020
PP No 181, Session 2018–2020
ISBN 978 1 922425 12 6 (print version), 978 1 922425 13 3 (PDF version)

Committee membership

Cesar Melhem
Western Metropolitan

Clifford Hayes
Southern Metropolitan

Dr Matthew Bach
Eastern Metropolitan

Melina Bath
Eastern Victoria

Jeff Bourman
Eastern Victoria

David Limbrick
South Eastern Metropolitan

Andy Meddick
Western Victoria

Dr Samantha Ratnam
Northern Metropolitan

Nina Taylor
Southern Metropolitan

Sonja Terpstra
Eastern Metropolitan

Participating members

Georgie Crozier, Southern Metropolitan
Dr Catherine Cumming, Western Metropolitan
Hon. David Davis, Southern Metropolitan
Dr Tien Kieu, South Eastern Metropolitan
Bev McArthur, Western Victoria
Tim Quilty, Northern Victoria

About the Committee

Functions

The Environment and Planning Committee (Legislation and References) is established under the Legislative Council Standing Orders Chapter 23—Council Committees and Sessional Orders.

The Committee's functions are to inquire into and report on any proposal, matter or thing concerned with the arts, environment and planning the use, development and protection of land.

The Environment and Planning Committee (References) may inquire into, hold public hearings, consider and report on other matters that are relevant to its functions.

The Environment and Planning Committee (Legislation) may inquire into, hold public hearings, consider and report on any Bills or draft Bills referred by the Legislative Council, annual reports, estimates of expenditure or other documents laid before the Legislative Council in accordance with an Act, provided these are relevant to its functions.

Government Departments allocated for oversight:

- Department of the Environment, Land, Water and Planning
- Department of Premier and Cabinet.

Secretariat

Michael Baker, Committee Manager
Vivienne Bannan, Inquiry Officer
Caitlin Connolly, Research Assistant
Justine Donohue, Administrative Officer

Contact details

Address Legislative Council Environment and Planning Committee
Parliament of Victoria
Spring Street
EAST MELBOURNE VIC 3002

Phone 61 3 8682 2869

Email epc.council@parliament.vic.gov.au

Web www.parliament.vic.gov.au/epc-lc

This report is available on the Committee's website.

Contents

Terms of Reference

On 14 August 2019, the Legislative Council agreed to the following motion:

That this House requires the Environment and Planning Committee to inquire into, consider and report, within 12 months*, on potential benefits to Victoria in removing prohibitions enacted by the *Nuclear Activities (Prohibitions) Act 1983,* and in particular, the Committee should—

1. investigate the potential for Victoria to contribute to global low carbon dioxide energy production through enabling exploration and production of uranium and thorium;
2. identify economic, environmental and social benefits for Victoria, including those related to medicine, scientific research, exploration and mining;
3. identify opportunities for Victoria to participate in the nuclear fuel cycle; and
4. identify any barriers to participation, including limitations caused by federal or local laws and regulations.

* Reporting date extended to 30 November 2020.

Chair’s foreword

The current energy market in Australia is in a state of transition, with major fossil fuel (coal) power generation plants reaching the end of their life and being replaced by other sources of electricity generation. Concerns about climate change and the impact of fossil fuels on carbon emissions, not only within Australia but globally, has driven this shift away from fossil fuels towards variable renewable energy sources. It is this need to shift towards low‑emissions power generation that the question of nuclear power has been raised in recent years.

Currently nuclear power plays no role in energy generation in Australia and never has. In fact, since the *Nuclear Activities (Prohibitions) Act 1983* (Vic) was enacted, there has been a legal prohibition on the construction and operation of nuclear facilities in Victoria. In addition to the Victorian legislation, Commonwealth laws also prohibit the use of nuclear energy for electricity generation across Australia.

It is this legal prohibition of nuclear energy production that has been the focus of this Inquiry.

During the course of the Inquiry, which attracted 80 submissions and during which the Committee held six days of public hearings of witnesses from Australia and overseas, the Committee heard a range of evidence both supporting and opposing the removal of the legal prohibitions on nuclear energy.

In this report, the Committee makes no recommendations and does not take a strong position on nuclear power as an alternative energy source in Australia, and particularly in Victoria.

It is clear that currently, it is not possible to accurately cost nuclear energy, as no nuclear energy industry exists in Australia and therefore any costing would be speculative and based on experiences of other countries with different infrastructure. However, figures produced by the CSIRO would indicate that traditional nuclear energy generation is currently expensive and unlikely to be taken up in Australia.

It will be interesting to see over the next few years whether new nuclear technologies, such as small modular reactors (SMRs) which are in the final stages of development, change the costing of nuclear energy over time.

Of course, the cost is only one element of the viability of nuclear power. Issues of waste management, public and environmental safety, potential health impacts and a range of other issues would need to be carefully considered before nuclear power became a reality in Australia. These are all addressed in the report.

The Committee undertook this Inquiry knowing that changes to the Victorian legislation would, in and of themselves, not lead to any significant change in the likelihood of nuclear power in Australia becoming a reality, given the overarching bans that exist at the national level. However, the Inquiry provided useful information that will be available to policymakers into the future.

In concluding this Inquiry, my final one as Chair of the Committee, I would like to thank the Committee members for the diligent and professional way they conducted themselves. Nuclear power has a long history of inciting significant passions, with both proponents and opponents feeling very strongly about the issue. While there were issues throughout the Inquiry that were the subject of dispute within the Committee, I believe that the report is balanced and fair.

I would also like to thank the Secretariat of the Committee, namely Mr Michael Baker, Committee Manager, Ms Vivienne Bannan, the Inquiry Officer, Research Assistant Ms Caitlin Connolly and the administrative staff, particularly Ms Justine Donohue, for the professional and skilled way they dealt with difficult subject matter. Their efforts were greatly appreciated by all members of the Committee and they should be commended.

Finally, I would like to make the point that this Inquiry has been undertaken entirely during the COVID-19 pandemic, with its substantial restrictions. Both Committee members and staff should be commended for managing to complete a complex inquiry under difficult circumstances and meeting deadlines throughout. The Committee has been prepared to adapt, with the help of technology, and to complete its work on time and for this I believe all involved can be justly proud.

Cesar Melhem MP
Chair

Findings

4 National energy policy and nuclear power in the National Electricity Market

FINDING 1: Regardless of technology development, priority should be given to the security, stability and accessibility of energy supply and the need to lower carbon emissions due to climate change and to ensure affordable energy. 58

5 Costs of nuclear energy

FINDING 2: Current estimates of the cost of nuclear energy in Australia are unreliable and accurately costing the full cost is not possible without a detailed business case being undertaken. 72

FINDING 3: Notwithstanding the ambiguities of the costings, the Committee received substantial evidence that nuclear power is significantly more expensive than other forms of power generation and it is recognised that, currently, nuclear is at the high end of the cost-range across all technologies. 72

FINDING 4: A business case is unlikely to be undertaken, given its costs and resources required, while a prohibition of nuclear energy activities remains and there is not likelihood of a plant being able to be built. 72

FINDING 5: Without subsidisation a nuclear power industry will remain economically unviable in Australia for now. 72

6 Nuclear fuel cycle and power generation

FINDING 6: Discussion about Victorian participation in the nuclear fuel cycle is entirely theoretical while the Commonwealth prohibitions remain in place. 84

FINDING 7: Until there is a change in the Commonwealth position, detailed discussions about emerging technologies in Victoria related to the nuclear fuel cycle and power generation are unlikely to advance. 106

8 Nuclear energy issues: waste management and the environment

FINDING 8: The success of any radioactive waste strategy relies on a level of acceptance and confidence across government, industry and the broader community of its legitimacy, effectiveness and integrity in its ability to deal with all facets of waste management, storage and disposal, including the long-term health and safety of workers, affected communities, particularly First Nations Peoples, and the environment. 159

FINDING 9: Those who propose a policy shift have not presented any argument, data or proof in support of their position that cannot be nullified by those arguing against. Any advantages are speculative in nature, and do not outweigh the identified and proven risks. 159

10 Nuclear activities in Victoria

FINDING 10: The nuclear medicine industry is not hindered significantly by the current prohibitions against uranium or thorium exploration and mining. Current legislative prohibitions only prohibit mining and the construction or operation of certain nuclear facilities, such as nuclear reactors. This does exclude Victoria from hosting a nuclear research reactor or other nuclear facilities which could be used to increase supply of radioisotopes for medical or industrial purposes. The Committee notes that if Victoria did seek to establish a research reactor, Victorian and Commonwealth prohibitions would need to be repealed to allow this to happen. Therefore, a repeal of just Victorian legislation would not be sufficient to expand our involvement in nuclear medicine beyond what is currently permissible. 196

FINDING 11: The current market for this material is receiving enough supply from international import and the OPAL reactor at Lucas Heights. The Committee does not believe that fully repealing the *Nuclear Activities (Prohibitions) Act 1983* would have a material influence on the nuclear medicine sector, as it is unlikely Victoria's involvement would increase beyond its current capacity. 197

FINDING 12: The Committee is not convinced that thorium exploration and mining is economically or technologically viable for Victoria. 198

1 About the Inquiry

1.1 Introduction

This Chapter introduces the *Inquiry into Nuclear Prohibition*. It includes the Inquiry's Terms of Reference and evidence gathering process, consisting of submissions, public hearings and research carried out by the Committee.

It should be noted from the outset that the Committee has not attempted to undertake an inquiry into nuclear energy, per se. The focus of the Committee's Inquiry is the prohibition of nuclear activities in Victoria, and the arguments for and against that prohibition. The Committee has provided significant amounts of background information that is designed to provide context for those arguments.

The Committee is not advocating any particular energy generation technology but canvases the arguments about different technologies within the context of the prohibition.

1.2 The Terms of Reference

On 14 August 2019, the Legislative Council resolved that the Environment and Planning Committee inquire into, consider and report, within 12 months, on potential benefits to Victoria in removing prohibitions enacted by the *Nuclear Activities (Prohibitions) Act 1983*, and in particular, the Committee should—

1. investigate the potential for Victoria to contribute to global low carbon dioxide energy production through enabling exploration and production of uranium and thorium;
2. identify economic, environmental and social benefits for Victoria, including those related to medicine, scientific research, exploration and mining;
3. identify opportunities for Victoria to participate in the nuclear fuel cycle; and
4. identify any barriers to participating, including limitations caused by federal or local laws and regulations.

On 15 May 2020, the Committee agreed to a motion extending the reporting date for the Inquiry's final report from 14 August 2020 to 30 November 2020. The Chair of the Committee notified the President of the Legislative Council that it had extended the Inquiry's reporting date under its temporary powers to extend inquiry reporting dates by agreement of the Committee rather than by motion in the House.[1] This provisional arrangement occurred under the temporary orders of the Legislative Council which were put in place due to the spread of COVID-19.

1.3 Submissions

The Committee advertised the Inquiry and called for submissions through its News Alert Service, the Parliament of Victoria website, and social media. The Committee sent out over 70 letters to various stakeholders inviting them to prepare a submission for the Inquiry. Stakeholders included government agencies and departments, industry groups, anti-nuclear advocates, medical professionals, academics, advocacy organisations and others.

The Committee received 80 submissions and 1 proforma submission which had 140 signatories. All submissions, except those regarded as confidential, were posted onto the Committee's website at: https://parliament.vic.gov.au/epc-lc/article/4348

1.4 Public Hearings

The Committee held public hearings on the following dates:

- 12 March 2020 (Melbourne)
- 25 June 2020 (Melbourne)
- 26 June 2020 (Melbourne)
- 14 August 2020 (via AV link)[2]
- 28 August 2020 (via AV link)
- 11 September 2020 (via AV link)

The Committee was interested in hearing from a wide variety of stakeholders from both sides of the debate on using nuclear for energy generation. Therefore, public hearings included government departments, pro- and anti-nuclear advocacy groups, unions, and industry representatives.

Transcripts for public hearings held throughout this Inquiry can be found at: https://parliament.vic.gov.au/epc-lc/article/4349.

1 This power lapsed on 2 June 2020.

2 AV link undertaken via Zoom.

2 Nuclear activity and regulation in Australia

2

2.1 *Nuclear Activities (Prohibitions) Act 1983* (Vic)

The *Nuclear Activities (Prohibitions) Act 1983* (Vic) (the Prohibitions Act) prohibits the exploration and mining of uranium and thorium[1] and imposes a ban on the construction and operation of certain nuclear facilities in Victoria.[2]

One of the earliest pieces of legislation brought into Parliament by the incoming Cain Government in 1982, the legislation was enacted to give expression to the then Government's policy that opposed certain nuclear activities and the development of a nuclear power industry in Victoria.[3] This policy was formulated on the back of scepticism around the reliability and cost of nuclear reactor technology for energy production and concern over waste disposal, weapons proliferation and safety.[4]

The legislation had four main underlying objectives, namely:[5]

- To prohibit exploration and mining for uranium and thorium
- To prohibit the construction and operation of nuclear reactors, uranium and thorium milling facilities and facilities for conversion, enrichment, fabrication, usage, reprocessing, storage or disposal of nuclear fuel and nuclear materials
- To prohibit possession, sale, transport or disposal of nuclear materials
- To consequentially amend other relevant Victorian legislation to give effect to these measures.

The purpose of this Inquiry is to consider whether or not the prohibitions enacted under this legislation continue to serve a need in Victoria.

2.1.1 Effect of repealing the Prohibitions Act

The repeal of the Prohibitions Act, in full or in part, would have no effect on the existing Commonwealth prohibitions on the use of nuclear energy for electricity generation and the construction and operation of certain nuclear facilities, which would continue to apply (see Section 2.2 for further detail). However, it would enable approval of

1 *Nuclear Activities (Prohibitions) Act 1983* (Vic), s 5. Under s 6, it is not an offence if a person mines or quarries uranium or thorium in the course of mining or quarrying another mineral in accordance with the person's mining title.

2 Ibid., s 8.

3 Victoria, Legislative Council, 1982, *Parliamentary debates*, vol. 368, pp. 1375–6.

4 Ibid., p. 1375.

5 Ibid., p.1376.

exploration and mining for uranium and thorium in Victoria under and subject to the requirements of both state and federal legislation.

Key provisions

Section 2 lists relevant definitions in the Prohibitions Act, notably:

- 'facility' is defined to mean a reactor, critical facility, conversion plant, fabrication plant, reprocessing plant, isotope separation plant, or separate storage installation
- 'nuclear activities' is defined to mean any procedure or operation involved in the mining, milling, conversion, enrichment, fabrication, use, reprocessing or disposal of nuclear material
- 'nuclear material' is defined to mean any radioactive substance associated with the nuclear fuel cycle, including fertile and fissile material, spent fuel and waste.

The objects of the Prohibitions Act, set out in section 3, are to protect the health, welfare and safety of the people of Victoria and to limit deterioration of the environment in which they dwell by prohibiting the establishment of nuclear activities and by regulating the possession of certain nuclear materials, in a manner consistent with and conducive to assisting the Commonwealth of Australia in meeting its international nuclear non-proliferation objectives.

Under section 5 the exploration, mining or quarrying for uranium and thorium is prohibited. An exception for incidental mining of uranium and thorium (within specified quantities) in the course of mining for another mineral is provided under section 6. Any discovery of uranium or thorium must be reported to the relevant Minister.[6]

Section 8 prohibits the construction and operation of uranium or thorium mills, nuclear material conversion or enrichment facilities, nuclear reactor fuel fabrication facilities, nuclear reactors and nuclear power reactors, spent fuel reprocessing facilities, and facilities for the storage or disposal of nuclear material resulting from prohibited activities.[7]

Section 9 prohibits possession, use, sale, transport, storage and disposal of nuclear material without a licence or exemption (including an explicit exemption for section 16 of the *Radiation Act 2005* (Vic), which provides exemptions from holding a licence in relation to certain radiation practices and sources, medical radioisotopes and radiology equipment for example).

---

6 *Mineral Resources (Sustainable Development) Act 1990* (Vic) s 113.

7 *Nuclear Activities (Prohibitions) Act 1983* (Vic) s 8.

2.2 Commonwealth laws and national regulatory framework

Commonwealth laws prohibit the use of nuclear energy for electricity generation across Australia, regulate the use of nuclear energy for medical and research purposes, permit uranium mining subject to Ministerial approval, and provide for the local implementation of Australia's international treaty obligations.

The overarching provisions of Australia's national nuclear framework are provided under Australia's international treaty obligations relating to nuclear activities, working in concert with key Commonwealth Acts. A selective list of key treaties and statutes that apply in Australia are listed in Table 2.1 below.

Table 2.1 Selective list of treaties and statutes applying to nuclear policy and activities in Australia

Title	Purpose
Treaties	
Convention on Nuclear Safety	An incentive-based instrument that commits States operating nuclear power plants to establish and maintain a regulatory framework governing the safety of nuclear installations.
Convention on the Physical Protection of Nuclear Material (CPPNM) & and 2005 Amendment	The only legally binding international agreement focusing on the physical protection of peaceful use nuclear materials. The 2005 Amendment legally binds States to protect nuclear facilities and material in peaceful domestic use, storage, and transport. Also provides for expanded cooperation among States regarding rapid measures to locate and recover stolen or smuggled nuclear material, mitigate any radiological consequences of sabotage, and prevent and combat related offences.
Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management	Focuses on minimising the effects of hazardous radiological materials and promoting an effective nuclear safety culture.
Comprehensive Nuclear-Test-Ban Treaty (CTBT)	Prohibits nuclear weapon test explosions.
International Convention on the Suppression of Acts of Nuclear Terrorism	Covers a broad range of acts and possible targets, including nuclear power plants and nuclear reactors. It criminalises the planning, threatening, or carrying out acts of nuclear terrorism.
Treaty on the Non-Proliferation of Nuclear Weapons (NPT)	Aims to limit the spread of nuclear weapons through the three pillars of non-proliferation, disarmament, and peaceful use of nuclear energy.
South Pacific Nuclear-Free Zone (SPNFZ) Treaty of Rarotonga	Prohibits nuclear explosive devices in the South Pacific. It is the second treaty to establish a nuclear weapons-free zone; also bans the testing and use of nuclear explosive technologies.
Statutes	
Environment Protection and Biodiversity Conservation Act 1999 (discussed in detail in Section 2.2.1 below)	Provides a legal framework for the protection and management of matters of national environmental significance, which includes protection of the environment from nuclear actions. A nuclear action requires approval under the Prohibitions Act if it has, will have, or is likely to have a significant impact on the environment. Specifically prohibits approval of actions involving the construction or operation of a nuclear fuel fabrication plant, a nuclear power plant, an enrichment plant, or a reprocessing facility.

2

Title	Purpose
Statutes	
South Pacific Nuclear Free Zone Treaty Act 1986 *Comprehensive Nuclear Test-Ban Treaty Act 1998*	Implements Australia's treaty obligations
Nuclear Non-proliferation (Safeguards) Act 1987	Provides the legislative basis for Australia's safeguards system. The principal object is to give effect to Australia's obligations under the NPT, Australia's Comprehensive Safeguards Agreement and Additional Protocol with the International Atomic Energy Agency (IAEA), the Convention on the Physical Protection of Nuclear Material (and its 2005 amendment); and agreements with various countries on the transfer of nuclear material, equipment and technology. Provides for commitments under international treaties to be managed through a system of permits issued by the Australian Safeguards and Non-proliferation Office (ASNO) for the possession of nuclear material, equipment and technology. Regulates the possession, transport and communication of nuclear material, and associated material, facilities, equipment and technology, as well as arrangements for the physical protection of nuclear material and facilities.
Australian Nuclear Science and Technology Organisation Act 1987	Establishes the Australian Nuclear Science and Technology Organisation (ANSTO)[a] and provides for the development and utilisation of nuclear and associated technologies, in particular, radiation and radioisotope applications in medicine, industry, science and agriculture.
Australian Radiation Protection and Nuclear Safety Act 1998 (and Australian Radiation Protection and Nuclear Safety Regulations 2018) (discussed in detail in Section 2.2.2 below)	Provides for the protection of human health and the environment from the harmful effects of radiation through a regime to regulate the operation and safety of nuclear installations and the management of radiation sources, where these activities are undertaken by Commonwealth Government entities. Establishes the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Specifically prohibits approval of actions involving the construction or operation of a nuclear fuel fabrication plant, a nuclear power plant, an enrichment plant, or a reprocessing facility. General provisions regulate the transportation of uranium and its by-products relating to radiation hazards. Regulations set out the licensing, inspection and enforcement framework, and specify licence conditions and dose limits. Also require ARPANSA to take into account international best practice in radiation protection and nuclear safety when assessing licence applications.
National Radioactive Waste Management Act 2012	Provides for the selection of a site for a radioactive waste management facility on voluntarily nominated land and the establishment and operation of such a facility on the site to ensure that radioactive waste generated, possessed or controlled by the Commonwealth is safely and securely managed.
Customs (Prohibited Exports) Regulations 1958 (made under the *Customs Act 1901*)	Regulation 9 requires an export licence for the export of radioactive material including refined uranium, plutonium and thorium.

a. Formerly the Australian Atomic Energy Commission.

Source: Legislative Council Environment and Planning Committee.

2.2.1 *Environment Protection and Biodiversity Conservation Act 1999* (Cth)

The *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (the EPBC Act) provides a legal framework for the protection and management of nationally and internationally important flora, fauna, ecological communities and heritage places, defined in the Act as matters of national environmental significance.

One of those matters is the protection of the environment from nuclear actions as defined under the EPBC Act. The Act recognises the protection of the environment from nuclear actions as a matter of national environmental significance; a nuclear action requires approval if it has, will have, or is likely to have a significant impact on the environment. Nuclear actions are referred to the federal Environment Minister and undergo an environmental assessment and approval process.

The EPBC Act specifically prohibits approval of actions involving the construction or operation of a nuclear fuel fabrication plant, a nuclear power plant, an enrichment plant, or a reprocessing facility.

Key provisions

The objects of the Act are set out in section 3(1). They include: protection of the environment; promotion of ecologically sustainable development; biodiversity conservation; heritage protection and conservation; promoting a cooperative approach to environmental protection and management involving governments, communities, land-holders and indigenous people; assisting in cooperative implementation of Australia's international environmental responsibilities; recognising the role of indigenous people in conservation; and promoting indigenous knowledge of biodiversity.

Section 10 provides that the Act does not override the concurrent operation of State and Territory laws unless there is an inconsistency, in which case the EPBC Act prevails.

Protection of the environment from nuclear actions is set out under subdivision E of division 1 of Part 3. Provisions include:

- Section 21(1)-(3): prohibition on taking a nuclear action that will or is likely to have a significant impact on the environment in certain circumstances (including imposition of financial penalties for contravention)
- Section 21(4): provides exceptions to the prohibitions set out in ss 21(1)-(3) in cases where an approval has been granted under Part 9, or for an action that is allowed to be taken without Part 9 approval under the provisions of Part 4
  - The relevant provisions of Part 4 and Part 9 (sections 37J and 140A, respectively) do not create an exemption for nuclear facilities (including fuel fabrications plants, power plants, enrichment plants or reprocessing facilities). However, they are silent in respect of uranium mining and milling facilities

(defined nuclear actions under s 22), meaning uranium mining and milling is permissible under the Act, subject to ministerial approval.

- Section 22 defines 'nuclear action' to mean:
  - establishing or significantly modifying a nuclear installation
    - A 'nuclear installation' is defined as a nuclear reactor for research or production of nuclear materials for industrial or medical use, a plant for preparing or storing fuel for use in a nuclear reactor, a nuclear waste storage or disposal facility with a greater activity level than that prescribed by regulations, a facility for production of radioisotopes with a greater activity level than that prescribed by regulations)
  - transporting spent nuclear fuel or radioactive waste products arising from reprocessing
  - establishing or significantly modifying a facility for storing radioactive waste products arising from reprocessing
  - mining or milling uranium ores, excluding operations for recovering mineral sands or rare earths
  - establishing or significantly modifying a large-scale disposal facility for radioactive waste
  - decommissioning or rehabilitating any facility or area in which an activity described above has been undertaken
  - any other type of action set out in the EPBC Regulations.

2.2.2 *Australian Radiation Protection and Nuclear Safety Act 1998* (Cth)

The purpose of the *Australian Radiation Protection and Nuclear Safety Act 1998* (Cth) (the ARPANS Act) is the protection of human health and the environment from the harmful effects of radiation through a regime to regulate the operation of nuclear installations and the management of radiation sources, where these activities are undertaken by Commonwealth Government entities. The Act also establishes the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and the Radiation Health and Safety Advisory Council.

Like the EPBC Act, the ARPANS Act specifically prohibits approval of actions involving the construction or operation of a nuclear fuel fabrication plant, a nuclear power plant, an enrichment plant, or a reprocessing facility. General provisions in the Act regulate the transportation of uranium and its by-products relating to radiation hazards.

The Act applies only to Australian Government entities and their contractors. It enables the regulatory framework to govern the safety of, among others, the Lucas Heights reactor. With a few minor exceptions, other parties using radioactive sources are controlled by relevant State or Territory legislation.

Key provisions

The object of the Act, set out in section 3, is to protect the health and safety of people, and to protect the environment, from the harmful effects of radiation.

Section 10 prohibits the CEO of ARPANSA from issuing a licence in respect of certain nuclear facilities. It also explicitly states that nothing in the Act can in any way be taken as authorising the construction or operation of such facilities.

Section 30 prohibits Commonwealth entities and contractors (including employees thereof) and other prescribed persons from the:

- construction, operation, possession, and decommissioning, disposal or abandonment of a controlled facility without a licence
- preparation of a site for a controlled facility
- remediation of a prescribed legacy site

(‘controlled facility’ is defined in section 13 to mean a nuclear installation, prescribed radiation facility, or prescribed legacy site).

ARPANSA is established and its functions are set out under Part 3, and the Radiation Health and Safety Advisory Council is established with functions set out under Part 4.

2.2.3 Commonwealth regulatory agencies

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)

ARPANSA is the Australian Government’s primary authority on radiation protection and nuclear safety; it regulates Commonwealth entities that use radiation with the objective of protecting people and the environment from the harmful effects of radiation. It also is the body responsible for engaging the international community on improved nuclear safety under the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

ARPANSA has approximately 130 staff, mostly located in Melbourne with some in Sydney.[8]

ARPANSA’s activities include the regulation of the nuclear installations operated by the Commonwealth; it does not have jurisdiction in the States and Territories. ARPANSA’s focus is 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.[9]

---

8 Dr Carl-Magnus Larsson, Chief Executive Officer, Australian Radiation Protection and Nuclear Safety Agency, public hearing, Melbourne, *Transcript of evidence*, 12 March 2020, p. 20.

9 Ibid.

ARPANSA regulates nuclear installations through five stages of operation from preparing a site for a controlled facility through to construction, operation, possession, control and finally to decommissioning, through a licensing system.

ARPANSA is responsible for developing codes, standards, guides and advice on radiation protection throughout Australia. It undertakes research, provides services, and promotes national uniformity and the implementation of international best practice across all jurisdictions.

Australian Safeguards and Non-proliferation Office (ASNO)[10]

ASNO is a division within Australia's Department of Foreign Affairs and Trade. It is responsible for ensuring that Australia's international obligations are met under the NPT, Australia's NPT safeguards agreement with the IAEA, the Convention on the Physical Protection of Nuclear Material (CPPNM), and Australia's various bilateral safeguards agreements.

ASNO has four main responsibilities in the nuclear area:

1. the application of safeguards in Australia;
2. the physical protection and security of nuclear items in Australia;
3. the operation of Australia's bilateral safeguards agreements; and
4. contribution to the operation and development of IAEA safeguards and the strengthening of the international nuclear non-proliferation regime.

ASNO's responsibilities and functions relating to management of nuclear security in accordance with the NPT and IAEA safeguards agreement is covered in detail in Chapter 7.

Australian Nuclear Science and Technology Organisation (ANSTO)

ANSTO is a statutory body formed in 1987 to replace the Australian Atomic Energy Commission. It is Australia's national nuclear organisation and the centre of Australian nuclear expertise. ANSTO operates much of Australia's landmark nuclear research infrastructure including the OPAL nuclear research reactor (covered in more detail in Section 2.4 below) and the Centre for Accelerator Science at Lucas Heights in NSW, the Australian Synchrotron at Clayton in Victoria, and the National Imaging Facility Research Cyclotron at Camperdown in NSW.[11]

---

10 Department of Foreign Affairs and Trade, *Australian Safeguards and Non-Proliferation Office (ASNO)*, <https://www.dfat.gov.au/international-relations/security/asno/Pages/australian-safeguards-and-non-proliferation-office-asno> accessed 30 January 2020.

11 Australian Nuclear Science and Technology Organisation, <https://www.ansto.gov.au> accessed 30 January 2020.

ANSTO is established under the *Australian Nuclear Science and Technology Organisation Act 1987* (Cth), which also sets out its functions, powers and other roles and responsibilities. ANSTO's core functions under the Act are to:[12]

- produce and use radioisotopes, isotopic techniques and nuclear radiation for medicine, science, industry, commerce and agriculture
- encourage and facilitate the application and use of the results from research and development
- manage radioactive materials and waste arising from various prescribed activities
- provide goods and services related to core activities
- provide advice to government and undertake international liaison in nuclear-related matters
- make available facilities, equipment and expertise for research in nuclear science and technology
- publish scientific and technical reports, periodicals and papers, and provide public information and advice.

ANSTO has a strong presence in Victoria with the Australian synchrotron, which uses the tradition of nuclear accelerator technology to produce powerful beams of light that are used in a very wide array of scientific and industrial applications.[13] ANSTO also has a history of decades-long support for and involvement with the Australian uranium mining industry, including through ANSTO Minerals, a business unit of the organisation that provides minerals process development consultancy.[14]

2.3 Regulation of nuclear and radiation-related activities in Victoria

The regulation of non-prohibited nuclear and radiation activities in Victoria is governed by the *Radiation Act 2005*,[15] including provision for the possession, use, sale, transport, storage or disposal of nuclear material.

2.3.1 *Radiation Act 2005* and Radiation Regulations

The *Radiation Act 2005* (Vic) (the Radiation Act), together with the Radiation Regulations made under the Act, is the primary legislation governing all permissible nuclear and radiation-related activity falling under Victorian jurisdiction. The purpose

12 Australian Nuclear Science and Technology Organisation, *Governance*, <https://www.ansto.gov.au/governance> accessed 30 January 2020.

13 Professor Andrew Peele, Group Executive, Research Translation and Director, Australian Synchrotron, public hearing, Melbourne, *Transcript of evidence*, 28 August 2020, p. 36.

14 Ibid.

15 *Nuclear Activities (Prohibitions) Act 1983* (Vic), s 9.

of the Act is to protect the health and safety of persons and the environment from the harmful effects of radiation.

That Act in effect implements the *National Directory for Radiation Protection*, which is published by ARPANSA.[16]

Radiation Advisory Committee[17]

The Radiation Act establishes the Radiation Advisory Committee with the function to consider, advise and report to the Minister for Health or the Secretary of the Department of Health and Human Services (DHHS) on any matters relating to the administration of the Radiation Act and Regulations,[18] including:

- the promotion of radiation safety practices
- recommending the criteria for the licensing of persons to use radiation sources and the qualifications, training or experience required by those persons
- recommending which radiation sources should be considered prescribed radiation sources
- radiation safety standards for the testing of prescribed radiation sources by approved testers
- the nature, extent and frequency of tests to be conducted on prescribed radiation sources and the specification of radiation safety tests
- codes of practice, standards or guidelines with respect to particular radiation sources, radiation practices or uses.

Radiation Team

The Radiation Act and Regulations are administered by the Radiation Team division within DHHS. The Radiation Team is responsible for regulating radiation practices and individuals authorised to use radiation sources, and issuing management licenses for the disposal of radioactive materials (including waste storage, exporting materials, disposal to sewer, release to air, transfer of ownership or relocation outside Victoria).[19]

The Radiation Team has 10.5 FTE staff, with qualifications in physics, nuclear physics, nuclear medicine and medical radiography, which is reflective of its overwhelming focus on the medical sector for radiation regulation.[20]

---

16 Ms Melissa Skilbeck, Deputy Secretary, Regulation, Health Protection and Emergency Management, Department of Health and Human Services. public hearing, Melbourne, *Transcript of evidence*, 12 March 2020, p. 8.

17 Department of Health and Human Services, *Radiation Advisory Committee*, <https://www2.health.vic.gov.au/public-health/radiation/radiation-regulatory-framework/radiation-advisory-committee> accessed 30 January 2020.

18 *Radiation Act 2005* (Vic), pt 10.

19 Department of Health and Human Services, *Radiation*, <https://www2.health.vic.gov.au/public-health/radiation> accessed 30 January 2020.

20 Ms Melissa Skilbeck, *Transcript of evidence*, p. 8.

It is responsible for regulating radiation practices, the use of radiation sources, and the testing of certain diagnostic X-ray apparatus in accordance with the Radiation Act and Regulations. It also assesses particular sites against approved security plans in relation to some types of radioactive material.

The Radiation Team works with several co-regulators, including ARPANSA, the Environment Protection Authority and WorkSafe, that have complementary objectives or functions, and/or regulate the same entities. Its major regulatory activities relate to the assessment and authorisation of licence applications and the monitoring of licence holders, as well as dealing with non-compliance with licence conditions. It also maintains a radiation safety website that provides up-to-date information for licence-holders.[21]

The Radiation Team is a control agency under the emergency management arrangements of the State, regulated through the *Emergency Management Act 2013* (Vic) (DHHS is the control agency for radiological spills and releases), which requires it to maintain preparedness for 24/7 emergency response in the event of radiation incidents.[22]

The Radiation Team also contributes to the development of national Codes and Standards in conjunction with Commonwealth agencies such as ARPANSA and the federal Department of Industry, Innovation and Science.

Regulation of nuclear medicine in Victoria[23]

The Radiation Act establishes a system of licensing for users of radiation equipment and managers of radiation practices. Radiation licences are issued by the Department of Health and Human Services. A use licence allows an individual to use specific types of a radiation sources for a specific purpose. Failure to hold the required use licence is an offence under the Radiation Act.

Nuclear medicine specialists, technicians and radiologists require a use licence to operate radiation sources/units in Victoria. Compliance with the *Code of Practice for Radiation Protection in the Medical Applications of Ionizing Radiation* is a condition of such licences.

2.4 Lucas Heights Reactor

Lucas Heights, Sydney is the location of the national nuclear research facility and home to Australia's only nuclear reactors. The facility and reactors at Lucas Heights are used for research purposes and are managed and operated by ANSTO.

---

21 Ibid., pp. 8–9.

22 Ibid., p. 9.

23 Department of Health and Human Services, *Medical*, n.d., <https://www2.health.vic.gov.au/public-health/radiation/licensing/use-licences-employees/sector-specific-information/medical> accessed 9 April 2020.

There are currently two reactors located at Lucas Heights—OPAL (currently in operation) and its predecessor HIFAR (High Flux Australian Reactor), currently undergoing decommissioning. A third reactor, MOATA, also located at Lucas Heights, was decommissioned in 2009.[24]

Operation of the current OPAL reactor is authorised by a facility licence issued in 2006 under s 32 of the ARPANS Act.[25]

2.4.1 Open Pool Australian Light-water (OPAL) Reactor[26]

Unlike nuclear power plants, which use the heat generated by nuclear fission to produce high-pressure steam that turns a turbine to produce electricity, OPAL (like its HIFAR predecessor) uses nuclear fission to produce and harness neutrons for scientific, industrial and medical purposes.

One of several research production facilities worldwide, these reactors function as 'neutron factories', producing radioisotopes for cancer detection and treatment, and neutron beams for fundamental materials research.

The OPAL reactor generates roughly 20 MW of heat using about 30 kg of uranium. In contrast, a typical nuclear power plant produces around 3,000 MW of heat to generate 1,000 MW of electricity and contains around 100,000 kg of uranium.[27]

The OPAL reactor's main uses are:

- production of radioisotopes for medical and industrial applications
- research in materials science and structural biology using neutron beams
- analysis of minerals and samples using the neutron activation technique and the delay neutron activation technique
- production of the basic material used in the manufacture of semiconductors.

2.4.2 Nuclear medicine and radiopharmaceuticals production[28]

ANSTO manufactures a range of radiopharmaceuticals that can be used as diagnostic and therapeutic agents. These nuclear medicines assist clinicians to make an accurate diagnosis of an illness or to therapeutically treat diseased organs or tumours.

24 Australian Nuclear Science and Technology Organisation, *Our History*, <https://www.ansto.gov.au/about/what-we-do/our-history> accessed 30 January 2020.

25 ARPANSA, *OPAL reactor operating licence process*, <https://www.arpansa.gov.au/regulation-and-licensing/regulation/about-regulatory-services/who-we-regulate/major-facilities/open-pool-light-water-reactor/operating-licence-process> accessed 30 January 2020.

26 Australian Nuclear Science and Technology Organisation, *OPAL multi-purpose reactor*, <https://www.ansto.gov.au/research/facilities/opal-multi-purpose-reactor> accessed 30 January 2020.

27 ANSTO, <https://www.ansto.gov.au/about/how-we-work/how-safe-is-opal>

28 Australian Nuclear Science and Technology Organisation, *Health Products*, <https://www.ansto.gov.au/products-services/health/health-products> accessed 9 April 2020.

Radioisotopes

Isotopes are atoms of the same element that have the same number of protons in their atomic nuclei but differing numbers of neutrons. Radioisotopes are radioactive isotopes of an element. They can also be defined as atoms that contain an unstable combination of neutrons and protons, or excess energy in their nucleus.

A radioisotope can occur naturally (such as uranium), or as a result of artificially altering an atom. In some cases a nuclear reactor is used to produce radioisotopes, in others, a cyclotron. Nuclear reactors are best-suited to producing neutron-rich radioisotopes, such as molybdenum-99, while cyclotrons are best-suited to producing proton-rich radioisotopes, such as fluorine-18.

Radioisotopes are an essential part of radiopharmaceuticals and have been used routinely in medicine for more than 30 years. Some radioisotopes used in nuclear medicine have short half-lives, which means they decay quickly and are suitable for diagnostic purposes; others with longer half-lives take more time to decay, which makes them suitable for therapeutic purposes.

Medical radioisotopes are made from materials bombarded by neutrons in a reactor, or by protons in an accelerator called a cyclotron. ANSTO uses both of these methods. Some hospitals also have their own cyclotrons, which are generally used to make radiopharmaceuticals with short half-lives of seconds or minutes.

Radiopharmaceuticals

A radiopharmaceutical is a molecule that consists of a radioisotope tracer attached to a pharmaceutical. After entering the body, the radio-labelled pharmaceutical will accumulate in a specific organ or tumour tissue. The radioisotope attached to the radiopharmaceutical undergoes decay, producing specific amounts of radiation that can be used to diagnose or treat human diseases and injuries.

About 25 different radiopharmaceuticals are routinely used in Australia's nuclear medicine centres. ANSTO manufactures a range of radiopharmaceuticals that can be used as diagnostic and therapeutic agents, including technetium-99 (tc-99m), the most widely-used radioisotope in nuclear medicine, which decays from its parent radioisotope, molybdenum-99 (mo-99). Mo-99 is produced in the OPAL reactor and delivered to practitioners within ANSTO-manufactured technetium generators. Another radiopharmaceutical produced by ANSTO is iodine-131, used to treat thyroid cancer. ANSTO also produces a range of radio chemicals to support research, industry and the manufacture of radiopharmaceuticals.

3 Australian uranium and thorium mining and export

3.1 Uranium: national overview

3.1.1 Mining and production

Australia has mined uranium since the 1950s, with mines operating in the Northern Territory, South Australia and Queensland. In 1984 the Hawke Government introduced the 'three mine policy', restricting participation in the export market to the then three operational uranium mines: Ranger, Narbalek and Olympic Dam; this policy was abandoned by the Howard Government 1996.[1]

Australia is the third-largest producer of uranium in the world, with an output of 7,618 tonnes in 2018–19, behind Kazakhstan (26,800 tonnes in 2019) and Canada (8,200 tonnes in 2019)[2]. The world's largest economic demonstrated resources (EDR)[3] of uranium are located in Australia, totalling approximately 1,325 kilo tonnes as at December 2018, accounting for 34% of EDR uranium globally.[4] The majority of Australia's conventional resources are contained within six deposits located in South Australia, Northern Territory and Western Australia.[5]

There are currently three operating uranium mines in Australia: Ranger in the Northern Territory (scheduled for closure in January 2021[6]), Four Mile in South Australia, and Olympic Dam, the world's largest uranium deposit (916 kilo tonnes EDR),[7] also in South Australia. According to the latest national resources and energy quarterly forecast at least six other proposed mines have potential to develop.[8] A map of identified conventional uranium resources across Australia is shown in Figure 3.1.

---

1 New South Wales Parliamentary Research Service, *Uranium Mining and Nuclear Energy in New South Wales*, issues paper, September 2019, pp. 53–4.

2 Office of the Chief Economist, 'Uranium', *Resources and Energy Quarterly: June 2020*, 2020.

3 Economic demonstrated resources (EDR), also referred to as 'conventional resources', is a measure of resources, such as uranium, indicating that potential profitable extraction or production under defined assumptions is possible.

4 Geoscience Australia, *Australia's Identified Mineral Resources*, Australian Government, 2019, pp. 19, 65.

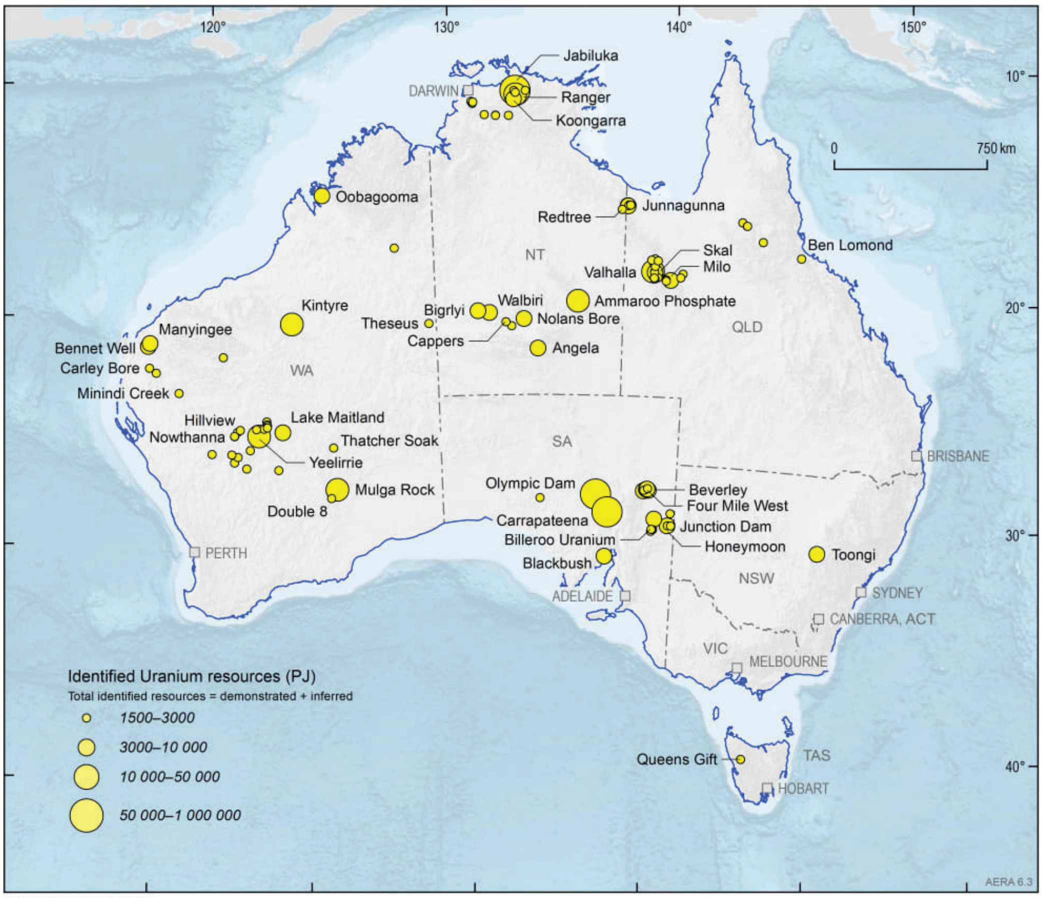
5 International Atomic Energy Agency, *World Uranium, Geology, Exploration, Resources and Production*, IAEA, Vienna, 2020, pp. 593–4.

6 Department of Industry, Science, Energy and Resources, *Regulating the Ranger Uranium Mine*, <https://www.industry.gov.au/regulations-and-standards/regulating-the-ranger-uranium-mine> accessed 19 August 2020.

7 Geoscience Australia, *Australian Energy Resources Assessment: Uranium and Thorium*, <https://aera.ga.gov.au/#!/uranium-and-thorium> accessed 19 August 2020.

8 Office of the Chief Economist, 'Uranium', p. 93.

Figure 3.1 Australia's identified uranium resources by deposit (tonnes)



Source: Geoscience Australia

Source: Geoscience Australia, *Uranium and Thorium*, <https://aera.ga.gov.au/#!/uranium-and-thorium>, accessed 19 August 2020.

Uranium mining is a nuclear action under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (the EPBC Act),[9] meaning the development of a uranium mine is a matter of national environmental significance requiring approval from the Commonwealth Environment Minister. A typical assessment and approval process takes at least three years from referral to ministerial approval.[10]

The regulatory treatment of uranium mining under the EPBC Act is consistent with Australia's generally cautious approach toward nuclear regulation and nuclear-related activities. It reflects the position that uranium mining carries unique risks and impacts that warrant a higher level of regulation compared to other types of mining.

In addition to the requirements of the EPBC Act, regulation and policy for the exploration and mining of uranium also varies by State and Territory. An overview of current legislative settings in Australian jurisdictions is shown in Table 3.1.

---

9 *Environment Protection and Biodiversity Conservation Act 1999* (Cth), s 22.

10 Minerals Council of Australia, *Nuclear exports & safeguards*, <https://minerals.org.au/uranium/exports-safeguards> accessed 19 August 2020.

Table 3.1 Australian State- and Territory-based settings for uranium mining and exploration

		Vic	NSW	Qld	SA	WA	Tas[a]	NT	ACT[b]
Permitted	Exploration	✗	✓	✓	✓	✓	✓	✓	–
	Mining	✗	✗[c]	✗[d]	✓	✗[e]	✓	✓	–
How prohibited	Legislation	✓	✓		–		–	–	–
	Government policy			✓	–	✓	–	–	–

a. There are no identified conventional uranium resources in Tasmania.

b. There is no mining in the Australian Capital Territory apart from quarries used for construction materials.

c. Uranium can be mined in the course of mining for another substance in New South Wales.

d. Queensland has no legislative prohibitions, however the current Government has adopted a policy of moratorium on uranium mining.

e. Western Australia has no legislative prohibition, however the current Government has implemented a 'no uranium' condition on future mining leases. Four uranium projects approved under the previous Government may still proceed.

Source: Legislative Council Environment and Planning Committee

The Committee notes the settings in the EPBC Act that apply to uranium mining are not supported by the Minerals Council of Australia (MCA), which advocates for the removal of uranium mining as a nuclear action under the Act. In its submission to the Inquiry the MCA stated that treating uranium differently from other minerals is not justified.[11] The MCA has stated that the case to retain the nuclear action trigger for uranium mining could only be made if it caused unique and significant environmental effects compared to other commodities that could not be appropriately and efficiently managed by other means.[12] In a separate policy paper, the MCA set out an argument that, based on Australia's management and regulation of weapons proliferation, the effects of radiation, and environmental impacts, the inclusion of uranium mining as a nuclear action:

> … creates an inequitable situation where two mines with identical impacts could be treated quite differently under the EPBC Act, simply because of the commodity that is being mined.[13]

3.1.2 Export

All uranium produced in Australia is exported.[14] In 2018–19, the total export volume was 7,571 tonnes (99.4% of total production volume for the same period). The 2018–19 nominal export value of Australian uranium was AUD$734 million.[15]

11 Minerals Council of Australia, *Submission 78*, p. 5.

12 Minerals Council of Australia, *Mining and the EPBC Act nuclear action trigger: A review of its rationale and operation*, Online, 2018, p. 13.

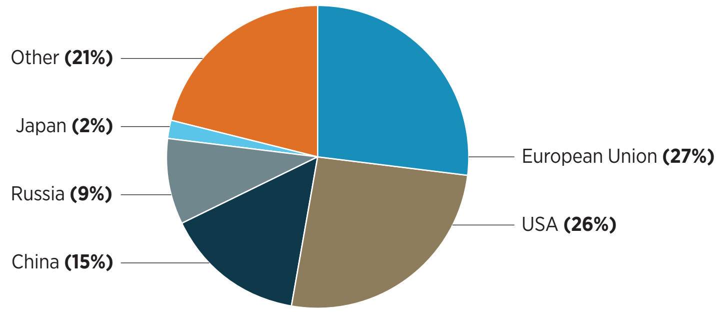
13 Ibid., p. 5.

14 Geoscience Australia, *Australian Energy Resources Assessment: Uranium and Thorium*.

15 Office of the Chief Economist, 'Uranium', p. 95.

Australian mining companies supply uranium under long-term contracts to electricity utilities in North America, Europe and Asia.[16] A general percentage breakdown of Australian uranium consumer markets as at June 2020 is shown in Figure 3.2.

Figure 3.2 Australian uranium consumer markets—June 2020



Source: Office of the Chief Economist, 'Uranium: Resources and Energy Quarterly June 2020', 2020, p. 90.

Australian uranium is exported in-line with Australia's Nuclear Non-Proliferation Treaty (NPT) obligations and only to countries and parties with which Australia has a bilateral nuclear cooperation (safeguards) agreement. These safeguards agreements establish treaty-level conditions on the use of all nuclear material exported from Australia and ensure that Australia's nuclear exports are handled in a manner consistent with Australia's uranium export policy.[17]

NPT obligations relating to uranium export are also discussed in Chapter 7.

3.1.3 Issues relating to uranium mining

Opposition to uranium mining has a long history in Australia. Some recurring themes were raised by various stakeholders in evidence they provided to the Committee on certain concerns commonly associated with uranium mining. This is not intended to be a comprehensive exploration of all issues related to uranium mining, rather it's a discussion of issues that were subject to substantial evidence received over the course of the Inquiry.

Radiation exposure

In its submission Australian Nuclear Science and Technology Organisation (ANSTO) noted that most of the major occupational risks to uranium mine workers are common across other types of mining operations, and these risks are managed under relevant OHS legislation. However, there were additional risks from radiological hazards associated with uranium mining that must also be managed. ANSTO stated:

16 Geoscience Australia, *Australia's Identified Mineral Resources*, p. 66.

17 Department of Foreign Affairs and Trade, *Australia's network of nuclear cooperation agreements*, <https://dfat.gov.au/international-relations/security/non-proliferation-disarmament-arms-control/policies-agreements-treaties/nuclear-cooperation-agreements/Pages/australias-network-of-nuclear-cooperation-agreements.aspx> accessed 30 January 2020.

> The most significant radiological hazard is usually the inhalation or ingestion of radioactive dusts or the inhalation of radon gas, which typically is managed through the use of ventilation and breathing protection apparatuses when necessary.[18]

Safety concerns and failures at Australian uranium mines were raised by a number of anti-nuclear stakeholders. Trevor Gauld, National Policy Officer, Electrical Trades Union (ETU) (Victoria) cited a 'multitude of incidents' at the Ranger uranium mine in asserting the dangers of mining generally and uranium extraction specifically.[19]

Dr Margaret Beavis, representing the Medical Association for Prevention of War (MAPW) (Australia) at a public hearing, pointed to issues at the Olympic Dam mine. Dr Beavis told the Committee:

> … there is massive failure of regulation with the BHP Olympic Dam mine, which mines uranium. After a failure in South America, where a number of people died, BHP was forced by stakeholders to do an audit of its dam facilities. Its own engineers said that at Olympic Dam there are three tailings facilities out of six that are at extreme risk of failure. This means the potential loss of life of 100 workers and environmental rehabilitation that would be impossible. Despite this being identified and known, Olympic Dam is being fast-tracked to expand, and there has been no mention made of the major breach of worker safety or environmental protections.[20]

Dr Tilman Ruff AO, also on behalf of the Association, went on to highlight the long-term health effects of radiation exposure on mine workers:

> … there are significant issues for uranium miners in Australia. At Olympic Dam we know that because of the risk, particularly of the inhalation of radon daughter products, especially polonium, some of those workers are getting around 10 millisieverts per year. That is a sizeable exposure. If you are a worker in your 20s, you have got 50, 60 years of life expectancy left. That will measurably increase your cancer and health risks in the long term, apart from the occupational risks of mining—of injury and noise-induced deafness and so forth. But this is not a safe space to be working in in terms of those exposures, and of course cigarette smoking compounds the risk of lung cancer with radon exposure so that is a particular additional hazard for those workers.[21]

Dr Helen Caldicott echoed these concerns in pointing to the impacts of whole-body radiation exposure experienced by miners and how that can contribute to increased incidences of more than 2,000 genetic diseases. [22] Dr Caldicott also highlighted the contribution of background radiation to increased incidences of cancer and other congenital anomalies among local and indigenous populations proximate to uranium mines in parts of North and South America.[23]

---

18 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 7.

19 Mr Trevor Gauld, National Policy Officer, Electrical Trades Union, public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 2.

20 Dr Margaret Beavis, Medical Association for Prevention of War (Australia), public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 24.

21 Dr Tilman Ruff AO, Medical Association for Prevention of War (Australia), public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 26.

22 Dr Helen Caldicott, public hearing, Melbourne, 28 August 2020, *Transcript of evidence*, p. 2.

23 Ibid., p. 11.

Conversely, in its submission the MCA noted that Australian Radiation Protection and Nuclear Safety Agency reported low relative doses of radiation of 1 mSv (milliSievert[24]) per year for uranium workers on the Australian National Radiation Dose Register in 2019,[25] which was lower than the 1.5 mSv per year average background level of radiation in Australia, lower than aircraft crew exposure at 3.5 mSv per year, and 'well short of the maximum permitted dose of 20 mSv per year averaged over five years and not more than 50 mSv in any one year.'[26] The dose rates for a worker at the Olympic Dam mine average less than 1 mSv in a year was also in ANSTO's submission.[27]

Economic viability

Some stakeholders questioned whether expanding Australia's uranium mining operations was economically viable. Dr Ruff from the MAPW (Australia) claimed that export earnings did not even cover the costs of employment. He told the Committee:

> Most of the people who work in uranium mining in Australia are pretty young. The average age is less than 30 in the last data I saw. They are a relatively small cohort. The industry has for over a decade never cracked close to $1 billion a year in export income. It employs, on the most recent estimates I have seen, a maximum of about 700 people. It would actually be cheaper to pay them to spend their time on yachts in the Caribbean than to pay them salaries for what they do for the income they generate.[28]

Mr Dave Sweeney, Nuclear-Free Campaigner, Australian Conservation Foundation argued that the entire sector was in decline:

> This uranium sector has been hard hit by the Australian uranium fuel Fukushima accident, and the market fallout from that has seen the commodity price go from US$120 per pound pre-Fukushima to $30 at best now. A 75 per cent reduction has seen the world's largest dedicated uranium producer, Cameco, which owns the two largest deposits not developed in Western Australia, shelve those projects. It bought within the last decade a $500 million project or ore body, and it now has a book value, today, of zero. That is not regulatory constraints; that is the reality. It is also that reality that has seen Rio Tinto curtail operations at Ranger in Kakadu and prepare to exit.[29]

---

24 A milliSievert is a radioprotection unit used to measure low radiation doses received either from a radioactive source or from other sources such as X-rays in medicine. It is generally a whole body effective dose, but it may also be an equivalent dose received by a particular tissue or organ. The dose resulting from the internal radioactivity of the human body amounts to 0.25 mSv. A dose of 1 mSv is considered to be within safe limits. Effects on human health are observed only beyond 100 mSv. It would take a thousands of milliSieverts dose to cause fatal injuries in the short term (https://www.radioactivity.eu.com/site/pages/MilliSievert.htm).

25 Minerals Council of Australia, *Submission 78*, p. 8.

26 Ibid.

27 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 6.

28 Dr Tilman Ruff AO, *Transcript of evidence*, p. 26.

29 Mr Dave Sweeney, Nuclear Free Campaigner, Australian Conservation Foundation, public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 14.

Even pro-nuclear stakeholders, such as Mr Robert Parker, Vice President of the Australian Nuclear Association, acknowledged there was a 'glut of uranium in the world in terms of mines' and he did not anticipate an expansion of the uranium industry to fuel any future nuclear reactors in Australia.[30]

In its submission ANSTO noted that there had been more recent interest and engagement in the global uranium market, with producer buying having steadily increased, and the global trade of uranium amounting to approximately US$4 billion in 2018. Despite this ANSTO pointed out that prices were unlikely to increase significantly in the short to medium term meaning there was little impetus to identify and develop new uranium projects.[31]

Notwithstanding global trends, ANSTO also highlighted the substantial developmental benefits that uranium and mining exploration activities could deliver for the communities in which those activities occurred. It noted that uranium exploration and mining in South Australia and Northern Territory had delivered significant local benefits to the economy and local communities, for example:

- from 2010–2016 the uranium industry contributed over AUD$3.5 billion to SA's export revenue and AUD$141 million in royalties
- operations over the lifetime of the Ranger mine (NT) resulted in over AUD$500 million in royalties
- the equivalent of 4.25% of Ranger sales revenue is paid to NT-based Aboriginal organisations
- Energy Resources of Australia, the company that operates Ranger, paid $10.7 million in royalties in 2018 and contributes over AUD$100 million per year in salaries and local spend in the Jabiru region.[32]

Environmental and land impacts

In its submission ANSTO set out some of the major environmental concerns associated with uranium exploration and mining, including:

- land clearance and land disturbance
- discharge of hazardous chemicals
- release of radioactive materials
- contamination of streams and groundwater from wastewater
- contaminated soil, sediments or other materials
- damage of the local ecology and water systems because of acid mine drainage.[33]

---

30 Mr Robert Parker, Vice President, Australian Nuclear Association, public hearing, Melbourne, 17 July 2020, *Transcript of evidence*, p. 21.

31 Australian Nuclear Science and Technology Organisation, *Submission 62*, pp. 9–10.

32 Ibid., p. 10.

33 Ibid., pp. 11–12.

While ANSTO argued that environmental impacts linked to uranium mining are less likely to occur as modern industry practices involve early identification of risks and the implementation of strategies to prevent, mitigate or manage risks across a mine's life-cycle,[34] it also pointed out:

> The environmental impacts associated with all mining activities are dependent on the conditions at the respective mine sites, the rigour of the monitoring programs to provide early warning of contaminant migration, and the efforts to prevent, mitigate, and control potential impacts. Environmental consequences share the same cause across all mining operations. The standard and type of mining practice, not the mineral or metal being mined, is the major distinguishing characteristic between good, satisfactory, and poor environmental outcomes.[35]

ANSTO also noted that the licensing process for new mines required comprehensive environmental impacts statements and assessments addressing:

- minimisation of impacts on flora, fauna and habitats
- contamination and pollution of land
- management and use of water resources.[36]

Proponents and opponents of uranium mining explored many similar issues and themes to those set out by ANSTO above in evidence they provided to the Inquiry. For example, in their joint submission, Friends of the Earth (FOE) Australia, Australian Conservation Foundation and Environment Victoria argued that current strategies for environmental protection are inadequate[37] and point to significant issues at current and former uranium mines such as Olympic Dam, Ranger and Beverley (including Four Mile), including leaks and spills from tailings, water consumption, exposure of wildlife to toxic and contaminated water and other materials, damage to culturally significant sites, in-situ leach and dumping of contaminated liquid into the ground water table, and inadequate rehabilitation of closed mines.[38]

Contrastingly, the MCA pointed to a strong regulatory environment and advances in modern industry practice, contending that Australian uranium mines were world-leaders in environmental performance. It highlighted an overview of the sector's performance conducted for the MCA in 2017 which found 'Australia's modern uranium mining industry is world class, and accordingly delivers world class environmental outcomes'.[39] The MCA also noted the OECD Nuclear Energy Agency's conclusion in a 2014 report that:

> Uranium mining remains controversial principally because of legacy environmental and health issues created during the early phase of the industry. Today, uranium mining is

---

34 Ibid., pp. 12–13.

35 Ibid., p. 13 (with sources).

36 Ibid., pp. 13–14.

37 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, p. 78.

38 Ibid., pp. 78–80, 86–8, 91–3 (with sources).

39 Minerals Council of Australia, *Submission 78*, p. 8.

> conducted under significantly different circumstances and is now the most regulated and one of the safest forms of mining in the world.[40]

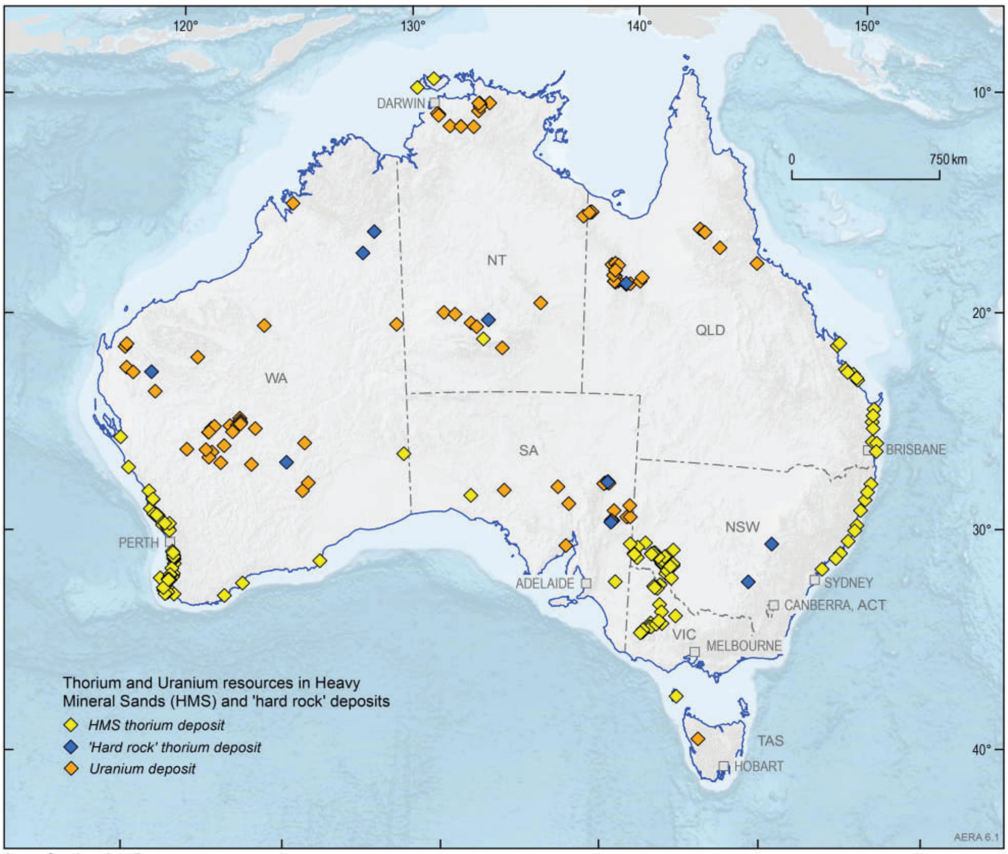
Environmental impacts relating to nuclear activities, including uranium mining, are further discussed in Chapter 8.

3.2 Thorium

Thorium is a naturally-occurring, slightly radioactive mineral found in most rocks and soils, it is approximately three times more abundant than uranium globally.[41] There is currently no production of thorium in Australia, but it is present in monazite which is mined with other heavy mineral beach sand deposits.

Figure 3.3 shows the total identified (demonstrated and inferred) thorium resources in heavy mineral and hard rock deposits around Australia.

Figure 3.3 Australia's identified thorium resources in heavy mineral sand and 'hard rock' deposits



Source: Geoscience Australia, Australian Energy Resources Assessment: Uranium and Thorium, <https://aera.ga.gov.au/#!/uranium-and-thorium>, accessed 21 January 2020.

---

40 Ibid., pp. 8–9 (with sources).

41 World Nuclear Association, *Thorium*, February 2017, <https://www.world-nuclear.org/information-library/current-and-future-generation/thorium.aspx> accessed 29 July 2020.

Due to the absence of any significant demand for thorium resources, there is also no widespread exploration for thorium in Australia. Large-scale commercial demand is expected to depend on the development of thorium-fuelled nuclear reactors which are still in the concept phase. A considerable amount of development work is required for thorium-based reactors to be commercialised.[42]

The World Nuclear Association has expressed the opinion that despite the 'tantalizing prospect' of thorium's use as a primary energy source, achieving cost-effect extraction of its latent energy value presents a barrier requiring significant investment in research and development to overcome.[43]

In 2008 Geoscience Australia undertook the Thorium Project in order to gain an enhanced understanding of the status and distribution of Australia's thorium resources for use in determining government policy and industry investment decisions and their potential as an alternative nuclear fuel source.[44] An output publication from this project noted:[45]

- Lack of large-scale demand for thorium has provided little incentive for companies to assess the cost of extracting thorium resources, therefore there is insufficient information to determine how much of Australia's thorium resources are economic for purposes of electricity power generation in thorium nuclear reactors
- Limited demand has resulted in very little exploration for thorium in Australia
- Future assessment of thorium resources by the minerals industry is dependent on the development of commercial-scale thorium nuclear reactors and the resulting demand for thorium resources.

The thorium nuclear fuel cycle, including molten salt and thorium reactor technology is discussed in Chapter 6.

3.3 Uranium and thorium mining in Victoria

The *Nuclear Activities (Prohibitions) Act 1983* prohibits the exploration and mining of uranium and thorium in Victoria.[46] It also imposes a ban on the construction and operation of uranium or thorium mills.[47] Any discovery of uranium or thorium must be reported immediately.[48]

---

42 Geoscience Australia, *Australian atlas of minerals resources, mines & processing centres: Thorium*, 2015, <http://www.australianminesatlas.gov.au/aimr/commodity/thorium.html> accessed 21 January 2020.

43 World Nuclear Association, *Thorium*.

44 Geoscience Australia, *Thorium Project*, <https://www.ga.gov.au/about/projects/resources/thorium> accessed 17 August 2020.

45 T P Mernagh Y Miezitis, and I B Lambert, *Resources and geology of Australia's thorium deposits*, Geoscience Australia, Online, 2008.

46 *Nuclear Activities (Prohibitions) Act 1983* (Vic) s 5 (under s 6, it is not an offence if a person mines or quarries uranium or thorium in the course of mining or quarrying another mineral in accordance with the person's mining title).

47 Ibid., s 8.

48 *Mineral Resources (Sustainable Development) Act 1990* (Vic), s 113.

3

Notwithstanding the legislated prohibition, Mr Noel Cleaves, Manager of Environmental Regulation and Compliance at the Department of Health and Human Services (DHHS) explained at a public hearing that, while more resources would need to be allocated to manage it, conceptually, no significant legislative change would be required to enable exploration and mining of uranium (and thorium) other than repealing the existing prohibition. The current mineral resources and radiation licencing frameworks could apply to uranium (and thorium) as it does to the exploration and mining of other resources, particularly mineral sands processes. Mr Cleaves told the Committee:

> I guess if we are making the distinction between uranium mining and processing and then nuclear power, uranium mining and processing is a little bit similar to what happens with mineral sand mining and processing. There are differences, but conceptually it is a little bit similar. There is an active mining process, a technical process, to extract the product that is in demand, and then there is some waste. Some of the waste will be radioactive, some will not be. All those processes will be authorised by us in a mineral sand context. There is a tight approval process. Obviously they go through an EES—an environment effects statement—process. We are involved in that, and then there will also be a management licence required before they can actually start the processes, and then we will require compliance with codes of practice, regular reporting et cetera. So the analogy for uranium mining and processing is a little bit similar to mineral sand. One thing we know from experience is that the community are very interested in things like mineral sand mining and processing, and clearly they would be very interested in uranium mining and processing, so we know we would have to allocate more resources to those sorts of things.[49]

Mr Cleaves went on to say:

> If one makes the assumption that there is an economically viable amount of uranium in concentrations, or thorium, then uranium mining and processing is the conceivable thing. If the Act did not exist, an application could come in from a company to say, 'We would like to establish a uranium mine and processing plant,' as exists in South Australia and has existed in the Northern Territory and, I think, has now been approved to be constructed in WA. In practical terms that is the only thing that is excluded in practice.[50]

3.3.1 Uranium mining

Conceptual regulation of uranium mining aside, the maintenance or lifting of the uranium mining prohibition in Victoria is a somewhat abstract debate. As shown in the map of Australia's identified uranium resources (Figure 3.1 above), it is generally accepted that there are no identified conventional resources of uranium in Victoria.[51] This view was consistently articulated by stakeholders in submissions to and public hearings conducted for this Inquiry. However, the Committee notes that as exploration is prohibited by the Act it is unclear whether unidentified resources may exist.

---

49 Mr Noel Cleaves, Manager, Environment Health Regulation and Compliance, Department of Health and Human Services, public hearing, Melbourne, 12 March 2020, *Transcript of evidence*, p. 11.

50 Ibid., pp. 12–13.

51 International Atomic Energy Agency, *World Uranium, Geology, Exploration, Resources and Production*, pp. 594, 596.

Mr Mark Zirnsak, Senior Social Justice Advocate, Synod of Victoria and Tasmania, Uniting Church in Australia told the Committee that:

> … Victoria has no known uranium deposits per se, so why there would be any consideration of wanting to open up for uranium mining when we have no known deposits again struck us as a strange thing to do.[52]
>
> […]
>
> … it would only be in the very remote possibility that in the future some uranium was discovered and it was actually allowed to be mined that it would become particularly relevant to Victoria and this inquiry.[53]

In his submission to this Inquiry, Mr Logan Smith noted that uranium mining would be 'very limited' because Victoria probably does not have sufficient deposits:

> Granted, exploration for and mining of uranium deposits could be made possible if legislation is changed but it is not particularly clear what Victoria holds in terms of uranium deposits. Should that come to pass, Victoria's contribution to low carbon energy production (domestically, nationally or worldwide) through mining uranium and thorium is going to be very limited.[54]

He also pointed out that:

> Increasing uranium production into a saturated market is unlikely to be a wise economical investment, nor will it have a significant effect on carbon emissions worldwide. This would be equally true if we developed uranium enrichment or fuel fabrication.[55]

In its submission ANSTO also noted that the lack of reliable data on uranium resources in Victoria makes it difficult to predict the potential value and the scale of associated benefits if prohibitions were lifted.[56]

The Committee received evidence suggesting that it was likely that current mining activities in Australia would sufficiently support a transition to nuclear energy generation without the need for additional mining activities. Mr Robert Parker, Vice President, Australian Nuclear Association believed that if Australia began generating electricity from nuclear power, the current mining activities would be sufficient to support that industry. He stated:

> For the numbers of reactors that one would see in Australia, I would not anticipate an expansion of the uranium mining industry to serve those. There is a significant amount already, and one would not necessarily see an expansion of uranium mining…[57]

---

52 Mr Mark Zirnsak, Senior Social Justice Advocate, Uniting Church in Australia (Synod of Victoria and Tasmania), public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 30.

53 Ibid., p. 32.

54 Logan Smith, *Submission 43*, p. 1.

55 Ibid.

56 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 10.

57 Mr Robert Parker, *Transcript of evidence*, p. 21.

Mr Parker's view was consistent with that of Mr Sweeney of the Australian Conservation Foundation, who contended that nuclear advocacy groups acknowledged that uranium mining is very unlikely in Victoria. At a public hearing Mr Sweeney told the Committee:

> It is not mining because both the Australian Nuclear Association and the Minerals Council have said that it is unlikely, indeed most unlikely, that there would be any expansion of uranium mining or push for uranium mining in Victoria when it is shutting down in other parts of the country.[58]

However, other stakeholders argued that whether uranium mining was viable in Victoria or not was beside the point. Women in Nuclear (WiN) Australia argued that the fact of the prohibition effectively meant that Victoria was unable to have a 'complete, informed and robust discussion' on the viability of uranium mining unless there was proper public education and debate.[59]

In its submission, the MCA stated:

> With its ban on uranium mining, Victoria effectively sends a message there is no point in investors considering Victoria in relation to uranium.[60]

Mr Benjamin Cronshaw in his submission also suggested that it could be 'interesting to examine whether there are viable uranium sites in Victoria', although he acknowledged that 'there would be problems getting community consent and bipartisan support for uranium mining in Victoria.'[61]

The issue of community consent and social license is discussed in Chapter 9.

At a public hearing Mr James Sorahan, Executive Director, MCA Victoria, queried the need for the ban given the absence of any serious proposals to mine uranium in Victoria.[62] He also argued that the ban made for an unnecessarily clunky approach to dealing with uranium and thorium extracted through mineral sands processing. He told the Committee:

> … uranium and thorium are a natural part of mineral sands mining in small quantities. They attach to rare earths, which are a small part of mineral sands mining, and uranium can be in the monazite crystals and it can sometimes attach to zircon crystals, which is a mineral sand. So they are in small quantities. The Act at the moment—as you are probably aware, section 6 effectively exempts mineral sands mining from this Act. So it envisages that some uranium and thorium will be extracted as part of mineral sands mining and seeks to exempt that specifically. Now, they are very small quantities. In the Act itself it is under 0.02 per cent of uranium and 0.05 per cent of thorium.

58 Mr Dave Sweeney, *Transcript of evidence*, p. 14.

59 Women in Nuclear (WiN) Australia, *Submission 36*, p. 17.

60 Minerals Council of Australia, *Submission 78*, p. 5.

61 Benjamin Cronshaw, *Submission 41*, p. 5.

62 Mr James Sorahan, Executive Director, Victoria Division, Minerals Council of Australia, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 35.

3

> Heavy mineral sands mining in Victoria has occurred in the past. There are about six project proposals on the table at the moment, which would provide a massive amount of jobs and investment in regional Victoria. So they should be exempted under this Act. But for absolute clarity and certainty, particularly for downstream processing, we should not have an Act like this in place, because it envisaged at the time, in 1983, before we had mineral sands mining, that this could be a problem. The extraction of other minerals in Victoria can involve the extraction of very small amounts of uranium and thorium because, as I said, it is everywhere in the crust of the earth. So it is just another reason why this is really quite a pointless Act, which is purely political from the anti-nuke movement of the early 1980s and really serves no purpose other than just creating another hassle and thing that gets in the way of other mining. Even though there is an exemption there and it should work, why do you need a clunky exemption for mineral sands mining or any other mineral? You should not need an exemption at all. The Act just should not be there.[63]

The Committee makes no comment on uranium because there are no economically viable deposits identified in Victoria.

3.3.2 Thorium mining

Unlike uranium, there are significant deposits of thorium located within Victoria (see Figure 3.3 above). Consequently, the lifting or maintenance of the legislated prohibition as it relates to thorium presents different considerations than is the case for uranium.

The Committee received evidence from the Australian Institute of Physics that while Victoria could contribute to establishing a commercial thorium market, it would be contingent on ‘significant demand which is not currently foreseen’[64] and that that ‘there is essentially no commercial market’ for thorium.[65]

The joint submission from FOE Australia, Australian Conservation Foundation and Environment Victoria argued that investigation of thorium deposits in Victoria is ‘irrelevant given that the prospects for the use of thorium as a nuclear fuel are zero or near zero’.[66]

Anti‑nuclear stakeholders also contended that exploration and mining of Victorian thorium deposits would have detrimental impacts on farming and agriculture. Ms Tracey Anton, in her submission, expressed concern that a consequence of mining thorium in Victoria would be ‘strip mining viable farmland in areas deemed important for Victoria’s future food security’.[67] Similarly, in her submission Ms Kim Grierson told the Committee that nuclear prohibition laws in Victoria should remain in place ‘to protect this State’s agricultural land and ocean coast,’ such as South Gippsland which has large thorium deposits.[68]

---

63 Ibid.

64 Australian Institute of Physics, *Submission 67*, p. 2.

65 Ibid.

66 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, p. 9.

67 Tracey Anton, *Submission 66*, p. 10.

68 Kim Grierson, *Submission 54*, p. 1.

In contrast, and despite the current lack of demand for thorium, the Committee received evidence from some pro-nuclear stakeholders that the significant thorium deposits located in Victoria might still present opportunities for the State to explore its use as a potential energy source. These stakeholders claimed the possible benefits of developing thorium-based nuclear activities in Victoria were:

- economic – including job creation in resource exploration, mining and power generation
- environmental – including waste management and zero-carbon emissions electricity
- safety – including smaller proliferation and meltdown risks (compared to uranium).

WiN Australia argued that Victoria's thorium deposits, such as those located in the Murray Basin, meant it was well placed to contribute to the research and development thorium reactor technology, although it conceded that the need for greater investment in this area meant there would be no significant demand for thorium in the short to medium term.[69] However, WiN did believe that the exploration and mining of thorium in Victoria could become economically viable in the medium to long term.[70]

Similarly, the Thorium Network's submission discussed in detail the benefits of thorium molten salt in creating opportunities for employment and developing new industries in Victoria. The Thorium Network contended that because some of the 'best Australian mineral sand deposits which include Monazite: a naturally occurring source of Thorium' are located in Victoria, the State is ideally placed to be a 'forerunner' in including thorium as part of its future energy mix.[71] The Thorium Network claimed the availability of deposits in Victoria could translate to job creation across a thorium industry, particularly in mining.[72]

The Thorium Network also argued that the introduction of a thorium industry in Victoria would lead to the creation of other new industries, stating in its submission:

> …low cost Thorium Molten Salt energy can also be used to produce H2, which can be used in fuel cells and/ or to make liquid fuels from CO2 such as Methanol and Dimethyl Ether. Both with superior properties compared to gasoline and diesel. Another opportunity for Victoria to become a frontrunner in the emerging Hydrogen economy.[73]

For the Committee's view on thorium-related opportunities in Victoria please refer to Section 10.1.2.

69 Women in Nuclear (WiN) Australia, *Submission 36*, p. 7.

70 Ibid., pp. 7–8.

71 The Thorium Network, *Submission 79*, p. 8.

72 Ibid.

73 Ibid.

4 National energy policy and nuclear power in the National Electricity Market

4.1 Overview of the current energy industry

The energy industry comprises three related but separate elements: the generation of energy, distribution of the energy produced and the selling of that energy to customers. For the purposes of this Inquiry, the focus is on the generation of energy which is where nuclear power fits into the energy mix. Regardless of power generation methods, distribution and retailing of energy will remain largely the same.

It should be noted here that this section does not intend to provide a comprehensive overview of the current energy industry in total, but simply provide a snapshot that can place the arguments for and against nuclear energy into some context.

4.1.1 Energy consumption in Australia

As an overview, energy consumption rose in Australia as a whole by 0.9% in 2017–18 to 6,172 petajoules, its highest ever level. This compares with average growth of 0.6% a year over the past ten years. Growth in 2017–18 was 52 petajoules. In 2017–18, the Australian economy grew by 2.8% to reach $1.8 trillion. The Australian population grew by 1.6% to reach 25 million people.[1]

According to the *Australian Energy Update 2019* and based on Australian Energy Statistics, the Australian economy has tended towards lower energy intensity and higher energy productivity over time, as economic growth in Australia over recent decades has generally outpaced growth in energy consumption. The Update suggests that this reflects 'cumulative improvements in energy efficiency as well as a shift in the Australian economy away from highly energy-intensive industries such as manufacturing towards less energy-intensive industries such as services', as well as increased use of renewable energy instead of fossil fuels for electricity generation.[2]

1 Department of Industry, Science, Energy and Resources, *Australian Energy Update 2019*, Australian Government, Online, 2019, p 2

2 Ibid., p 8

4

Energy generation

Some key statistic for the generation of energy in Australia include:

- Total electricity generation in Australia rose marginally in 2017–18 to 261 terawatt hours (940 petajoules). This figure includes industrial, rooftop solar PV and off-grid generation.
- About 13% of Australia's electricity was generated outside the electricity sector by industry and households in 2017–18.
- Brown coal-fired generation fell by 17% in 2017–18, while black coal rose by 3%, with the combined share of coal at 60% of total generation. The share of coal was also 60% in calendar year 2018.
- Australia is now less reliant on coal than at the beginning of the century, when coal's share was more than 80% of electricity generation.
- Natural gas-fired generation grew 7% in 2017–18, remaining at about 21% of total electricity generation. Its share fell in calendar year 2018, to 19% of total generation.
- Renewable generation increased 10% in 2017–18, contributing 17% of all generation. The majority of renewable electricity growth was in wind, but growth also occurred in solar. Generation from municipal and industrial waste and biogas was 3% of renewable generation.
- Renewable generation grew in calendar year 2018, to 19% of total generation. Hydro accounted for 7% of total generation in 2018, while wind accounted for 6%.
- Solar accounted for 5% of total generation in 2018, with the majority of this small-scale PV. Large-scale solar was the fastest growing source of generation in 2018.[3]

There was only a modest increase in electricity generation in Australia in 2017–18, with growth of only 1% leading to a total electricity generation of 261 terawatt hours (or 940 petajoules). While this was a relatively small increase, it still resulted in the highest total generation on record for Australia.[4] In addition to power plant output, this figure includes all generation including rooftop solar PV generation, generation by industrial facilities, off-grid generation, and electricity consumed by the generating entity.[5]

According to the Update, about 13% of Australia's electricity was generated by industry and households. This share varies considerably across state and territories, including contributing over one-third of total generation in Western Australia, probably as a result of the significant mining industry generation in that state.

3 Ibid., p. 3.

4 Ibid., p. 24.

5 Ibid.

The energy mix

Currently in Australia, the energy mix relies largely on fossil fuels (coal and gas), hydro technologies and increasingly wind and solar technologies (renewables).

Under the current arrangements, Queensland, New South Wales, Victoria, South Australia, Tasmania and the Australian Capital Territory have interconnected electricity and gas networks with electricity being sold through a wholesale spot market (the National Electricity Market or NEM). Under this arrangement, all retail customers in the NEM are able to choose their electricity and gas supplier which means that energy can be provided from anywhere within the network.[6]

Western Australia and the Northern Territory do not form part of this network and have their own separate electricity and gas networks and markets.

While this energy market arrangement may continue, the generation of energy is changing and key questions relate to whether energy will continue to be generated through the use of fossil fuels or whether renewable energy will begin to make up the majority of energy generation in Australia. It is here that the question of nuclear power generation has been raised in recent years.

The current energy mix in Australia is changing with Australia being now less reliant on coal than at the beginning of the century, with coal's share falling from more than 80% of electricity generation to about 60% in 2018. According to Commonwealth Government figures, fossil fuels contributed 81% of total electricity generation in 2018, including coal (60%), gas (19%) and oil (2%). Renewables contributed 19% of total electricity generation in 2018, specifically hydro (7%), wind (6%), and solar (5%).[7]

According to the most recent published Australian Energy Statistics, Australia's coal consumption in 2016–17 was 18% lower than its peak in 2008–09, when its share of the energy mix was around 40%. Brown coal consumption in 2016–17 was around 24% lower than in 2008–09. This partly reflects the closure of twelve coal-fired power stations in the five years to 2016–17.[8]

---

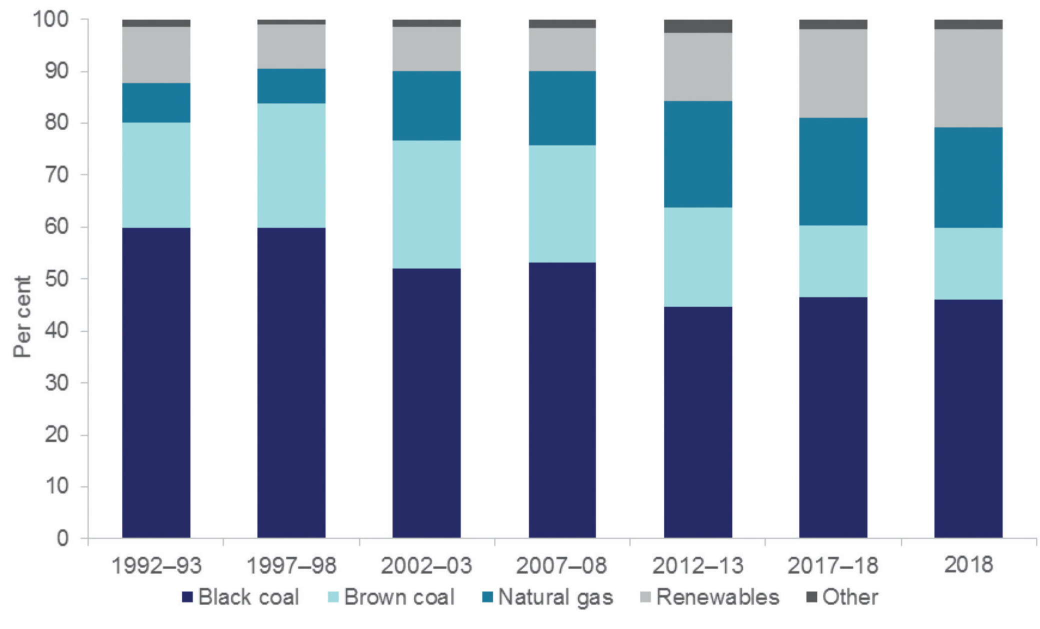
6 Australian Energy Regulator, *Industry information*, <https://www.aer.gov.au/industry-information> accessed 16 July 2020.

7 Department of Industry, Science, Energy and Resources, *Australian electricity generation - fuel mix*, <https://www.energy.gov.au/data/australian-electricity-generation-fuel-mix> accessed 16 July 2020.

8 Department of Industry, Science, Energy and Resources, *Australian Energy Update 2018*, Australian Government, Online, 2018, p. 8.

4

Figure 4.1 Australian electricity generation—fuel mix 2018



Source: Department of the Environment and Energy, *Australian Energy Update*, 2019, p. 26.

Partly as a result of the need to mitigate the impacts of climate change, there has been a shift towards renewable energy sources as they have a lower level of carbon emissions than traditional fossil fuel energy sources. According to Commonwealth Government data, as ageing coal generators exit the market, over 93% of investment since 2012–13 has been in wind and solar plant.[9]

In its *State of the Energy Market Report 2020*, the Australian Energy Regulator (AER) stated that the transition that is happening in the Australian energy sector could deliver significant benefits because:

- renewable energy is a relatively cheap fuel source, and if integrated efficiently into the power system, it can deliver low-cost sustainable energy
- for individual consumers, the uptake of solar photovoltaic (PV) and battery systems can help them save on power bills and manage their energy use in ways to suit their needs
- it has the potential to empower individual consumers to take initiative on environmental concerns.[10]

The Report did, however, raise concerns about integration issues within the energy sector. It stated that much of this new generation by renewable energy sources is located in 'sunny or windy areas at the edges of the grid with relatively weak transmission network capacity.'[11]

9 Australian Energy Regulator, *State of the Energy Market 2020*, Online, 2020.

10 Ibid., p. 11.

11 Ibid.

It also noted that the fossil fuel plant being replaced traditionally provided critical technical stability services such as inertia and system strength. The report stated that the ability of wind and solar plant to provide these services has been limited. As a result, the rising proportion of renewable generation is bringing:

> … more periods of low inertia, weak system strength, more erratic frequency shifts, and voltage instability.[12]

However technological advances in renewable energy are very likely to greatly improve its performance in the very near term.[13]

The issue of reliability of supply of energy has been one of the most significant debates as the energy mix moves away from traditional fossil fuel sources and towards renewable energy sources. As the *State of the Energy Market* Report suggests, weather dependent sources of energy such as wind and solar generation create a need for 'firming' capacity, such as fast start generation, battery storage and pumped hydro plant to fill supply gaps when there is a lack of either wind or sunshine.[14]

To illustrate this issue, the Report stated that there had been more frequent market interventions to maintain a reliable and secure power system, with the Australian Energy Market Operator (AEMO) using the Reliability and Emergency Reserve Trader (RERT) mechanism in each of the past three summers to secure back-up supply, at a cumulative cost to the market (and energy customers) of around $126 million.[15]

Despite the challenges that face the renewable energy transition, renewable plant produced record output in 2019. Wind farms accounted for 8% of output, and solar farms for 2.5%. In addition, rooftop solar photovoltaic systems met another 5.2% of the market's electricity needs.[16] Despite this growth, however, investment in wind and solar plant slowed from mid-2019, as 'technical issues with integrating new plant into the system' delayed projects.

Currently there are coordinated planning reforms being undertaken that aim to better integrate renewable plant, rooftop solar PV, demand response and battery storage into the system, with a focus on 'ensuring the transmission grid can meet transport needs.'[17]

It has long been argued by the nuclear energy industry and others that the energy mix in Australia should include the nuclear power option. Currently, this is prohibited under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

---

12 Ibid.

13 BloombergNEF, *Battery Pack Prices Fall As Market Ramps Up With Market Average At $156/kWh In 2019*, 3 December 2019, <https://about.bnef.com/blog/battery-pack-prices-fall-as-market-ramps-up-with-market-average-at-156-kwh-in-2019> accessed 21 October 2020.

14 Australian Energy Regulator, *State of the Energy Market 2020*, p. 11.

15 Ibid.

16 Ibid.

17 Australian Energy Regulator, *State of the Energy Market 2020*, p. 8.

The Act provides protection of the environment from nuclear actions as defined under the Act. The EBPC Act specifically prohibits approval of actions involving the construction or operation of a nuclear fuel fabrication plant, a nuclear power plant, an enrichment plant, or a reprocessing facility.

The legislative framework covering nuclear activity in Australia have been covered in more detail in Chapter 2.

However, in this overview it is sufficient to say that currently nuclear power plays no role in energy generation in Australia and never has. The relative merits of that situation and the merits or otherwise of changing the place of nuclear power in the energy mix were the subject of most of the submissions and evidence to this Inquiry.

4.1.2 Victorian context

In Victoria, there has been a significant reduction in the use of coal generated energy, following the closure of the Hazelwood coal-fired power station in 2017. In fact, total energy consumption fell 5% in 2017–18 following this closure. Energy consumption in Victoria is unlikely to remain lower for any length of time and therefore it is likely that there is going to be a need to replace the energy generated from the coal-fired power station.

Victoria's electricity transmission network is interconnected with South Australia, New South Wales, Tasmania and indirectly with Queensland. This allows the transportation of electricity from the States when electricity demand in Victoria is relatively high, or from Victoria when demand is relatively low. Electricity generation in Victoria has traditionally been concentrated in the Latrobe Valley, with large coal-fired power stations and some gas plants supplying the main load centre of Melbourne. Power has also been supplied by the Snowy hydro scheme in the north east, plus two wind farms on the southern coast.

More recently, the amount of wind generation has risen significantly, with more than twenty wind farms connecting to the grid, mostly dispersed throughout south west Victoria. Also, six new solar farms have joined the network along the border with New South Wales. Two utility-scale storage batteries were also added to firm up intermittent generation.

Meanwhile, the amount of coal-fired power has decreased significantly with the 2017 exit of Hazelwood station which supplied around 20% of Victoria's electricity consumption, and to a lesser extent with the exit of Anglesea coal power station in 2015. Table 4.1 below shows the trends in the energy mix for Victoria over the past decade.

4

Table 4.1 Electricity generation in Victoria by fuel type—gigawatt hours

	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14
Non-renewable fuels						
Black coal	–	–	–	–	–	–
Brown coal	52,094.0	51,541.7	51,066.5	52,059.7	45,317.6	43,977.7
Natural gas	1,451.9	1,697.9	1,289.8	1,142.5	3,247.7	3,239.3
Oil products	20.4	1.1	38.2	4	10.7	145.8
Other[a]	61.1	115.9	114.5	–	–	–
Total non-renewable	**53,627.4**	**53,356.6**	**52,509.0**	**53,206.2**	**48,576.0**	**47,362.8**
Renewable fuels						
Biomass	292.0	303.4	339.6	859.3	845.1	886.9
Wind	573.0	1 406.0	1 434.4	1 416.2	2,005.1	2,771.9
Hydro	557.8	843.7	1,118.5	1,047.4	940.3	1,103.0
Large scale solar PV	–	–	–	–	–	4.4
Small scale solar PV[b]	24.1	66.2	205.5	378.7	580.1	674.2
Geothermal	–	–	–	–	–	–
Total renewable	**1,446.9**	**1,213.3**	**1,663.6**	**2,285.4**	**4,370.6**	**5,440.4**
TOTAL	**55,074.3**	**54,569.9**	**54,172.6**	**55,491.6**	**52,946.6**	**52,803.2**

	2014–15	2015–16	2016–17	2017–18	2018–19
Non-renewable fuels					
Black coal	–	31.9	36.3	13.0	–
Brown coal	48,336.8	46,202.2	43,557.8	36,008.4	34,461.3
Natural gas	2,390.9	1,892.2	2,658.7	3,829.9	3,319.3
Oil products	156.0	70.6	109.3	178	195.3
Other[a]	–	–	–	–	–
Total non-renewable	**50,883.7**	**48,196.9**	**46,362.1**	**40,029.3**	**37,975.9**
Renewable fuels					
Biomass	672.2	747.7	694.5	701.2	789.8
Wind	3,067.8	3,341.8	3,560.9	4,303.9	4,884.8
Hydro	1,170.9	1,207.6	824.8	789.9	1,200.3
Large scale solar PV	9.1	11.5	13.8	39.4	462.5
Small scale solar PV[b]	874.8	1,056.1	1,231.7	1,481.2	1,898.6
Geothermal	–	–	–	–	–
Total renewable	**5,794.8**	**6,364.7**	**6,325.7**	**7,315.6**	**9,236.0**
TOTAL	**56,678.5**	**54,561.6**	**52,687.8**	**47,344.9**	**47,211.9**

4

Calendar year

	2015	2016	2017	2018	2019
Non-renewable fuels					
Black coal	–	–	–	–	–
Brown coal	47,848.0	45,682.7	38,276.7	35,961.4	33,136.8
Natural gas	1,736.0	1,634.4	4,186.0	2,972.2	3,894.3
Oil products	128.4	121.6	170.6	183.3	195.3
Total non-renewable	**49,712.4**	**47,438.7**	**42,633.3**	**39,116.9**	**37,226.4**
Renewable fuels					
Biomass	736.2	761.4	692.2	748.7	789.9
Wind	3,288.5	3,703.2	3,748.3	4,616.8	5,358.6
Hydro	1,323.3	960.3	749.3	1,137.1	960.7
Large scale solar PV	11.9	13.6	19.8	197.3	739.7
Small scale solar PV[b]	970.6	1,141.3	1,343.8	1,660.0	2,159.4
Geothermal	–	–	–	–	–
Total renewable	**6,330.5**	**6,579.8**	**6,553.4**	**8,359.9**	**10,008.3**
TOTAL	**56,042.9**	**54,018.5**	**49,186.7**	**47,476.8**	**47,234.7**

a. Includes multi-fuel fired power plants. This series was discontinued in 2013–14 and multi-fuel allocated to specific fuel types.

b. The 2018–2019 and 2019 estimates may continue to grow as there can be a 12 month lag in the provision of small-scale solar data.

Source: Department of the Industry, Science, Energy and Resources, Australian Energy Statistics, Table O, May 2020.

Energy consumption in Victoria fell 5% in 2017–18, reflecting the large decline in brown coal consumption for electricity generation after the closure of Hazelwood brown coal power station in Victoria in March 2017.[18]

Electricity generation decreased in 2017–18 (by 10%) but increased in all other states and territories. Again, this decline reflects the closure of the Hazelwood power station.

Gas-fired generation fell by 9% in New South Wales and by 10% in Queensland, but rose in all other regions, with a 29% increase in South Australia, and a 44% increase in Victoria to help replace the supply that left with the closure of Hazelwood.[19]

It should be noted that AEMO forecast a significant fall in gas usage, with a decline from 20 petajoules to in 2019 to 8 petajoules in 2020 and to stay relatively flat to 2024 due to the increased amount of renewable generation which is intended to assist in reaching the Victorian Renewable Energy Target (VRET).[20]

18 Department of Industry, Science, Energy and Resources, *Australian Energy Update 2019*, p. 20

19 Ibid.

20 Australian Energy Market Operator, *Victorian Gas Planning Report Update: Gas Transmission Network Planning for Victoria*, online, March 2020, p. 6.

In 2018, more than 75% of electricity generation in Queensland, New South Wales and Victoria was coal-fired. In Victoria, due to the closure of Hazelwood, brown coal's share was 76% in 2018, down from 85% in 2016.[21]

Projections of electricity prices

On a national basis, residential electricity prices and bills are expected to decrease in the period from 2018–19 to 2021–22. This trend is primarily driven by wholesale costs reducing in most of the States and Territories. Prices fall markedly over the whole reporting period as new capacity enters the system. Total capacity of committed projects includes 2,338 MW of solar, 2,566 MW of wind and 210 MW of Open Cycle Gas Turbine. The Australian Energy Market Commission has modelled total capacity of new investments based on finding an optimal mix of generation investment which meets power system needs at lowest cost to consumers. Based on this modelling, total capacity of newly built projects includes 1,555 MW of battery storage, 1,553 MW of wind and 372 MW of solar.[22]

In Victoria, the Government has introduced its Energy Fairness Plan, which builds on the *Independent Review into the Electricity and Gas Retail Markets in Victoria* and incorporates the delivery of fairer energy regulation and is a significant regulatory change. The plan seeks to protect Victorians with the introduction of stronger protections for consumers and tougher penalties for retailers who do the wrong thing. Further, in 2019 the Government implemented the 'Victorian Default Offer' to provide a simple-to-understand, reliable offer for consumers.[23]

Specifically, in Victoria the projections are:

- Annual residential bills in Victoria are expected to decrease by 4.6% (or $53) over the whole reporting period.
- Wholesale costs are expected to go down by 16.8% (or $79) over the reporting period contributing -6.9 percentage points. This is driven by the influx of new renewable generation including 2,421 MW of committed projects and 945 MW of new projects (modelled). This additional supply places downward pressure on wholesale pricing.
- Regulated network costs are expected to increase by 8.2% (or $38) over the reporting period contributing 3.3 percentage points. This is driven by an increase in distribution costs.

---

21 Department of Industry, Science, Energy and Resources, *Australian Energy Update 2019*, p. 29.

22 Australian Energy Market Commission, *Residential Electricity Price Trends 2019*, Online, 2019, p. 3.

23 Victorian Government, *Putting power back in the hands of Victorians*, <https://www.budget.vic.gov.au/putting-power-back-hands-victorians> accessed 20 October 2020.

- Environmental costs are expected to go down by 23.4% (or $21) over the reporting period contributing -1.8 percentage points. This is driven by a decrease in Large-scale Renewable Energy Target costs stemming from a reduction in the cost of large-scale generation certificates.
- The residual cost component explains the remaining variations in the annual residential bill, contributing 0.8 percentage points.[24]

Emphasis on renewable energy

Victoria has been actively pursuing a policy of renewable energy into the future and has enshrined its policy direction in legislation.

In October 2019, the Renewable Energy (Jobs and Investment) Amendment Bill 2019 (Vic) passed the Victorian Parliament, bringing the VRET to 50% by 2030.[25]

According to government statements, the increased target of 50% by 2030, now embedded in the *Renewable Energy (Jobs and Investment) Act 2017* (Vic), builds on the existing, legislated renewable energy generation targets of 25% by 2020 and 40% by 2025. The Victorian Government has stated that:

> The Victorian Renewable Energy Target 2018–19 Progress Report finds that Victoria is well on track to meet the first VRET target for 25% renewable energy generation by 2020.[26]

As outlined in its Renewable Energy Action Plan,[27] the Government is developing a series of policy reforms aimed at reducing emissions and based on a focus on renewable energy. This package of reforms includes the Renewable Energy Action Plan, which seeks to ensure that Victoria's energy supply remains:

- affordable
- safe and secure
- creates jobs
- attracts investment
- grows the economy.

Nuclear power is not part of the Government's future plans and other than reiterating the prohibition on nuclear activities set out in legislation, is not discussed in the Government's current energy strategies.

---

24 Australian Energy Market Commission, *Residential Electricity Price Trends 2019*, p. 11.

25 Department of Environment, Land, Water and Planning, *Victoria's renewable energy targets*, April 2020, <https://www.energy.vic.gov.au/renewable-energy/victorias-renewable-energy-targets> accessed 1 September 2020.

26 Ibid.

27 Department of Environment, Land, Water and Planning, *Renewable Energy Action Plan*, online, 2017.

4.2 Nuclear and renewables in the energy mix

One of the key themes during the Inquiry was that, as a general rule, proponents of nuclear power are not in any way seeing it as the sole source of power and energy generation. It is generally seen by its proponents as an energy source that should be included in the mix of power generation and that renewable energy should also be a significant form of energy. There was very little evidence given to the Committee that suggested renewable energies were not a positive advance in Victoria's energy mix.

Proponents of nuclear energy simply emphasised the fact that renewable energy had issues of stability and energy security that would need to be supplemented significantly and that nuclear power was best placed to provide this stable baseload power in a low emissions environment.

Despite this, there were some concerns raised by proponents of nuclear energy about the emphasis placed on renewables as the future of energy generation. These concerns were raised in submissions and in oral evidence in public hearings and are discussed later in this Chapter.

It is not the Committee's intention to undertake a detailed review of the state of the energy system in Australia. Such a review is beyond the scope of this Inquiry. For context, however, it is worth briefly discussing the transitional stage that the energy sector in Australia is moving through and how energy policy is reacting to it.

4.2.1 An energy market in transition

It is indisputable that the current energy market in Australia is in a state of transition, with major fossil fuel (coal) power generation plants reaching the end of their life and being replaced by other sources of electricity generation. Concerns about climate change and the impact of fossil fuels on carbon emissions, not only within Australia but globally, has driven this shift away from fossil fuels towards variable renewable energy sources.

The AEMO has suggested that the transition in Australia is faster than other countries. It has stated that:

> Historically, Australia's power system has been based on large-scale power stations located around fuel centres supplying remote load centres through large-scale transmission, which is how the physical assets that comprise the current NEM (National Energy Market),were designed and built. Now, the NEM like other power systems around the world, is undergoing a rapid transition. On certain measures, the rate of change in Australia is the fastest of any country in the world. [28]

28 Australian Energy Market Operator, *2020 Integrated System Plan (ISP)*, Online, 2020, p. 21.

According to the AER, energy businesses have responded to the concerns within the community by changing their approach to generation investment. It states in its latest *State of the Energy Market* Report that no energy business has invested in new coal-fired generation in Australia since 2012.[29]

This Report provides some useful context for the current transition and transformation of the Australian energy sector.

4

4.2.2 State of the Energy Market 2020

In its *State of the Energy Market 2020* Report, the Australian Energy Regulator stated that the energy sector is in the midst of its own transition from a centralised system of large fossil fuel (mainly coal) generation towards a decentralised system of widely dispersed, relatively small scale renewable (mainly wind and solar) generators.[30] It describes renewable energy as a relatively cheap fuel source and stated that if it was integrated efficiently into the power system it could deliver low cost sustainable energy.

It acknowledged in the Report that integration issues have arisen because much of the new generation via renewables is located in sunny or windy areas at the edges of the grid and has currently relatively weak transmission network capacity. It also acknowledged that the fossil fuel plant that was being replaced had provided critical technical stability including system strength and security of supply which has not been able to be provided by renewable generation. As stated earlier, the AER suggests that the rising proportion of renewable generation is bringing more periods of low inertia, weak system strength, more erratic frequency shifts, and voltage instability.

The Report stated that:

> This volatility has consequences, such as the rising cost of procuring market services to keep system frequency within safe limits.[31]

However, the Electrical Trades Union (ETU) (Victorian branch) argued that the renewable energy mix is more complex than simple reliance on sunny and windy days. Battery technology is rapidly advancing.[32] The ETU noted in its submission there is great potential for pumped hydro that ‘can be used to support a secure and cheap national electricity grid with 100% renewable energy’.[33] Mr Trevor Gauld from the ETU elaborated on this issue at a public hearing:

> … renewables opportunities are not confined to large-scale solar, though that is one piece in the puzzle. The opportunity to exploit offshore wind is huge. The opportunity to further explore onshore wind is huge. The ANU recently—maybe a few years ago—

---

29 Australian Energy Regulator, *State of the Energy Market 2020*, p. 29.

30 Ibid., p. 11.

31 Ibid.

32 BloombergNEF, *Battery Pack Prices Fall As Market Ramps Up With Market Average At $156/kWh In 2019*.

33 Electrical Trades Union, Victorian branch, *Submission 56*, p. 10.

released a report identifying 22 000 locations around Australia for potential hydro and pumped hydro opportunities.[34]

According to the AER, the weather dependent nature of wind and solar generation creates a need for firming capacity, such as fast start generation, battery storage and pumped hydro plant to fill supply gaps when a lack of wind or sunshine curtails renewable plant. This greater weather-driven volatility also requires better demand and supply forecasting.[35]

AEMO intervened in the market to manage security issues. The AER reported that the market operator has directed generators to operate even if it is not economic for them to do so. It has also de-energised transmission lines in Victoria and instructed load shedding twice in 2019. Load shedding is when power companies reduce electricity consumption by switching off the power supply to groups of customers because the entire system is at risk.

In addition to reliability and security challenges, the AER report identified other risks including the efficient investment in use of energy infrastructure. Issues such as the efficient location of new generation facilities and the coordination of generation and transmission investment were identified.

Despite the challenges that are being faced in shifting from fossil fuel based generation of electricity to the variable renewable energy generated by mainly solar power and wind, the AER has also recognised that technological advancements and cost reductions of grid scale wind and solar generation have outpaced predictions made a decade ago.[36]

The *State of the Energy Market 2020* Report stated that the global levelised cost of onshore wind generation had fallen by 35% between 2010 and 2018. Over the same period, the globalised level cost of large-scale solar PV fell by 77%. In Australia, it quoted the CSIRO and AEMO which estimated the levelised cost of electricity (LCOE) in 2020 for large-scale solar PV and onshore wind of around $50 per megawatt-hour, which it was estimated would be reduced substantially by 2050.[37]

The work of the CSIRO found that the cost of these technologies is significantly lower than the construction cost of new black coal or brown coal generators and that the life-cycle costs of wind and solar generators are now becoming competitive with the operational costs of conventional generators. In the case of wind generation, cost reductions are being driven by advancements in turbine technology with the diameter of the rotors and hub heights increasing significantly, resulting in larger turbines which increases generation capacity.[38]

---

34 Mr Trevor Gauld, National Policy Officer, Electrical Trades Union, public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 8.

35 Australian Energy Regulator, *State of the Energy Market 2020*, p. 11.

36 Ibid., p. 31.

37 Ibid.

38 Ibid.

While the challenges of the transition in the energy market are clear, it is unlikely that the current transformation will reverse or will even slow over the next years and decades. The trend towards an array of smaller scale, dispersed generators is being driven by some interrelated factors including community concerns about the impact of fossil fuel generation on carbon emissions, and their impact on climate change, as well as an environment of high energy prices which has encouraged consumers to change their behaviour in both using energy more efficiently and to generate their own power.[39]

This has developed its own momentum, and as the uptake of renewables rose, economies of scale drove down construction and installation costs. Technologies are also improving which is further lowering costs. According to the AER, these developments have reinforced incentives for further investment and this cycle has helped to establish Australia's solar PV and wind industries.

In response to the transition away from fossil fuels towards alternative sources of electricity generation, the AEMO has published its Integrated System Plan (ISP) for 2020. This provides a roadmap for the transformation of the electricity generation system for the next two decades.

4.2.3 Integrated System Plan 2020

The Integrated System Plan 2020 (ISP) is designed to guide the development of the Australian electricity generation system from now until 2040. This plan is a whole of system roadmap designed to 'maximise net market benefits and deliver low cost, secure and reliable energy through a complex and comprehensive range of plausible energy futures.'[40] The ISP has been developed using a cost benefit analysis, least-regret scenario modelling and detailed engineering analysis. It has identified the least system cost investments needed for Australia's future energy system and has identified targeted augmentation of the transmission grid. It is the intention of the ISP to set out the optimal development path needed for Australia's energy system and it is the claim of the AEMO in developing the ISP that it will create a modern and efficient energy system that delivers $11 billion in net market benefits and meets the systems reliability and security needs through its transition.[41]

Some of the key findings from the ISP include:

- Distributed energy generation capacity is expected to double or even triple with residential, industrial and commercial consumers expected to continue to invest heavily in distributed PV, with increasing interest in battery storage and load management.
- Over 26 GW of new grid scale renewables is needed which will replace the approximately 15 GW or 63% of Australia's coal-fired generation that will reach the end of its technical life and so likely retire by 2040.

---

39 Ibid., p. 29.

40 Australian Energy Market Operator, *2020 Integrated System Plan (ISP)*, p. 9.

41 Ibid.

- From 6 to 19 GW of new dispatchable resources are needed in support to firm up the inherently variable nature of distributed and large-scale renewable generation. Australia will need new flexible, dispatchable resources including utility scale pumped hydro, large-scale battery energy storage systems, distributed batteries, VPP and other demand-side participation. New flexible gas generators could play a greater role if gas prices remained low.
- Power system services are critical to the secure operation of the power system, and active management of power system services will continue to grow in importance for voltage control and system strength, frequency control and inertia, ramping and dispatch ability.[42]

The ISP 2020 has stressed the requirement that the power system needs to meet reliability and security requirements within operating limits and in accordance with operating standards. It states that primary of these is that the system remains in a satisfactory operating state through a contingency and can be returned to a secure operating state within 30 minutes.[43]

4.2.4 A mix of technologies

According to the ISP 2020, across all of the scenarios considered, the NEM is evolving from a centralised coal-fired generation system, to 'a highly diverse portfolio dominated by Distributed Energy Resources (DER) and Variable Renewable Energy (VRE), supported by enough dispatchable resources to ensure the power system can reliably meet demand at all times' [44].

The mix of technologies includes the current fossil fuel-based generation (coal and gas), and an increasing focus on VRE, in particular solar and wind power. Nuclear technology is not considered, at this stage, to be part of the future energy mix. The view has been expressed to the Committee that this is a limitation of the ISP 2020. The submission from Engineers Australia commented on this, saying:

> It [the ISP] does not consider nuclear technologies because they are not a credible option in the current environment [i.e. they are prohibited]. Nonetheless, the ISP could be used to better articulate the role of alternative technologies to provide a view on the likely scope and investment horizon for nuclear power in the Australian context. [45]

The view that the lack of discussion about a nuclear option being considered is a mistake was expressed by a number of participants in the Inquiry.

---

42 Ibid., p. 12.

43 Ibid., p. 23.

44 Ibid., p. 39.

45 Engineers Australia, *Submission 63*, p. 9.

In evidence in a public hearing, Mr Geoff Dyke of the Construction, Forestry, Maritime, Mining and Energy Union (CFMMEU) said that:

> We believe a mix of nuclear, hydro, wind and solar will deliver the lowest cost, most reliable, zero-emissions electricity grid to transition to as coal-fired power stations retire.[46]

In its submission, the Australian Nuclear Association supported this view, stating that 'decarbonising our electricity system will need an optimum economic mix of low carbon technologies to work together.'[47]

The Minerals Council of Australia (MCA) stated:

> Repealing the Nuclear Activities (Prohibitions) Act 1983 along with the repeal of the nuclear energy ban in the Commonwealth's Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is critical if Victoria and Australia are to seriously embrace all technologies so our future energy mix is affordable, reliable and clean.[48]

The Australian Workers' Union (AWU) pointed to the international experience in including nuclear power in its energy mix, saying in that submission to the Inquiry:

> Nuclear energy produces net-zero emissions and more than 33 countries around the world use it as a significant source of baseload energy in their energy mix. With our vast reserves of uranium, Australia would be one of the best placed countries in the world to take advantage of low-cost, abundant, low-emissions nuclear energy.[49]

While support for nuclear energy as part of diverse energy mix was a common theme in a number of submissions, it wasn't a view that it was universally held. It has been suggested that with Australia's access to solar and wind energy, renewable energy will more and more become the viable alternative to fossil fuels and will make nuclear energy unnecessary.

Professor Derek Abbot, a physicist and electrical engineer based at the University of Adelaide, in his submission included an article he had written which asks:

> … maintaining our current levels of consumption in a sustainable manner requires harnessing only 0.02% of the light at the surface of our planet. So do we really need nuclear power? Is nuclear sustainable? Given the awesome potential of renewable energy, is there an economic place for nuclear power?[50]

Other submissions echoed the view that renewable energy is so abundant in Australia and the debate on nuclear is unnecessary.

---

46 Mr Geoff Dyke, Secretary, Victorian Branch, Construction, Forestry, Maritime, Mining and Energy Union, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 2.

47 Australian Nuclear Association, *Submission 50*, pp. 4–5 (quoting OECD 2019, The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables, Nuclear Energy Agency, Organisation for Economic Co-operation and Development, June , no. 7299).

48 Minerals Council of Australia, *Submission 78*, p. 3.

49 Australian Workers' Union, *Submission 71*, p. 18.

50 Professor Derek Abbott, *Submission 23*, p. 4.

In evidence in a public hearing, Professor John Quiggin, VC Senior Research Fellow, School of Economics, University of Queensland, told the Committee that:

> … the combination of drastic reductions in the cost of renewables and the emergence of battery storage as a feasible option mean, in my view, it is likely that we can deliver a firmed renewable system at lower cost than the nuclear power and that nuclear power would be a reserve option that we do not indeed need to call on.[51]

4.3 Supply and demand: grid stability and energy security

This section has been divided into two sub-sections: (1) Grid stability—which focuses on the issue of energy supply and stabilising the energy grid; and (2) Energy security—which focuses on securing the energy grid, preventing an energy crisis and the avoidance of energy blackouts.

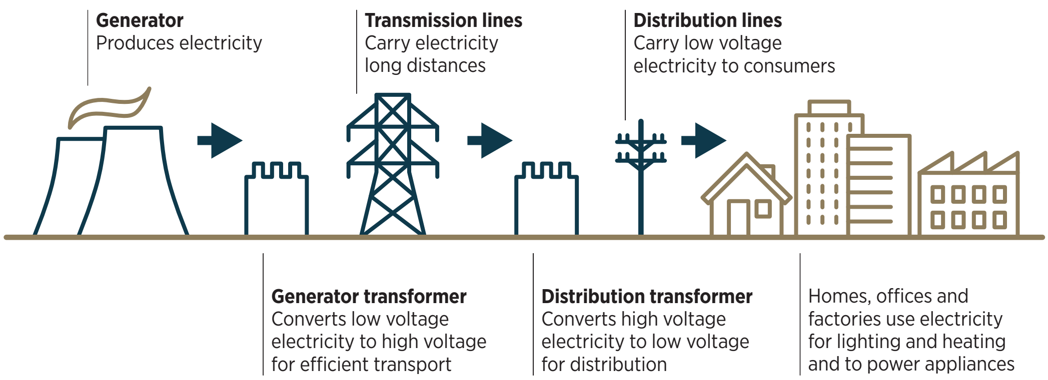
4.3.1 Grid stability

An energy grid is an interconnected network which delivers electricity from the producers to consumers. The grid generally consists of:

- generators
- generator transformers
- transmission lines
- distribution transformers
- distribution lines.

Figure 4.2 shows the process of the energy grid based on the National Electricity Market grid model.

Figure 4.2 Electricity generation, transmission, and distribution



Source: Adapted from AEMO, 'About the National Electricity Market (NEM),' 2020, https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/about-the-national-electricity-market-nem, last accessed 18 August 2020.

---

51 Professor John Quiggin, VC Senior Research Fellow, School of Economics, University of Queensland, public hearing, Melbourne, 14 August 2020, *Transcript of evidence*, p. 36.

Australia's electricity grids which are comprised of two main electricity and many remote (island) grids are centrally designed consisting of:

- 850,000 km of distribution grids distributing electricity across large distances
- 45,000 km of transmission grids delivering electricity from the transmission grid to households and businesses.[52]

Victoria's electricity grid is managed by the NEM, along with the other eastern and south-eastern states.[53]

Many pro-nuclear stakeholders acknowledged that renewable energy technologies have an important role to play in Victoria's energy mix and most did not argue that nuclear should entirely replace renewables' contribution. Rather, there was concern that renewable energy would not be able to provide sufficient baseload power. Therefore, pro-nuclear stakeholders recommended that nuclear energy should provide zero-emission base-load power which supports renewable technologies.

In its submission, the AWU maintained that:

> Australia's industrial sector needs a large amount of reliable electricity which cannot currently be substituted for renewables and battery technologies. These cannot be replaced by small-scale renewables in the existing grid, and it is unlikely to be replaced in great part by large-scale renewables and/or hydro.[54]

The AWU argued that 'the only option for baseload power in a zero-carbon future and a flailing hydro subsector is nuclear energy.'[55]

GE Hitachi Nuclear Energy stated that nuclear energy can provide 'positive contributions to any electrical grid' as well as be integrated with renewables to provide sufficient backup energy supply. In explaining why backup energy sources are important, its submission stated:

> The additional source of power is needed to rapidly ramp up to meet evening demand after the sun goes down, producing a graph that resembles the silhouette of a duck. To address this phenomenon, nuclear would be a good redundant clean energy source and can help provide ramp-up capabilities for the evening hours.[56]

The Hon. Peter Vickery QC suggested that the solution to successfully decarbonising and increasing electricity generation is to incorporate nuclear energy in support of renewables:

> … the central conundrum – how do we de-carbonize and limit global warming, while at the same time increase electricity generation on a very large scale, which is so desperately needed in Australia?

---

52 Clean Energy Council, *Grid*, <https://www.cleanenergycouncil.org.au/resources/technologies/grid> accessed 6 August 2020.

53 Ibid.

54 Australian Workers' Union, *Submission 71*, p. 22.

55 Ibid., p. 25.

56 GE Hitachi Nuclear Energy, *Submission 77*, p. 3.

> This potentially may be achieved in this country, as it has in Britain and many other countries of the world, by the addition of carbon free nuclear power to the energy mix in support of wind, solar and hydro.[57]

At a public hearing, Dr Mark Ho, President, Australian Nuclear Association told the Committee that:

> Nuclear is the only current low-carbon, non-storage firming option for intermittent wind and solar generation. Nuclear power plants are concentrated thermal plants which maximise current grid infrastructure and minimise expensive grid build outs. Nuclear has a capacity factor of up to 92 per cent, meaning it is nearly always on. And with an operational life of 60 years or beyond, the longevity of nuclear plants outcompetes all other forms of energy generation.[58]

The CFMMEU Mining and Energy Division's (Victoria) submission expressed concern that renewable technologies are unsuitable to support the power grid and are adding unnecessary costs:

> While technical solutions can mitigate some detriments of renewables, these solutions tend to be very complex and add extreme costs to the power grid, while still not totally overcoming the no wind – no sun scenario. Energy storage is also unlikely to provide sufficient storage capacity that is required to overcome the no wind – no sun scenario either…
>
> CFMMEU M&E Vic is very concerned about this approach because we believe it will lead to major blackouts, unaffordable electricity and the future economic shutdown of Victoria's industry; resulting in massive job losses and citizen wealth decline. A disastrous transition of the Victoria's electricity grid can be avoided but only if Victoria transitions to a mix of DISPATCHABLE power supplemented by renewables rather than just relying on renewables alone.[59]

Mr Robert Parker, Vice President, Australian Nuclear Association argued that 'when we put more and more renewables into our system, we need more and more grid.'[60]

In his submission, Mr Barry Murphy argued that:

> … the generation of electricity within the National Grid is at risk of developing an over-reliance on intermittent, variable sources of energy without an underpinning of dispatchable forms of generation such as nuclear power.[61]

57 Hon. Peter Vickery QC, *Submission 33*, p. 11.

58 Dr Mark Ho, President, Australian Nuclear Association, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 16.

59 Construction, Forestry, Maritime, Mining and Energy Union, *Submission 20*, p. 2.

60 Mr Robert Parker, Vice President, Australian Nuclear Association, public hearing, Melbourne, 17 July 2020, *Transcript of evidence*, p. 21.

61 Barry Murphy, *Submission 27*, p. 1.

Mr Murphy went on to say that he believed that nuclear power would be the 'only all-weather 24 x hour zero-emissions dispatchable alternative to supply reliable electricity' if fossil fuels are removed from the energy mix.[62]

In contrast, the ETU's (Victoria branch) contended that:

> Existing nuclear reactors are highly centralised and inflexible generators of electricity. They lack capacity to respond to changes in demand and usage, are slow to deploy and not well suited to modern energy grids or markets.
>
> …
>
> … the concept of base load is an economic, not technical issue and much of Australia's electricity network was historically designed to attach large volumes of inefficient load to the network to allow fossil fuel generators to run continuously at high outputs to achieve maximum plan efficiency.
>
> The current levels of renewable deployment have already rendered the concept of base load power redundant in some parts of the network…
>
> The already planned for deployment of additional renewable energy is likely to render the need for so called base load obsolete well before a nuclear plant could be constructed.
>
> Australia needs a flexible, responsive energy system with appropriate levels of intermittent generation sources firmed through hydro, pumped hydro and battery storage solutions. [63]

Similarly, submission Proforma A made the argument that:

> … existing nuclear reactors are highly centralised and inflexible generators of electricity. They lack capacity to respond to changes in demand and usage, are slow to deploy and not well suited to modern energy grids of markets.[64]

In his submission, Professor Derek Abbott also suggested that nuclear energy is not suitable for the current direction of Australia's energy market:

> Nuclear is not suited to the modern electricity grid. Due to rapid advances in power electronics, changing nature of demand, and greater variety of generators, the grid needs storage and generators that respond rapidly. Nuclear has a slow response and thus is not an ideal source, leading to a poor or even negative return on investment.[65]

Professor Abbott's submission included, as supplementary evidence, a journal article titled *Nuclear Power: Game Over* which refuted several arguments nuclear proponents made around grid stability, intermittency and the incapacity of renewables to the support the electricity grid. On the issue of grid stability, the article argued that:

---

62 Ibid., p. 2.

63 Electrical Trades Union, *Submission 56*, p. 10.

64 *Submission Proforma A*, p. 1.

65 Professor Derek Abbott, *Submission 23*, p. 1.

> Nuclear lobbyists create a further false dilemma by suggesting renewables make the electricity grid unstable and therefore nuclear power is required to ensure stability. First, nuclear power is not required because controllable renewable sources (with synchronous generation, such as solar thermal, hydroelectric power, and pumped hydro) already stabilise the grid. It is true that other renewable sources do give rise to grid management issues, but this is bread and butter for grid engineers.[66]

Furthermore, in his article Professor Abbott discussed the issue of intermittent renewables. He gave the analogy of rain to explain that intermittent technologies are not inherently unreliable:

> A common argument nuclear proponents raise is that renewables are intermittent; therefore nuclear power is essential to keep the lights on 24/7. This is wrong on a number of levels.
>
> First, intermittency does not automatically imply reliability. Take the analogy of rainfall. Rain is very intermittent and yet we have a continuous supply of water when we turn on the taps. Why? Because there is reservoir storage, river flow, and many pipe-interconnected collection areas and aquifers. Our water supply would be unreliable if we didn't adequately design an appropriate grid of pipework, dams, and reservoirs. There's no equivalent of a 'nuclear station' providing a constant baseload supply of water. The intermittency in rainfall becomes reliable due to planned storage and spatial diversity. The same principles apply to electricity.[67]

4.3.2 Energy security

Along with grid stability and supply, many stakeholders discussed the issue of energy security. Namely, the need to establish an electricity grid which can prevent, as much as reasonably possible, rolling blackouts. This is a particularly pertinent issue for Victoria because its energy grid is interconnected with other states through the NEM grid. The NEM grid interconnects five jurisdictions: Victoria, New South Wales and the Australian Capital Territory, Queensland, South Australia and Tasmania. According to the AEMO website, the NEM involves:

> … wholesale generation that is transported via high voltage transmission lines from generators to large industrial energy users and to local electricity distributors in each region, which deliver it to homes and businesses.
>
> The transport of electricity from generators to consumers is facilitated through a 'pool', or spot market, where the output from all generators is aggregated and scheduled at five-minute intervals to meet demand.[68]

---

66 Derek Abbott, 'Nuclear Power: Game Over: Australian Quarterly', 2016, p. 14.

67 Ibid., p. 13.

68 Australian Energy Market Operator, *About the National Electricity Market*, 2020, <https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/about-the-national-electricity-market-nem> accessed 18 August 2020.

Mr Mark Richards, Mining & Energy Division, CFMMEU, described the effects of the interconnected energy grid between Victoria and other States:

> We saw South Australia black out and they came back online due to Victoria having an energy supply essentially. We rely on New South Wales with interconnectors. What I would say is: on I think it was 23 January 2000 there was a system disturbance where they lost one of the power stations, at I think Liddell – 600 megawatts. That caused another one to go out in sympathy in New South Wales. We then had a system disturbance here that nearly blacked out the state, and it is the one document that has never been released by AEMO at the time that talks about how we nearly lost the state. The frequency dropped to 49.1, from memory. It was the worst we have had, and it is something that has never been released. This was from 20 years ago. So if we are closing down more power stations, which is our spinning inertia, if we close another one, we are looking at a grid that is really reliance on interconnectors and possible brownouts and blackouts.[69]

This was also discussed by the CFMMEU in its submission as an argument against transitioning to a 100% renewable electricity grid. The submission provided examples of recent national electricity grid events which the CFMMEU believed showed the importance of having a dispatchable power system to meet electricity demand:

> There have been many glaringly national electricity grid events over recent years that should trigger a re-think by rational governments over the rapid and unproven current transition towards 100% renewables. These include: Tasmanian energy crisis caused by drought & failure of Basslink, the South Australia's 'system black' caused by a storm, the Alice Springs 'system black' caused by a cloud, and the Victorian 2019 summer 'brown outs' caused by insufficient dispatchable generation and the predicted future grid instability in West Australia caused by excessive solar generation.[70]

The CFMMEU's submission went on to argue that the above examples showed:

> All these events highlight the critical importance of having sufficient dispatchable power to meet electricity demand and to deliver other vital technically characteristics for the electricity system so that it is stable and reliable.[71]

Mr Patrick Gibbons, MCA suggested that to ensure grid security, particularly in areas that require 24/7 power, when fossil fuels are phased out small modular reactors (SMRs) should be built at the edge of the electricity grid:

> You can place [SMRs] on-grid and at the edge of grid – so right at the edge of where the electricity grid is in regional areas where there is a demand for basically 24/7 power. You can also place them off-grid in remote communities, where, again, you have that demand for power, but it is not on the grid…[72]

---

69 Mr Mark Richards, Mining & Energy Division, Construction, Forestry, Maritime, Mining and Energy Union, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 4.

70 Construction, Forestry, Maritime, Mining and Energy Union, *Submission 20*, p. 14.

71 Ibid.

72 Mr Patrick Gibbons, Minerals Council of Australia, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 38.

The variability of supply of renewable energy is acknowledged by the AEMO in its ISP 2020. It estimates that the NEM will need 16 to 19 GW of new flexible, utility-scale dispatchable resources to firm up the 'inherently variable resources'.[73] The investment in dispatchable resources is seen to include utility-scale pumped hydro, or battery storage, with the assumption that technology costs will continue to fall on the market arrangement sufficiently incentivised this development.

It is the expectation that the technology in these dispatchable resources will continue to develop. It expressed the belief that utility-scale energy storage can shift the timing of renewable energy production, reduce the magnitude of new interregional transmission required and provide firming support during peak loads or when renewable production is low.[74] The AEMO said in its report:

> Ultimately, the NEM will draw on a technologically diverse mix that may diversify further as other technologies, such as hydrogen, mature. In the end, a well – designed market is best positioned to determine the optimal mix of these dispatchable resources as technological, economic and policy decision factors evolve over time.[75]

There were a number of proponents of nuclear energy who expressed the view that battery storage, as a significant supplement to VRE is still not yet able to provide the security of supply required. In evidence, Mr Ian Hore-Lacy of the World Nuclear Association told the Committee:

> That big South Australian Tesla battery is a great success, but it is used…for ancillary services—frequency control most of all—and very little for energy storage. And that is the case with most large batteries being connected to the grid around the world; they are mainly for ancillary service purposes to stabilise the grid where you have got a high proportion of renewables. Actually storing significant amounts of energy… would become hugely expensive.[76]

Mr Hore-Lacy went on to say that:

> … without significant contribution from nuclear power Victoria will only have the choice of continuing to burn a lot of coal for electricity…with its CO2 implications, or having ruinously expensive electricity depending on levels of battery storage which are pure fantasy. [77]

Mr Geoff Dyke, Secretary, Victorian Branch, CFMMEU, explained that:

> Across Victoria and South Australia there is 190 megawatts of grid batteries that cost $190 million. They provide a supply that would last seconds to minutes depending on the load, and with a 10-year life. They were only installed to cater for the effects of wind and solar. Additionally the South Australian government spent $600 million on

73 Australian Energy Market Operator, *2020 Integrated System Plan (ISP)*, p. 50.

74 Ibid.

75 Ibid.

76 Mr Ian Hore-Lacy, Senior Adviser, World Nuclear Association, public hearing, Melbourne, 14 August 2020, *Transcript of evidence*, p. 50.

77 Ibid., p. 46.

> diesel generation. They have got 550 megawatts of diesel generators sitting there not running, which is one-third of the South Australian electricity grid. We believe that is symptomatic of poor system design. [78]

The South Australian Nuclear Fuel Cycle Royal Commission, which reported prior to the building and commissioning of the world's largest battery system in 2017,[79] also cast doubts upon the current capacity of battery systems, stating in its report:

> While battery storage technologies for a range of South Australian commercial and residential consumers are likely to be viable in the near future (particularly for those with time-of-use or capacity-based tariffs and who can integrate photovoltaic systems), the same is not true for on-grid storage. Battery, thermal or pumped hydro storage may have a future role by displacing additional transmission capacity and/or peaking generation capacity. A recent CSIRO analysis, based on expected declines in battery prices, concluded that the levelised cost of energy from lithium-ion batteries could be competitive with gas peaking power plants by 2035, but only in parts of the network such as South Australia and Queensland where there is a significant requirement for peaking capacity.[80]

It has also been claimed that battery storage is too expensive to be an economically viable solution to fluctuations in energy supply from VRE.[81]

Mr Michael Shellenberger of Environmental Progress, a research and policy organisation in the United States, told the Committee that the use of battery storage adds to the cost of energy generation:

> So it is all of the things you have to do to manage all of those unreliable renewables coming onto the grid, whether it is batteries or hydrogen or pumped storage or just operating your gas turbines to idle to really ramp up, plus all the additional people required to coordinate this. The reason grid electricity is so cheap is because we are constantly matching supply and demand. When those two things become unmatched and you add energy conversions, taking electricity off the grid and bringing it back on, you are significantly adding significant cost to the electricity.[82]

The additional cost of the use of storage to maintain constant supply was also a theme of evidence given by Mr Barrie Hill, a retired engineer and consultant in power generation and utilisation in Australia, United Kingdom and New Zealand. Mr Hill told the Committee in his submission that:

> It is technically possible to interrupt customer electricity supplies or to release energy stored in batteries to partially alleviate some of these issues. These options have limited utility and very high cost compared with conventional operations. As engineering

78 Mr Geoff Dyke, *Transcript of evidence*, p. 3.

79 Hornsdale Power Reserve is a 150MW/194MWh grid-connected energy storage system co-located with the Hornsdale Wind Farm in the Mid North region of South Australia. Between 2017 and 2020, it was the largest lithium-ion battery in the world.

80 Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, Government of South Australia, South Australia, 2016, p. 66.

81 Ibid.

82 Mr Michael Shellenberger, Environmental Progress, public hearing, Melbourne, 14 August 2020, *Transcript of evidence*, p. 16.

> knowledge currently stands, electricity cannot be cost effectively stored at grid scale except as potential energy in large hydroelectric pumped storage projects.[83]

This view of battery storage is not universally accepted. Some of the evidence given to the Committee considered battery storage to be a way of making renewable energy sources a viable long-term option and that rapid advances are likely to make such technologies increasingly viable. They are also likely to become more cost effective as the technology develops.

In a public hearing, Professor Quiggan told the Committee that:

> Well, certainly, battery storage to a significant extent is feasible right now. It might run into limits well into the future, but I think that is the policy we are going to need for the foreseeable future to firm up the grid, especially as we see increasing failures in the coal-fired power station part of the system.[84]

The Committee notes that the CSIRO *GenCost Report 2020* has identified falling costs of battery storage. The Report stated that:

> Aurecon (2020) has provided battery costs for 1, 2, 4 and 8 hour energy duration. The 1 hour battery costs are 24% lower than the 2018 costs estimated by GHD (2018). Together with the CSIRO (2017) estimates, this indicates a declining trend over two years and aligns with stakeholder feedback that battery costs have lowered.[85]

The Report suggests that the 'current costs for the battery only component of battery storage systems is around $420/kWh based on Aurecon (2020), down from $600/kWh in GHD (2018).' [86]

The GenCost Report provides some additional analysis on battery costs to indicate where they now stand in terms of competitiveness by simply annualising the capital cost and comparing battery storage costs to pumped hydro storage. The data indicates that battery storage is capital cost competitive at low storage duration, of up to 8 hours storage. The data for the available durations shows that pumped hydro capital costs increase at a lower rate with storage duration and, as a result, are more capital cost competitive at longer durations. [87]

Recent reports of the 50% expansion of the world's largest lithium ion battery in South Australia in 2020 indicate that the potential output for the batteries has been expanded by 50 MW. It's been reported that an independent review found the battery had saved South Australian consumers more than $150 million since 2017 and the South Australian Government is advocating for more grid scale and household batteries. One media report stated that the reason that large-scale batteries such as the one in Jamestown

---

83 Barrie Hill, *Submission 47*, p. 3.

84 Professor John Quiggin, *Transcript of evidence*, p. 41.

85 Jenny Hayward Paul Graham, James Foster, and Lisa Havas, *GenCost 2019–20*, CSIRO, Online, 2020, p. 6.

86 Ibid., p. 18.

87 Ibid., p. 26.

are so crucial is that South Australia has had an enormous uptake of renewable energy with more than 278,000 houses in South Australia having rooftop solar panels.[88]

This media report indicated that the huge take-up of domestic solar panels has created an enormous aggregated solar generator that the grid may not be able to handle. It said that the problem arises when surplus power generated by rooftop solar panels is fed back into the grid at a rate that the grid cannot handle. According to the South Australian Energy Minister:

> There are times when we have nearly more electricity going back into the grid from solar than we have coming out of it, and if it crosses that threshold, it will be a disaster for the grid.[89]

As a way of managing this problem, the South Australian Government has allowed the State's electricity distributor to remotely switch off solar panels during peak times. This will allow the solar panels to operate and deliver electricity to the house they are attached to but the surplus will not be put into the grid. The Government is advocating for the wide scale adoption of domestic batteries.[90]

Conclusion

As stated at the outset of this section, it is not the Committee's intention to advocate for any particular technology nor to attempt a technical comparison. Such a detailed analysis is outside of the scope of this Inquiry. In the Committee's view, however, any discussions about the relative merits of a particular energy generation technology needs to take into account all elements of the cost of such technologies.

The current planning for future energy generation clearly has battery storage technology as a significant supplement to VRE to ensure continuity of supply. The Committee has no view on whether such technologies will provide the necessary security of supply in the medium to long-term. It is, however, difficult to make direct comparisons with other options such as nuclear energy generation while those other options are prohibited.

FINDING 1: Regardless of technology development, priority should be given to the security, stability and accessibility of energy supply and the need to lower carbon emissions due to climate change and to ensure affordable energy.

88 Sara Tomevska, 'Tesla battery in South Australia expanded by 50 per cent, energy minister lauds benefits', *ABC News*, 2 September 2020, <https://www.abc.net.au/news/2020-09-02/tesla-battery-expanded-as-sa-energy-minister-lauds-benefits/12622382> accessed 03 September 2020.

89 Ibid.

90 Ibid.

5 Costs of nuclear energy

5.1 Introduction

The issue of costs is a particularly thorny one as there is no domestic nuclear industry upon which to base firm costings in the Australian market. Some of the costings used in policy development have been criticised by proponents of nuclear power and some of the arguments put forward are covered in this chapter.

5.2 Costing of energy

The economics of energy production needs to consider several aspects in order to calculate overall viability and competitiveness across technologies:

- Capital costs—site preparation, construction, manufacturing and financing
- Plant operating costs—cost of fuel, operation and maintenance and decommission funding
- External costs—for example projected costs of dealing with an accident or emergency
- Other costs—for example system costs or technology-specific taxes (eg nuclear- or carbon-specific).

5.2.1 How are costs compared across different electricity technologies?

To compare the costs of different energy sources on a consistent basis, the levelised cost of energy (LCOE) measure is often used. LCOE is a cost measure of a power source which can be used to determine the minimum constant price an electricity source needs to be sold at in order to break even (i.e. it is the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a plant).

The LCOE method of costing energy generation is commonly used in the development of energy policy. It is noted that some in the energy sector consider this method to be limited. These limitations are noted in later in this chapter.

LCOE is the net value of all costs over a lifetime divided by the sum of electrical energy produced. It also takes into consideration:

- investment expenditures
- operations and maintenance expenditure

- fuel expenditure
- electrical energy generated
- discount rate(s)
- expected lifetime of system or power station(s).

Despite being the predominant method used to calculate costs across different energy technologies, LCOE has several limitations including:

- ignores time effects associated with matching electricity production to demand:
  - *Dispatchability:* ability of a generating system to come online and go offline or increase generation as demand changes
  - *Measuring:* the extent to which availability matches or conflicts with market demand
- does not consider indirect costs of generation—such as external factors or upgrade requirements
- does not consider the influence of energy efficiency and conservation.

According to the World Energy Council's report a number of factors can influence the overall cost-competitiveness of nuclear technology such as upfront capital costs and uranium prices. The high-cost region represents the European Pressurized Reactors under construction in France and Finland. Whereas, the low-cost region are projects like Abu Dhabi's Barakah nuclear plant and China's nuclear plants.[1] In explaining the difficulties in determining precise costs for nuclear plants the report states:

> Little price discovery is available on many nuclear plants, and due to the very long planning and construction horizon relative to other generation options projects can be subject to significant cost overruns.[2]

Due to the large number of factors that may influence overall cost competitiveness of nuclear energy, and the vast range of costs that are reported worldwide depending on the circumstances of the different countries involved, cherry picking particular costs is not helpful in determining how cost-effective nuclear power might be in Australia. At a public hearing Dr Dylan McConnell, Climate and Energy College, University of Melbourne, told the Committee:

> To that end, there are basically two main points I would like to make: firstly, that the emerging dynamics and requirements of the power system present a bit of a challenge to technologies with a cost structure like that of nuclear; and secondly, without strong government intervention, nuclear power will face a lot of challenges in a liberalised

1 World Energy Council and Bloomberg New Energy Finance, *World Energy Perspective: Cost of Energy Technologies*, World Energy Council, online, 2013.

2 Ibid.

power system like the one we have here. Both of these combine to create basically significant barriers for the development of nuclear power in Australia.[3]

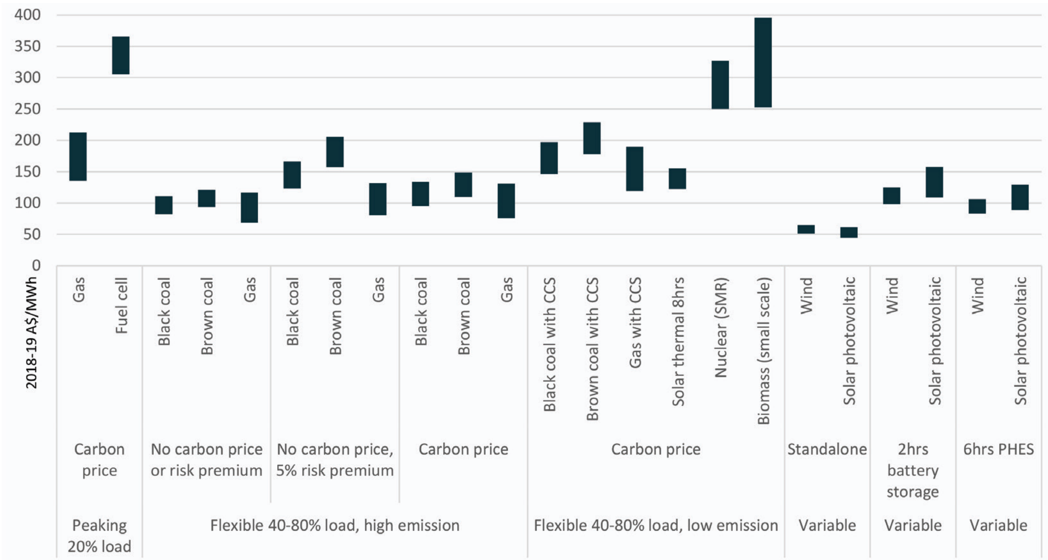
5.2.2 Australia

In December 2018, the CSIRO released *GenCost 2018* which provided updated projections of electricity generation cost and included modelling for nuclear energy generation based on small modular reactors (SMRs). The choice of SMR may appear strange given that no such reactors have yet been built and are operating anywhere. However, the reasons given are reasonable and are based on the assumptions that that smaller plant are likely to be the only type employed in Australia in the future and 'feedback from stakeholders suggested that large plant of any kind (nuclear, coal and gas) will be more difficult to deploy because of falling minimum demand and the greater redundancy required to cover an unplanned outage of a large plant'.[4]

It should be noted that in this GenCost 2018 report, as nuclear prohibitions are still in place in Australia, the projected LCOE for nuclear remains static across the entire reference period (2020–2050). Therefore, all nuclear cost estimates and analysis are predictive modelling.

Figure 5.1 shows the calculated LCOE by technology and category for 2020, including for nuclear (SMR).

Figure 5.1 Calculated LCOE by technology and category for 2020.



Note: Ranges are primarily based on differences in carbon prices, capital fuel costs and capacity factors.

Source: CSIRO, *GenCost 2018*, p. 28.

---

3 Dr Dylan McConnell, Climate and Energy College, University of Melbourne, public hearing, Melbourne, 11 September 2020, *Transcript of evidence*, p. 21.

4 Jenny Hayward Paul Graham, James Foster, Oliver Story and Lisa Havas, *GenCost 2018: Updated projections of electricity generation costs*, CSIRO, Online, 2018, p 4

The LCOE range for nuclear is AUD$250-325/MWh, which is the second-highest range of all energy technologies calculated. However, this high range could be attributed to the fact that no nuclear energy generation occurs in Australia and any new technology would have a high LCOE on introduction.[5]

Black and brown coal remained largely static in their LCOE ranges in both the no carbon price and carbon price scenarios.[6]

Table 5.1 Black and brown coal LCOE ranges

	No carbon price AUD$/MWh	**Carbon price** AUD$/MWh
Black coal	approximately 75–115	approximately 95–140
Brown coal	approximately 155–205	approximately 110–150

Source: CSIRO, *GenCost 2018*, p. 28.

Table 5.2 Wind and solar LCOE ranges, under battery storage and PHES variable

	Wind AUD$/MWh	**Solar** AUD$/MWh
2 hours battery storage (variable)	approximately 100–125	approximately 110–160
6 hours PHES[a] (variable)	approximately 80–105	approximately 90–125

a. Pumped hydro energy storage.

Source: CSIRO, *GenCost 2018*, p. 28.

However, the LCOE for wind and solar under the variable standalone scenario was lower than conventional technologies.

Table 5.3 Wind and solar LCOE range, under standalone variable

	Wind AUD$/MWh	**Solar** AUD$/MWh
Standalone (variable)	approximately 50–60	approximately 45–55

Source: CSIRO, *GenCost 2018*, p. 28.

According to the data produced in the GenCost 2018 Report, Nuclear energy is the most expensive form of electricity generation, with projections based on the SMRs currently under development suggesting it will remain the most expensive (in $/kW) until at least 2050.

5 Ibid., p. 28.

6 Ibid.

In his submission, Professor John Quiggan from the University of Queensland noted the conclusion of the South Australian Nuclear Fuel Cycle Royal Commission (SANFCRC) that 'it would not be commercially viable to generate electricity from a nuclear power plant in South Australia in the foreseeable future' was consistent with his own findings.[7] He further noted the that experiences at nuclear power plants around the world as further proof of this:

> Events since then have reinforced that conclusion. A number of nuclear projects in the US and UK have been abandoned or deferred indefinitely, including VC Summer (US), Moorside (UK), Wylfa (UK) and Kaminoseki (Japan), while cost estimates for projects under construction, including Vogtle (US), Flamanville (France) and Olkiluoto (Finland) have risen further. The only new1 project to begin construction in the OECD2 has been the Hinkley C project. As discussed below, the viability of this project depended critically on the adoption of ambitious goals for emissions reductions and a high price for carbon.[8]

Professor Quiggan went on to argue:

> The introduction of a carbon price of $50/tonne would raise concerns about the economic disruption. Moreover, the price need not be attained until construction of nuclear power plants was about to commence, which is unlikely before 2025. Further, in view of past policy reversals, a sustained commitment to carbon pricing would be required before investors would be willing to risk their capital. [9]

Professor Quiggan also recommended in his submission that a carbon price of $25/tonne should be introduced immediately, and increased at a real rate of 5% a year, reaching $50/tonne by 2035.[10]

Figure 5.2 shows the relative costs of all main sources of energy in 2020, 2030, 2040 and 2050 claimed by the CSIRO's 2018 report. The intention is to show not only the relativities of costs based on the GenCost 2018 data, but the trend of costs over the next 30 years.

---

7 Professor John Quiggin, *Submission 14*, pp. 6–7.

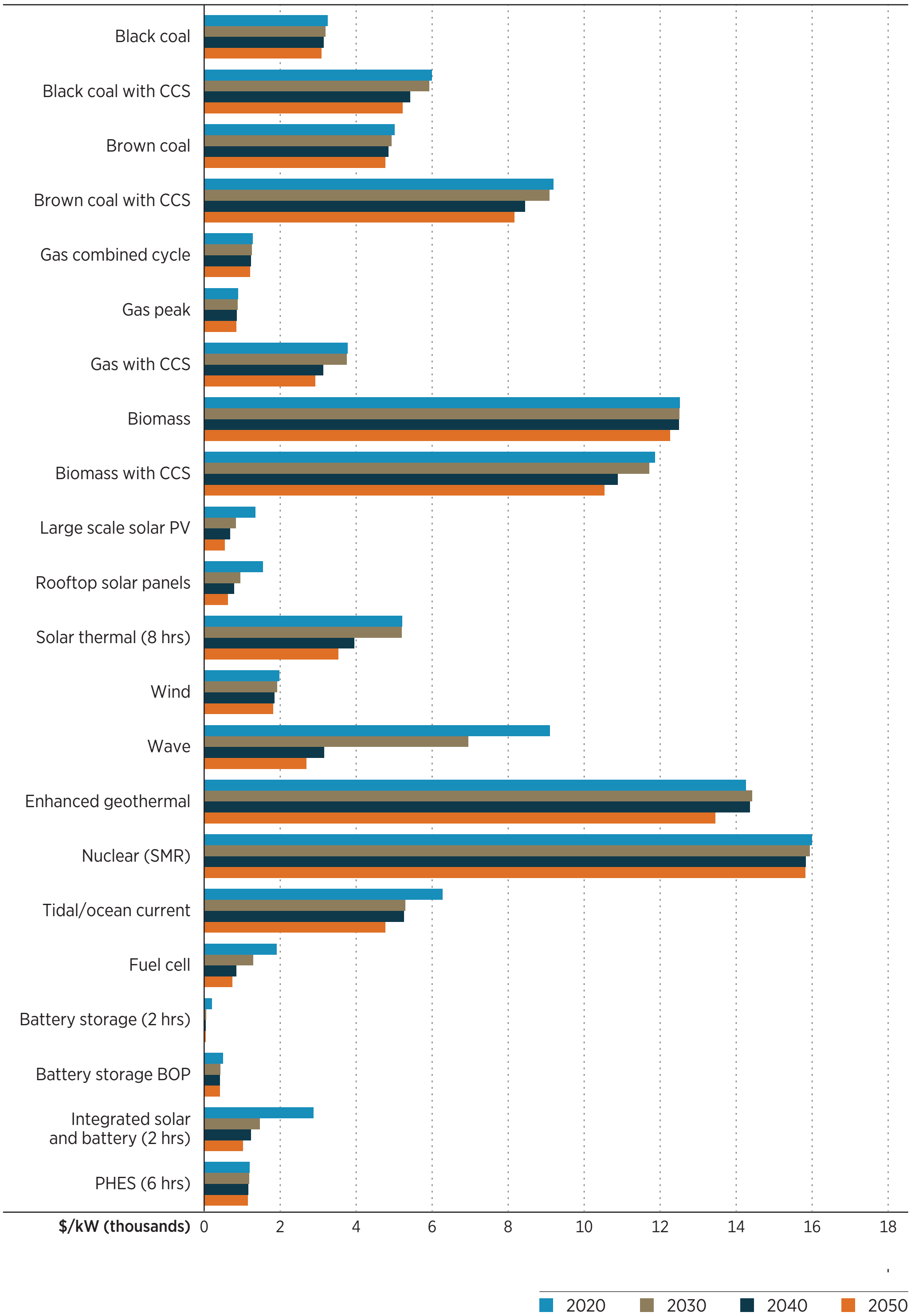
8 Ibid.

9 Ibid, p 10.

10 Ibid.

5

Figure 5.2 Projected capital costs of energy by fuel type, 2020–2050



Note: This data is based on an assumption of 4-degree warming scenario.

Source: CSIRO, *GenCost 2018*, p. 52.

As can be seen in the modelling undertaken for the GenCost 2018 report, in addition to being the most expensive energy source by cost per kW, the cost of nuclear power also was projected to reduce little over the thirty year period.

The Committee heard during the course of the Inquiry that these projections are misleading for a number of reasons. The Minerals Council of Australia suggested in its submission that:

> … its fundamental shortcoming is that it fails to indicate when power is produced. System costs of back-up, storage and ancillary services are required to ensure grid stability and the reliable provision of power and needs to be factored in to each type of generation cost.[11]

This view was echoed by a number of other submissions. The submission from nuclear advocacy group Nuclear Now was also critical of the data used in the GenCost 2018 report, stating that its data:

> From a simple levelised cost critique, wind and solar continue to drop in price and have become cost competitive; however when system costs are included, the economics can change… For a low penetration of variable renewable sources on a grid these costs are reasonably low, but as their presence increases these costs can rise significantly.[12]

The most strongly worded criticisms of the GenCost 2018 conclusions on costs of nuclear power were provided by Bright New World, a not-for-profit environmental organisation located in South Australia which is a strong advocate for nuclear power to be included in the Australian energy mix.

It its submission, Bright New World stated that in relation to the GenCost 2018 data:

> Bright New World has reviewed the document and its supporting work for the treatment of SMR nuclear technology. The results are not consistent with 'wide stakeholder engagement and transparency' and certainly not presenting results that are a function of 'global technology deployment.' [13]

The Bright New World submission referred to the GenCost 2018 analysis of the costs of nuclear power as seriously flawed and stated that:

> The stated capital expenditure ($16,000/kW) and levelised cost of electricity for SMR nuclear is indefensible and does not withstand scrutiny. Given the reliance many Australian stakeholders place on this report, and the trust placed in AEMO and CSIRO, this section of the GenCost work requires urgent revision, from suitable qualified professionals, to inform current political conversations in Australia.[14]

---

11 Minerals Council of Australia, *Submission 78*.

12 Nuclear Now, *Submission 75*, p. 5.

13 Bright New World, *Submission 74*, p. 22.

14 Ibid.

In evidence before the Committee in a public hearing, Dr Ben Heard of Bright New World, went further on this point, stating that in his view the figure of $16,000 per kW used in the GenCost cannot be justified, and is not justified by the report. He told the Committee:

> On CSIRO GenCost: are they wrong? Yes, they are wrong. I have written a long and detailed report that they are wrong. They quoted a figure of $16 500 per kilowatt installed for SMR nuclear technologies. The figure had no reference. I searched every published study for SMR nuclear technologies worldwide. The highest figure approached around about $9000. Under questioning in committee, they were not able to provide a reference for the technology. The findings the previous committee found were that that was unverifiable, and, 12 to 18 months later, no-one has been able to find a reference for that figure.[15]

In the GenCost 2020 report, published in May, the CSIRO has recognised that there were significant disputes about various elements of the date the used for nuclear power. In addressing these issues, the new report stated that:

> … we found that, while GHD's source was unclear, there is no hard data to be found on nuclear SMR. While there are plants under construction or nearing completion, public cost data has not emerged from these early stage developments. In lieu of hard data, estimates are only available from vendors (quoting future project costs) or from applying engineering principles. Past experience has indicated that vendor-based estimates are often initially too low and also do not meet our definition of current costs.[16]

The report goes on to say that almost all of the feedback it received about the costs of nuclear power in GenCost 2018 was to 'endorse vendor estimates of costs for delivery of future SMR capacity in the late 2020s.'[17]

The Committee did receive submissions from vendors who were in the process of developing SMRs and these vendors provided cost estimates for their proposed plant.

NuScale Power, a United States company which has received approvals to develop an SMR and which is in the process of preparing for tests of its first of a kind reactor, provided the Committee with a submission and appeared before the Committee in a public hearing to give evidence.

In both its submission and its oral evidence, NuScale provided costings of its reactor for both the first of a kind and 'nth-of-a-kind', or subsequent reactors.

---

15 Dr Ben Heard, Bright New World, public hearing, Melbourne, 14 August 2020, *Transcript of evidence*, p. 27.

16 Jenny Hayward Paul Graham, James Foster, and Lisa Havas, *GenCost 2019-20*, CSIRO, Online, 2020, p. 4.

17 Ibid.

The NuScale first-of-a-kind cost is claimed to be US$2.9 billion in capital costs, with 'nth-of-a-kind' subsequent plants costing US$2.45 billion. [18] This equates to US$4,350/kW and US$3,600/kW[19] respectively. Converting that to Australian dollars the figures are close to AUD$6,100/kW and AUD$5,000/kW respectively. This represents a very substantial difference to the figure of AUD$16,000/kW suggested by the GenCost 2018 report.

A couple of caveats should be noted about the NuScale costing. Firstly, the cost is based on a generic Southeast US site, where other nuclear reactors already exist and therefore supply chains, transportation infrastructure, regulatory processes and other elements of a mature industry are established. This, in Australia, is not the case and therefore there are likely to be additional costs in establishing a reactor.

These additional costs were acknowledged by NuScale in its evidence in a public hearing during the Inquiry. In response to a question that suggested an estimate by the Utah Associated Municipal Power Systems (UAMPS) was more than US$6.1 billion (AUD$8.5 billion) to build the SMR, Mr Thomas Mundy, the Managing Director of NuScale, told the Committee that:

> … the (US)$2.9 billion is for the generic site. That is an overnight cost. It does not include warranty, contingency, fees, profit, interest charged, owners' costs and a number of other things. That is just the cost if you were to build it overnight and what you would pay. [20]

He went on to say:

> The $6.1 billion is a very conservative estimate which includes contingency and these other components—interest, which is a very large component when you are talking about financing a power plant that costs $3 billion. That is the difference between essentially $3 billion and the higher number that UAMPS has identified to its customer base as to what the total project cost will be if everything is incurred, all the contingency is used up, all the fees are paid—all those kinds of components.[21]

Even with the additional costs calculated by UAMPS, however, the costs claimed by NuScale are still substantially lower than the 2018 report estimates.

In its GenCost 2020 report, the CSIRO also addressed the issue of the lower costs provided by vendors. In addressing the SMR costings, saying:

> Constructing first-of-a-kind plant includes additional unforeseen costs associated with lack of experience in completing such projects on budget. SMR will not only be subject to first-of-a-kind costs in Australia but also the general engineering principle that

---

18 NuScale Power, Submission 42, p 15

19 That is in 2017 US$.

20 Mr Thomas Mundy, NuScale Power, public hearing, Melbourne, 14 August 2020, *Transcript of evidence*, p. 13.

21 Ibid.

> building plant smaller leads to higher costs. SMRs may be able to overcome the scale problem by keeping the design of reactors constant and producing them in a series. This potential to modularise the technology is likely another source of lower cost estimates.[22]

It suggested that even where the industry reaches a scale where small modular reactors can be produced in series, 'this will take many years to achieve and therefore is not relevant to estimates of current costs (using our definition)'.[23]

In the most recent iteration of the GenCost report, published in May 2020, there has been no assumed current capital cost amendment for nuclear SMRs.

However, the report does acknowledge that despite the fact that there are no real projects to base costing on and therefore there is significant uncertainty about the costs, there is a broad consensus that we should see more competitive costs from the late 2020s if assumed planned projects go ahead.

The 2020 report acknowledged that the 2018 report did not capture this expected improvement in costs over time and so the CSIRO's projection model was modified to include SMRs as a separate nuclear technology category which means that it was assigned its own higher learning rate, which is more consistent with an emerging technology. This is instead of being included in a broad nuclear technology category which as a mature technology had a lower learning rate.

The GenCost 2020 report made capital cost assumptions based on different scenarios. Firstly, what they referred to as the central scenario applies a moderate 4 degrees consistent climate policy with no extension to current renewable energy policies globally. Secondly, the high variable renewable energy (VRE) scenario which applies a strong climate policy (similar to but higher than the 2 degrees carbon price applied in GenCost 2018) that supports high electrification across sectors such as transport and buildings and subsequently high electricity demand. Under this scenario, renewable energy resources are less constrained (physically and socially) and balancing variable renewable electricity is less challenging. Finally, the diverse technology scenario assumes that physical and social constraints mean that access to variable renewable energy resources is more limited. Governments subsequently limit their renewable targets below the threshold required for major deployment of balancing solutions. Consequently, there is a greater reliance on non-renewable technologies and a carbon price consistent with a 2 degrees consistent climate policy provides the investment signal necessary to deploy these technologies.

Therefore, the GenCost 2020 report is now projecting a substantial cost reduction to around $7,220/kW in the early 2030s in the central scenario[24] and to $7,140/kW in the event of the diverse technology scenario.[25]

---

22 Paul Graham, *GenCost 2019-20*, p. 4.

23 Ibid.

24 Ibid.

25 The diverse technology scenario assumes that physical and social constraints mean that access to variable renewable energy resources is more limited.

In Figure 5.3 below, it can be seen that the current cost estimate for nuclear SMRs remains the same as the original, and disputed, figure. However, a greater learning rate which was not applied to the original cost has seen their estimate of capital costs reduce substantially over time.

This is unlikely to significantly reduce the disagreement about the initial estimate.

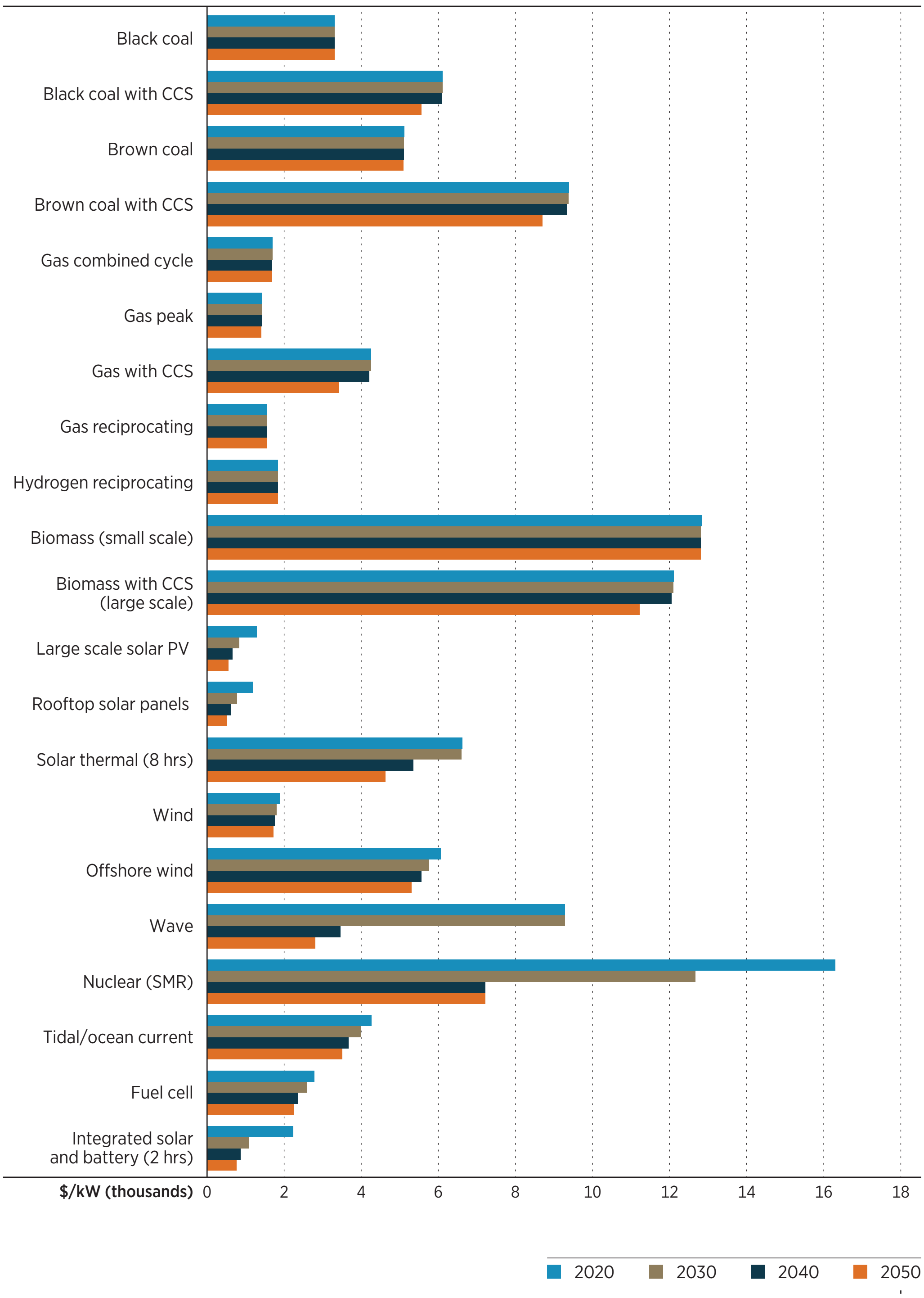
Further complicating the issue of costs, the Committee was also told that cost blowouts are common in the nuclear industry so any estimated figures may need to be treated with caution. In its submission to the Inquiry, Friends of the Earth identified a number of blowouts in the cost of nuclear power plants around the world, citing recent examples of significant cost increases:[26]

- The estimated cost of the high-temperature gas-cooled SMR (HTGR) under construction in China has nearly doubled.
- The cost of Russia's floating SMR quadrupled.
- The estimated cost of Argentina's SMR has increased 22-fold above early, speculative estimates and the cost increased by 66% from 2014, when construction began, to 2017.
- The cost estimate for the Vogtle project in US state of Georgia (two AP1000 reactors) has doubled to more than US$13.5 billion per reactor and will increase further. In 2006, Westinghouse said it could build an AP1000 reactor for as little as US1.4 billion—10 times lower than the current estimate for Vogtle.
- The estimated cost of about €12.4 billion for the only reactor under construction in France is 3.8 times greater than the original €3.3 billion estimate.
- The estimated cost of about €11 billion for the only reactor under construction in Finland is 3.7 times greater than the original €3 billion estimate.
- The estimated combined cost of the two EPR reactors under construction in the UK, including finance costs, is £26.7 billion (the EU's 2014 estimate of £24.5 billion plus a £2.2 billion increase announced in July 2017). In the mid-2000s, the estimated construction cost for one EPR reactor in the UK was £2 billion, almost seven times lower than the current estimate.

26 Jim Green, 'The SMR 'hype cycle' hits a hurdle in Australia', *Nuclear Monitor*, no. 886, 8 June 2020, p. 10, accessed 5 November 2020.

5

Figure 5.3 Projected capital costs of energy by fuel type, 2020–2050



Source: CSIRO, *GenCost 2019–20*, pp. 37–41.

5.2.3 Conclusion

It is clear from both the different sources of costing and the substantially different capital cost estimates per kilowatt, there is unlikely to be any agreement about the relative cost of nuclear power in Australia until there is a specific and detailed business case for building and operating a nuclear plant. Such a business case would need to be based on Australian conditions, the establishment of an Australian regulatory framework, Australian manufacturing and construction costs and the development of expertise. Projections of costs based on other jurisdictions, with different regulatory regimes, different levels of maturity of the industry, different manufacturing and labour costs, as well as financing costs, are an extremely imprecise art and leave substantial uncertainty when attempting to estimate the genuine cost of nuclear power in Australia.

As stated by the Australian Nuclear Association it its submission:

> Even though nuclear energy is economic for many countries, the cost of a nuclear power plant in Australia will not be known until there is a firm proposal. Assumptions about possible costs are no basis for the prohibition of nuclear power technology. Nuclear power plants will only be built if nuclear energy is economic.[27]

A number of submitters and witnesses have made the point that the necessary business case or firm proposals will not be attempted while a prohibition remains in place. In its submission to the Inquiry, Nuclear Now stated that:

> Without first repealing the nuclear prohibition in Victoria and federally, it is very difficult to develop an accurate estimate as to what might be the costs of nuclear power. Removing these legislative barriers would provide a market signal to the international nuclear industry to consider investment in the state. With the prohibition in place, there is no incentive for vendors to produce a properly costed business case.[28]

In a public hearing, Dr Heard of Bright New World, echoed this point, telling the Committee:

> We have these conversations with companies and they say, ‘We have a global market to serve. We cannot go and invest the serious time and money that is required to develop a business case in jurisdictions that make it clear in law that we are not welcome and that our technology is not welcome’.[29]

---

27 Australian Nuclear Association, *Submission 50*, p. 5.

28 Nuclear Now, *Submission 75*, pp. 17-8.

29 Dr Ben Heard, *Transcript of evidence*, p. 30.

This view was further supported by energy economist Professor Stephen Wilson in a public hearing who told the Committee that lifting the ban on nuclear activities will 'improve our ability to come to a much deeper understanding of the financial, environmental and social values' involved in the debate about nuclear energy and it will reduce the uncertainty range. He said that:

> At the moment the depth to which companies can go without breaking the law or are willing to go because the law is there is limited. So all we can really do is pretty high-level desktop translational analysis from overseas. We cannot get seriously into the depth of what would it really look like in Australia. But once the ban is lifted people can actually start to do that. Knowledge is valuable, so having the knowledge of what it would really cost and starting to reduce the uncertainty range around those numbers has value because that then can inform other to investment decisions.[30]

FINDING 2: Current estimates of the cost of nuclear energy in Australia are unreliable and accurately costing the full cost is not possible without a detailed business case being undertaken.

FINDING 3: Notwithstanding the ambiguities of the costings, the Committee received substantial evidence that nuclear power is significantly more expensive than other forms of power generation and it is recognised that, currently, nuclear is at the high end of the cost-range across all technologies.

FINDING 4: A business case is unlikely to be undertaken, given its costs and resources required, while a prohibition of nuclear energy activities remains and there is not likelihood of a plant being able to be built.

FINDING 5: Without subsidisation a nuclear power industry will remain economically unviable in Australia for now.

30 Professor Stephen Wilson, Energy Economist, public hearing, Melbourne, 11 September 2020, *Transcript of evidence*, p. 6.

6 Nuclear fuel cycle and power generation

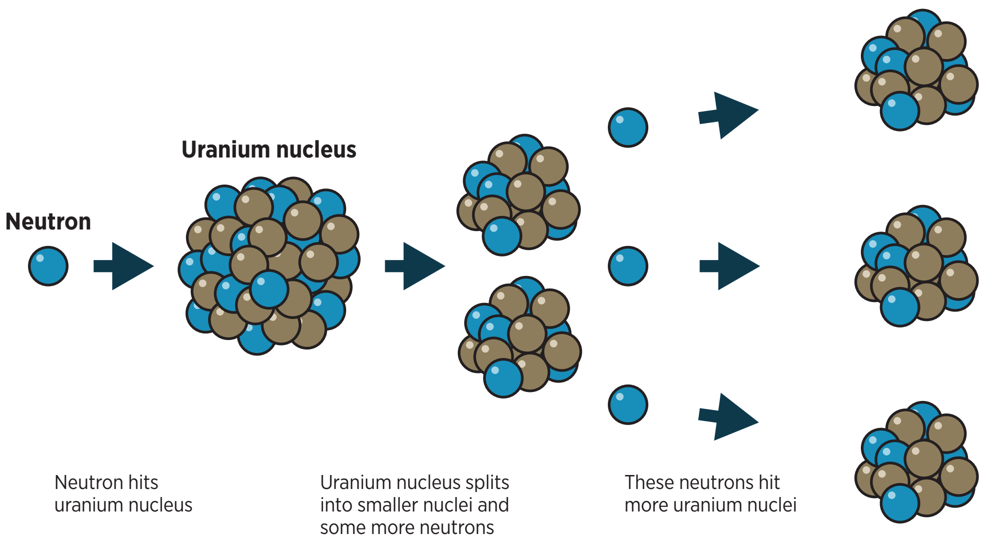
6.1 Nuclear power generation and the fuel cycle

This section provides a basic overview of nuclear energy. It is not meant as an exhaustive or expert explanation of the science, rather it is general information drawn from a variety of sources to provide a rudimentary explanation of nuclear energy.

6.1.1 Nuclear fission

Nuclear power plants generate electricity through the chain reaction process of nuclear fission. Shown in Figure 6.1 (below), nuclear fission is the process of splitting a large atomic nucleus into smaller nuclei. Two or three neutrons are also released in the process. The energy from the neutrons powers a nuclear reactor. Managing the chain reaction allows energy to be produced.

Figure 6.1 Process of nuclear fission (uranium nucleus)



Source: Adapted from BBC, *Nuclear fission and fusion: Glossary*, <https://www.bbc.co.uk/bitesize/guides/zx86y4j/revision/1> accessed 13 November 2019.

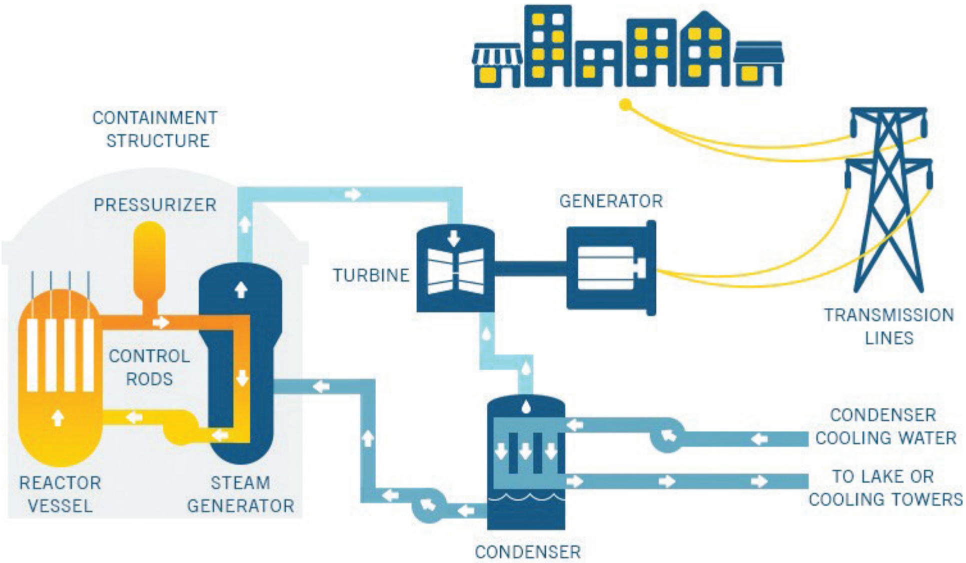
6.1.2 Generating electricity with nuclear energy

Nuclear power plants operate similarly to fossil fuel plants: an energy source is burned to create heat, which produces steam. The steam is used to turn a turbine attached to a generator, which produces electricity.

In a nuclear power plant, the nuclear reactor core contains fissionable isotopes[1] in control rods.[2] These rods act as neutron sponges to control the rate of radioactive decay. If an operator wants to stop a chain reaction, they push the control rods all the way into the reactor core where it absorbs all the neutrons. The operator then pulls out the control rods to slowly produce the desired amount of heat.

A liquid (usually water) is circulated through the reactor core, where the heat from the fission reaction produces steam. This is piped through the steam turbines which are connected to an electric generator. Steam is condensed and recycled through the generator to ensure no contamination of the air or water takes place. The electric generator produces electricity. This process is summarised in Figure 6.2.

Figure 6.2 Process of generating electricity through nuclear energy



Source: Louis Colangelo, *Nuclear Energy: making the world more energy efficient one atom at a time*, <http://www.pitt.edu/-ljc42/IndividualWebPageEngineeringTrendsAndIssues.html> accessed 13 November 2019.

6.1.3 Nuclear fuel cycle

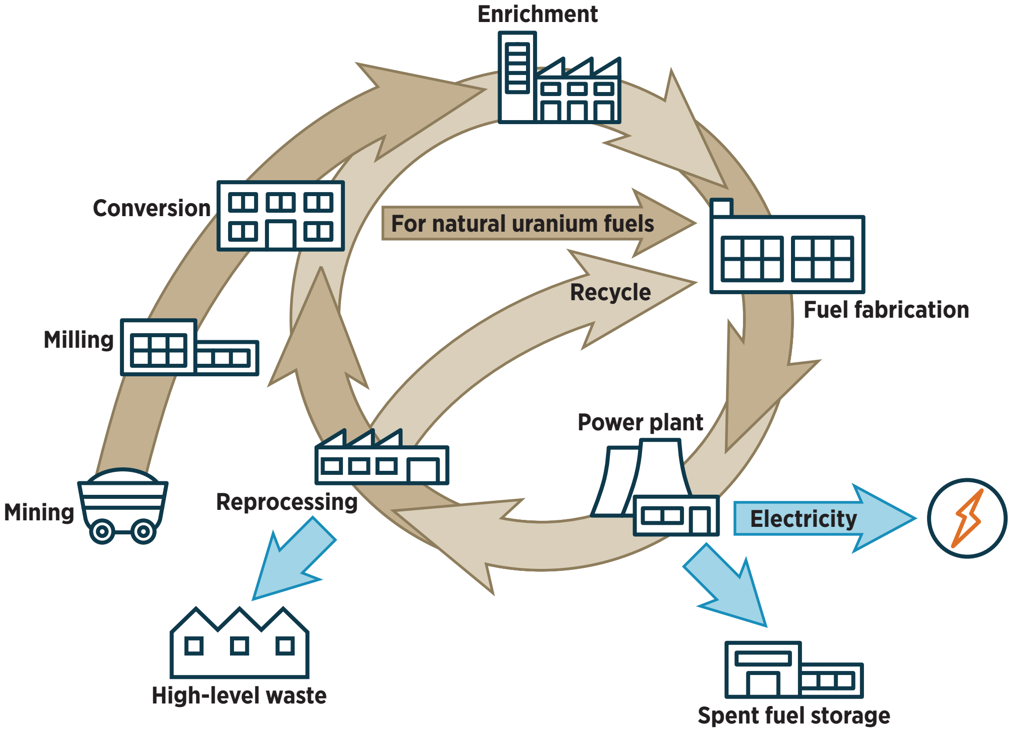
The nuclear fuel cycle refers to the collection of activities associated with the production of electricity using nuclear fuel. The cycle starts with uranium mining (the primary fuel used in the production of nuclear power) and ends with disposal of nuclear waste.[3] A basic representation of the nuclear fuel cycle is shown in Figure 6.3.

1 Isotopes are atoms of elements with the same number of protons and electrons but different number neutrons.

2 Control rods are used to absorb excess neutrons and control the rate of nuclear fission reactions.

3 World Nuclear Association, *The Nuclear Fuel Cycle*, <https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/introduction/nuclear-fuel-cycle-overview.aspx> accessed 30 January 2019.

Figure 6.3 The nuclear fuel cycle



Source: Adapted from Professor Peter Johnston, RMIT, *Australia and Nuclear Energy Power* <https://www.slideserve.com/PamelaLan/australia-and-nuclear-energy> accessed 30 January 2019.

6.2 Viability of other nuclear fuel cycle activities

Chapter 3 addresses the viability of mining and Chapter 5 addresses nuclear power generation in Victoria. This section examines the viability of other nuclear fuel cycle activities, including enrichment, fuel fabrication, reprocessing and waste management. For discussion on the social, environmental and security concerns of the nuclear fuel cycle see Chapters 7, 8 and 9.

6.2.1 Enrichment and fuel fabrication

Nuclear fuel used in a reactor needs to have a higher concentration of U235 isotopes than exists in natural uranium ore. When the U235 isotopes are enriched (concentrated) they become fissionable material, which are necessary for the nuclear reaction used to produce electricity.[4] According to the United States Nuclear Regulatory Commission (NRC), commercially, U235 isotopes are enriched 3% to 5% (from natural state of 0.7%), and then further processed for nuclear fuel.[5]

4 United States Nuclear Regulatory Commission, *Uranium Enrichment*, April 2019, <https://www.nrc.gov/materials/fuel-cycle-fac/ur-enrichment.html> accessed 21 July 2020.

5 Ibid.

There are several enrichment processes used by the global nuclear industry, including:

- **Gaseous Diffusion:** uranium hexafluoride gas (UF_6) is fed into a pipeline where it is pumped through special filters. These filters have tiny holes that the UF_6 struggles to pass through. The enrichment process occurs because the lighter UF_6 gas molecules, containing U_{234} and U_{235} atoms, diffuse faster than the heavier UF_6 gas molecules containing U_{238}. At the end of the process, the enriched uranium gas is condensed back to liquid and poured into containers.[6]
- **Gas Centrifuge:** UF_6 gas is placed into a cylinder and rotated at a high speed. This causes heavier gas molecules to move towards the outside of the cylinder, and lighter gas molecules collect towards the centre. The gas molecules containing enriched U_{235} is withdrawn and fed into the next centrifuge. The process is repeated across multiple centrifuges until the UF_6 is enriched enough for energy production.[7]

6

The Australian Nuclear Science and Technology Organisation (ANSTO) explained to the Committee in its submission the process of uranium enrichment and fuel fabrication:

> Enrichment is the physical separation and concentration of the isotope uranium-235 (U-235) in the uranium hexafluoride, with modern enrichment plants using gas centrifuges to achieve this separation. Fuel fabrication is the conversion of enriched gaseous uranium back into solid form, uranium oxide; the formation of uranium oxide into pellets; and the consolidation of these pellets into sealed zirconium alloy tubes for loading into a fuel assembly for a reactor core.[8]

Nuclear fuel fabrication and enrichment is prohibited at federal level under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

Viability of uranium enrichment and fuel fabrication in Victoria

For Victoria to seriously consider establishing front-end nuclear activities or producing nuclear energy, federal prohibitions need to be lifted. Even if Victoria were to repeal its own prohibitions this would only lift bans on the exploration and mining of uranium or thorium.

However, even if federal prohibitions were lifted several stakeholders still questioned the viability of establishing enrichment or fuel fabrication services in Victoria. Stakeholders believed that significant regulatory change would be required and expressed concern that the front-end market was overly-saturated and there would be no demand for Victorian services; especially if nuclear energy was not also introduced meaning there was no domestic need for enriched uranium or nuclear fuel.

6 Ibid.

7 Ibid.

8 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 26.

ANSTO, in its submission, discussed the challenges and considerations of expanding 'front-end' nuclear activities, such as enrichment and fuel fabrication, in Victoria:

> The 2006 *Uranium Mining, Production and Nuclear Energy Review* (UMPNER), commissioned by the former Howard Government, considered the challenges and opportunities for Australia becoming involved in conversion, enrichment, and fuel fabrication activities. The UMPNER taskforce concluded that, while there was no case for the Australian Government to subsidise entry into this value-adding industry, neither was there a strong case to discourage the development of the industry in the country.
>
> Aside from market-based issues discussed below, the expansion of 'front-end' of the nuclear fuel cycle in the State, in particular, enrichment, would require serious consideration of foreign policy requirements and implications.[9]

ANSTO further explained that:

> Victoria also would need to ensure that there is a sufficiently robust regulatory framework and a capable independent regulator (this could be the Australian Radiation Protection and Nuclear Safety Agency were its remit to be extended to cover non-Commonwealth facilities), as with the introduction of any other nuclear fuel cycle activities.[10]

Several stakeholders questioned whether 'front-end' nuclear activities could be viable considering that the global market is already saturated with suppliers. In its submission to this Inquiry, Bright New World argued that:

> Front end services of enrichment and fabrication are already oversupplied and heavily regulated, and back end services of waste management and disposal would require favourable location aspects.[11]

This was reiterated in the Azark Project's submission which argued that uranium enrichment is not an option in Australia. The submission stated:

> The South Australian royal commission considered the possibility of enriching uranium in Australia, which would in principle vastly increase its value.
>
> But the commission found that while Australia could easily build the technical capacity, the global market is already oversupplied. There is currently no commercial market for more enriched uranium, and it's unlikely to grow significantly.[12]

---

9 Ibid.

10 Ibid.

11 Bright New World, *Submission 74*, p. 5.

12 Azark Project, *Submission 21*, p. 18.

The following excerpts are taken from other submissions which similarly argued Australia should not develop its own front-end nuclear activities because enough services exist internationally:

- 'Australia should not step up other front-end fuel cycle facilities: conversion, enrichment, or fuel fabrication since these services are readily and cheaply available internationally.'[13]
- 'Enriched uranium is currently a buyer's market due to the strong competition among several international providers.[14]

In contrast, WiN Australia believed that there are opportunities for Victoria to establish front-end nuclear activities:

> Opportunity exists for Victoria to be involved in establishing fuel processing and fabrication facilities. Consideration for enrichment activities as well as nuclear fuel processing would need to account for International Atomic Energy Agency requirements and Australian treaty commitments (e.g. Non-proliferation Treaty), as well as approvals and licensing from Australian regulatory bodies, namely ASNO and ARPANSA. This has potential for an entire new industry for the state of Victoria which could support national and international nuclear fuel requirements.[15]

6

However, WiN Australia did not provide any specific details about what opportunities could exist in front-end nuclear activities. In fact the provision of front end nuclear for Australia is not economically feasible as fuel processing activities would occur overseas as explained by Mr Hore-Lacy from the World Nuclear Association at a public hearing:

> We would import the finished fuel, yes, because I think, and by most people's reckoning, it would not be economic to build those facilities for fuel fabrication and enrichment and conversion in Australia because there is surplus capacity overseas at very competitive prices, but it would quite likely be Australian uranium that we might use.[16]

6.2.2 Reprocessing of nuclear fuel

Nuclear reprocessing is the process of extracting fission products and unused uranium from spent nuclear fuel, so that it can be recycled back into nuclear fuel for thermal reactors. Australia has adopted a type of closed nuclear fuel cycle, as opposed to an open cycle where waste from nuclear fuel is not reused. Australia does not have domestic spent fuel reprocessing activities, instead reactor fuel is sent overseas for reprocessing and the reprocessing waste (material not used in reprocessed nuclear fuel) is returned to Australia and stored as intermediate-level waste.[17]

13 Ian Hore-Lacy, *Submission 32*, p. 2.

14 Barrie Hill, *Submission 47*, p. 19.

15 Women in Nuclear (WiN) Australia, *Submission 36*, p. 19.

16 Mr Ian Hore-Lacy, World Nuclear Association, public hearing, Melbourne, *Transcript of evidence*, 14 August 2020 , p 53

17 Dr Carl-Magnus Larsson, Chief Executive Officer, Australian Radiation Protection and Nuclear Safety Agency, *Transcript of evidence*, 12 March 2020, p. 22.; Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 29.

In its submission, ANSTO described Australia's reprocessing activities in greater detail:

> Australia also has adopted a type of closed fuel cycle. According to current Australian Government policy, all of Australia's used fuel from the OPAL multi-purpose research reactor will be sent to France for reprocessing. The small amount of residual wastes will be shipped back to Australia for management and disposal, while the uranium extracted during the reprocessing operation will be fabricated into fresh fuel for use in nuclear power reactors in Europe.[18]

In countries where commercial reprocessing occurs, plants use the plutonium uranium extraction (PUREX) process. The World Nuclear Association described what the PUREX process is:

> [PUREX] separates uranium and plutonium very effectively. This involves dissolving fuel elements in concentrated nitric acid. Chemical separation of uranium and plutonium is then undertaken by solvent extraction steps (neptunium – which may be used for producing Pu-238 for thermo-electric generators for spacecraft – can also be recovered if required). The Pu and U can be returned to the input side of the fuel cycle – the uranium to the conversion plant prior to re-enrichment and the plutonium straight to MOX fuel fabrication.[19]

The World Nuclear Association also explained the purpose of reprocessing spent fuel:

> Over the last 50 years the principal reasoning for reprocessing used fuel has been to recover unused plutonium, along with less immediately useful unused uranium, in the used fuel elements and thereby close the fuel cycle, gaining some 25% to 30% more energy from the original uranium in the process. This contributes to national energy security. A secondary reason is to reduce the volume of material to be disposed of as high-level waste to about one-fifth. In addition, the level of radioactivity in the waste from reprocessing is much smaller and after about 100 years falls much more rapidly than in used fuel itself.[20]

It further explained to what percentage fissionable material can be recovered in reprocessing:

> Reprocessing used fuel to recover uranium (as reprocessed uranium, or RepU) and plutonium (Pu) avoids the wastage of a valuable resource. Most of it – about 96% - is uranium, of which less than 1% is the fissile U-235 (often 0.4–0.8%); and up to 1% is plutonium. Both can be recycled as fresh fuel, saving up to 30% of the natural uranium otherwise required. The RepU is chiefly valuable for its fertile potential, being transformed into plutonium-239 which may be burned in the reactor where it is formed.[21]

---

18 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 29.

19 World Nuclear Association, *Processing of Used Nuclear Fuel*, June 2018, <https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/processing-of-used-nuclear-fuel.aspx> accessed 22 July 2020.

20 Ibid.

21 Ibid.

Viability of reprocessing spent nuclear fuel in Victoria

Similar to mining, enrichment and fuel fabrication, some stakeholders believe that reprocessing in Victoria may not be economically viable because enough facilities exist globally. Furthermore, reprocessing is seen as a risky investment in particular because currently uranium is cheap,[22] disincentivising the need to reprocess fuel at all.

In its submission, ANSTO discussed that most countries with nuclear energy programs have opted for an open nuclear fuel cycle because of challenges with reprocessing, including 'high costs, technical complexity, and political and foreign policy considerations, as well as the low price of uranium.'[23] Furthermore the submission explained that the South Australian Nuclear Fuel Cycle Royal Commission (SANFCRC) found that:

> … 'a new reprocessing facility based on current technology would not be economically viable under current and likely future market conditions.' This finding has been illustrated in the decision of the United Kingdom to close it long-standing reprocessing program, despite its expanding nuclear power program.[24]

Dr Carl-Magnus Larsson of Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) was unsure in a public hearing if there is room in the current market for more reprocessing facilities:

> A reprocessing facility, as I said, would be prohibited under the legislation as it is now, and there are not many reprocessing facilities in the world. Whether there is actually room for further reprocessing capability and capacity in the world, I do not have the answer to that.[25]

In contrast, WiN Australia recommended that if Victoria developed nuclear energy technology it should also develop 'reprocessing of used fuel due to the benefits reprocessing brings in terms of recycling and sustainability, waste volumes and waste lifespan.'[26] However, at a public hearing, Dr Jo Lackenby, President of WiN Australia, did acknowledge that there are political considerations which would make it difficult to introduce spent fuel reprocessing:

> Technologically they are very possible but politically they are much, much more difficult to pull. We are all aware of the acronym 'nimby'—not in my backyard—and there is another one, 'banana': build absolutely nothing anywhere near anyone…[27]

In his submission, Mr Logan Smith contended that Australia could play a leading role in global spent fuel reprocessing if it introduced the proper infrastructure along with energy production capabilities. He asserted that Australia could import spent

22 Nuclear Now, *Submission 75*, p. 19.; Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 29.

23 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 27.

24 Ibid.

25 Dr Carl-Magnus Larsson, *Transcript of evidence*, p. 26.

26 Women in Nuclear (WiN) Australia, *Submission 36*, pp. 22–3.

27 Dr Jo Lackenby, President of WiN Australia, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 11.

nuclear fuel from around the world and reprocess it 'into fuel to run [the] nation'. The submission went on to say that:

> It is quite literally, run zero emission nuclear reactors on the reprocessed SNF that the world pays us to take back, from the uranium we originally sold.
>
> It is an incredibly bold plan that, if successfully executed, would be certainly a step toward Australia becoming 'the clever country' and a respected partner in the nuclear fuel cycle.[28]

Several stakeholders suggested that reprocessing facilities could carry proliferation risks, as many states believe reprocessing or highly enriched uranium increases the potential to make nuclear weapons.[29] The issue of spent fuel reprocessing and weapons proliferation is discussed in more detail in Chapter 7.

6.2.3 Waste Management

Radioactive or nuclear waste is a by-product of nuclear processes such as energy generation and fuel processing, nuclear medicine, and nuclear research that no longer has a feasible use and contains radioactive materials at levels that are potentially hazardous to humans and/or the environment and requires ongoing management to ensure its safety.

Radioactive materials have a half-life (the time it takes for half of the radioactive atoms to decay), which means that their level of radioactivity decreases over time. However, not all types of radioactive waste can be managed in the same way. For example, radionuclides with a short half-life can be stored until they are safe to dispose of as normal waste whereas long-lived radionuclides, such as uranium, remain radioactive for thousands, if not millions, of years.[30]

Broadly, nuclear waste falls into three categories:[31]

1. **Low-level waste (LLW)** emits radiation at levels that require minimal shielding during handling, transport and storage. It is commonly found on items such as gloves, cloths and filters used at nuclear plants and research facilities.
2. **Intermediate-level waste (ILW)** emits higher levels of radiation than LLW and requires more shielding during handling, transport and storage. It is generated from certain reactor operations and radiopharmaceutical production.
3. **High-level waste (HLW)** emits radiation at levels requiring significant shielding and isolation from human contact. It also requires cooling due to its heat-generating capacity. HLW is primarily produced from nuclear power generation. The level

28 Logan Smith, *Submission 43*, p. 4.

29 For example see: Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*; Frank Simpson, *Submission 24*; Noel Wauchope, *Submission 25*.

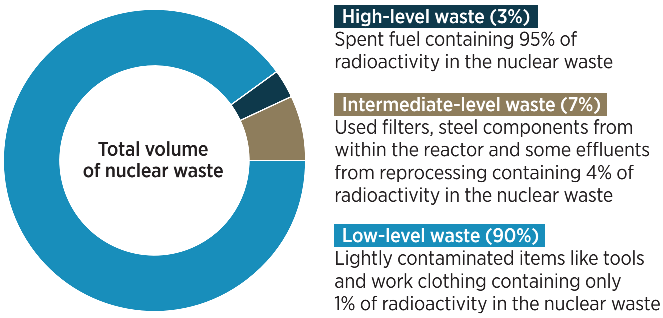
30 ARPANSA, *Radioactive waste safety in Australia*, <https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/radioactive-waste-safety> accessed 16 March 2020.

31 ANSTO, *Managing Waste*, n.d, <https://www.ansto.gov.au/education/nuclear-facts/managing-waste> accessed 19 November 2019.

of HLW radioactivity gradually diminishes over time as the radioactive elements decay into more stable elements that are safer to handle, but this process can take thousands of years or longer.

Australia produces mostly low-level waste and some intermediate-level waste (for example, from the production of nuclear medicines). No high-level waste is produced in Australia.[32]

Figure 6.4 Percentage breakdown of the volume of low-, intermediate- and high-level nuclear waste worldwide



Source: Adapted from World Nuclear Association, *What is nuclear waste, and what do we do with it?*, <https://www.world-nuclear.org/nuclear-essentials/what-is-nuclear-waste-and-what-do-we-do-with-it.aspx> accessed 6 April 2020.

6.2.4 Waste from nuclear power generation

High-level waste primarily comes from spent fuel from nuclear power reactors and waste by-products from the repurposing of spent fuel. The uranium used to fuel nuclear power reactors is typically in use for five years after which it is no longer viably efficient in generating electricity and becomes 'spent fuel'.

Radioactive isotopes of lighter elements created from nuclear fission, called 'fission products', account for most of the heat and penetrating radiation in HLW. However, some uranium atoms also form heavier elements such as plutonium, called 'transuranic', which do not produce as much heat or penetrating radiation compared fission products, but take much longer to decay. Transuranic wastes account for most of the radioactive hazard remaining in HLW after 1,000 years.[33]

Repurposing of spent fuel can recover fissile and fertile materials (namely unused plutonium and uranium) from fission products in order to provide fresh fuel for nuclear power plants, gaining 25–30% more energy from the original uranium fuel in the process. The level of radioactivity in the waste from reprocessing is much lower, and after approximately 100 years this level falls much more rapidly than in used fuel itself.[34]

---

32 Sophie Power, 'Radioactive waste management', *Parliamentary Library, Parliament of Australia,*, <https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook45p/RadioactiveWaste> accessed 6 April 2020.

33 United States Nuclear Energy Regulatory Commission, *Backgrounder on Radioactive Waste*, <https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/radwaste.html> accessed 11 September 2020.

34 World Nuclear Association, June 2018

Because nuclear fuel is so energy dense, very little is required to produce a significant amount of electricity. As a result, a correspondingly small volume of waste is produced. The average waste from a reactor supplying one person's electricity needs for a year would be about the size of a house brick, of which approximately 5 grams is HLW. The generation of electricity from a typical 1,000 megawatt nuclear power station, produces three cubic metres of HLW per year if the used fuel is repurposed.[35] In fact, the Committee heard evidence that the entirety of nuclear waste produced since nuclear reactors came into being could fit onto a soccer field, piled 10 metres high.[36]

In its submission to the Inquiry, the Medical Association for Prevention of War (Australia) noted:[37]

- the average nuclear power reactor produces 300m^3 of LLW and ILW per year and some 30 tonnes of solid packed HLW per year
- 12,000 tonnes per year of spent fuel (HLW) is produced globally
- in 2018 the International Atomic Energy Agency (IAEA) reported that in 2015 there existed approximately 370,793 tonnes of nuclear fuel-derived waste around the world.

High-level waste accounts for only 3% of the volume of all nuclear waste, however it is responsible for 95% of the total radioactivity[38] and requires extremely long time periods—hundreds of thousands of years in some cases[39]—of containment and isolation from people and the environment.

Management and disposal of high-level waste

While radiation levels of HLW decrease rapidly during the first 30 to 50 years of storage, with the most radioactive elements decaying within the first 500 years, the less radioactive but longer-lived elements of used nuclear fuel require containment and isolation for at least 100,000 years.[40] The level of radioactivity and heat produced by used fuel is dependent on the length of time the fuel was used in the nuclear reactor core, the longer time spent in the core the greater the amount of radioactivity when it is removed.[41]

After spent fuel is removed from a reactor, it generates significant heat for several decades. To manage this the fuel is placed in water pools or dry storage containers to allow it to cool while shielding the environment from radiation. After the heat

---

35 World Nuclear Association, *What is nuclear waste, and what do we do with it?*, <https://www.world-nuclear.org/nuclear-essentials/what-is-nuclear-waste-and-what-do-we-do-with-it.aspx> accessed 6 April 2020.

36 Mr Patrick Gibbons, Minerals Council of Australia, public hearing, Melbourne, *Transcript of evidence*, 25 June 2020, p. 39.

37 Medical Association for Prevention of War (Australia), *Submission 34*, p. 17.

38 World Nuclear Association, *Radioactive Waste Management*, <https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx> accessed 6 April 2020.

39 United States Nuclear Energy Regulatory Commission, *Backgrounder on Radioactive Waste*.

40 Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, Government of South Australia, South Australia, 2016, p. xv.

41 Ibid, p. 81.

diminishes to a point where it no longer requires cooling, spent fuel can be repurposed or disposed of permanently.[42]

The long timescales over which spent fuel remains radioactive has led to a general industry consensus on the concept of deep geological disposal, a process whereby spent fuel is placed in cannisters and located in underground repositories. These engineered and geological barriers act in concert to completely isolate the radioactive particles as they decay, limiting their release to the environment.[43]

With the exception of the Onkalo underground repository in Finland, which is reportedly due to come into operation in 2020,[44] there are currently no facilities for permanent disposal of spent fuel anywhere in the world, although progress has been made by several other countries in this area (notably Sweden, Belgium and France).[45] However many other well-developed proposals in other nations have stumbled in the face of strong community, environmental and political opposition. Consequently, spent fuel waste in many countries is kept in temporary dry storage facilities until a permanent disposal strategy is implemented.[46]

A discussion of nuclear and radioactive waste management in Australia, including the potential for HLW management, is covered further in Chapter 8.

FINDING 6: Discussion about Victorian participation in the nuclear fuel cycle is entirely theoretical while the Commonwealth prohibitions remain in place.

6.3 New and emerging technologies

New reactor design and technology is the main driver stoking a renewed interest in the possibility of cost-competitive nuclear energy production. The Committee received a lot of evidence which debated the viability and efficacy of various new and emerging technologies across the nuclear industry. Of particular interest to stakeholders was the development of Small Modular Reactors (SMRs) and the use of thorium to produce energy. This section examines the evidence provided to the Committee on both of these developments.

42 Nathalie Mikhailova, 'Developing the First Ever Facility for the Safe Disposal of Spent Fuel', *IAEA Bulletin*, 10 July 2019, <https://www.iaea.org/newscenter/news/developing-the-first-ever-facility-for-the-safe-disposal-of-spent-fuel> accessed 6 April 2020.

43 Nuclearinfo.net, *Waste from nuclear power*, <http://nuclearinfo.net/Nuclearpower/WebHomeWasteFromNuclearPower> accessed 7 April 2020.

44 Anne Kauranen, 'World's first underground nuclear waste storage moves forward in Finland', *Reuters*, 25 June 2019, <https://www.reuters.com/article/us-finland-nuclear-waste/worlds-first-underground-nuclear-waste-storage-moves-forward-in-finland-idUSKCN1TQ1NL> accessed 7 April 2020.

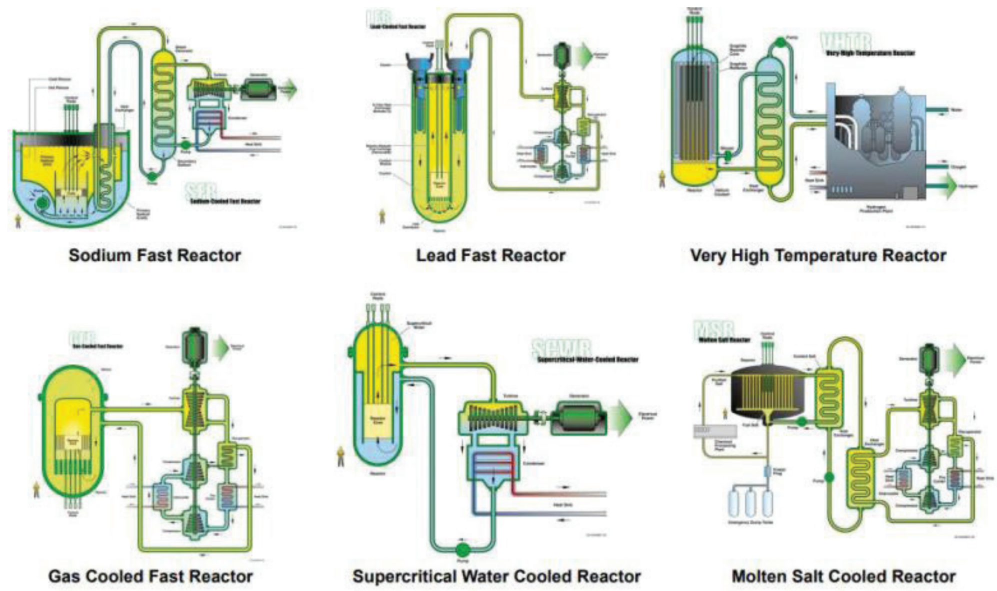
45 Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, p. 85.

46 Nuclearinfo.net, *Waste from nuclear power*.

Whilst, some stakeholders did focus on other emerging technologies this report has chosen to focus on these two because they were discussed by many stakeholders, particularly SMRs.

Another emerging technology discussed by stakeholders was Generation IV (Gen-IV) reactors, which are currently under development by the Generation IV Nuclear Reactor Forum. Gen-IV reactors, according to the World Nuclear Association, are the 'next generation of nuclear technology'[47] with improvements being made in fuel efficiency, waste reduction, proliferation resistance, and safety standards.[48] Figure 6.5 shows the six reactor designs that are the focus of research by the Generation IV Nuclear Reactor Forum.

Figure 6.5 Six Generation IV nuclear reactor designs



Source: Australian Nuclear Science and Technology Organisation, *Generation IV Nuclear Reactors*, N.D., <https://www.ansto.gov.au/research/programs/nuclear-fuel-cycle/generation-iv-nuclear-reactors> accessed 29 July 2020

Gen-IV reactors are characterised by the Generation IV International Forum, as:

> … future-generation nuclear energy systems that can be licensed, constructed, and operated in a manner that will provide competitively priced and reliable energy product while satisfactorily addressing nuclear safety, waste, proliferation, and public perception concerns.[49]

The global nuclear industry predicts that Gen-IV reactors should become available and begin construction in 2030.[50] Figure 6.6 shows an overview of the generations of nuclear energy systems, including Gen-IV. In 2017, Australia, represented by ANSTO,

---

47 World Nuclear Association, *Generation IV Nuclear Reactors*, May 2019, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/generation-iv-nuclear-reactors.aspx> accessed 30 July 2020.

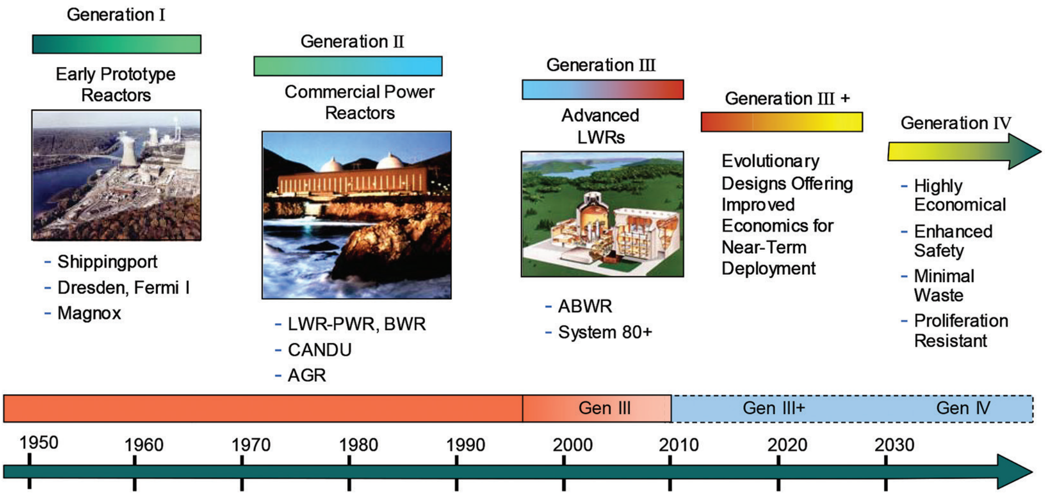
48 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 22

49 US Nuclear Energy Research Advisory Committee and Generation IV International Forum, 'The Generation IV Technology Roadmap in Brief', in, *A Technology Roadmap for Generation IV Nuclear Energy Systems*, online, 2002, p. 5.

50 Ibid.

acceded to the framework agreement of the Generation IV International Forum which sets out international collaboration for developing next generation nuclear technology for civil energy production. Australia is nominated to assist in the research and development of the molten salt reactor design concept.

Figure 6.6 **Overview of the generations of nuclear energy systems**



Source: US Nuclear Energy Research Advisory Committee and Generation IV International Forum, 'The Generation IV Technology Roadmap in Brief,' *A Technology Roadmap for Generation IV Nuclear Energy Systems*, online, Generation IV Roadmap in Brief, 2002, p. 5.

Many pro-nuclear stakeholders discussed what they believed were the proposed benefits of Gen-IV reactors, which are summarised as follows:

- reduce overall energy cost production[51]
- be more efficient in converting energy density[52] and using fuel[53]
- reduce waste, have more stringent safety standards and be proliferation resistant.[54]

Some stakeholders expressed that Gen-IV reactors are not a viable option for Victoria or Australia because 'there are no commercially operating examples, even though the basic technology is not new.'[55] These stakeholders believed it would be imprudent to base future energy policy planning on these technologies because they are still unproven and questions remain about their prospects for commercialisation. This conclusion was also drawn by the SANFCRC, which found that:

> … advanced fast reactors and other innovative reactor designs are unlikely to be feasible or viable in the foreseeable future. The development of such a first-of-a-kind project in

51 Women in Nuclear (WiN) Australia, *Submission 36*, p. 10.

52 Nuclear for Climate Australia, *Submission 44*, p. 9.

53 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 22.

54 Ibid.; Nuclear Now, *Submission 75*.

55 Philip White, *Submission 17*, p. 10.

> South Australia would have high commercial and technical risk. Although prototype and demonstration reactors are operating, there is no licensed, commercially proven design. Development to that point would require substantial capital investment. Moreover, electricity generated from such reactors has not been demonstrated to be cost competitive with current light water reactor designs.[56]

The following sections focus on the emerging technologies of small modular reactors (SMRs) and a thorium-based fuel cycle.

6.3.1 Small Modular Reactors

The Committee heard from many stakeholders, both for and against nuclear energy, on the issue of SMRs. SMRs are nuclear fission reactors with a generating capacity of up to 300 MWe, much smaller than conventional full-scale reactors which have a typical capacity of 1,000–1,500 MWe. SMRs allow for less on-site construction, increased containment efficiency, and heightened nuclear materials security and have been proposed as a way to bypass financial barriers posed by conventional reactors. These advanced reactors, envisioned to vary in size from a couple of megawatts up to hundreds of megawatts, can be used for power generation, processing heat, desalination, or other industrial uses. SMRs can employ light water as a coolant or other non-light water coolants such as a gas, liquid metal, or molten salt.

6

Mr Geoff Dyke, Secretary, Victorian Branch of the CFMMEU explained to the Committee some of the differences between a conventional reactor and SMRs:

> The small modular nuclear reactors are about 60-megawatt modules. Most of the current commercial reactors are either 1000 megawatts or 1400 megawatts in size, so they are very large. One of the advantages of being large is scale of size reduces the cost because you do not need as much equipment. The only thing is in the Western world nuclear construction costs have been increasing. They are probably 50 per cent higher than Asian power stations. So, one way of reducing construction costs is to have modular reactors mass-produced in a factory and then shipped out to the country of use.
>
> They are the two main options, small modular reactors—but even the current technology for the big power plants that are 1000 and 1400 megawatts are into their third and fourth generation of safety improvements. Things like where the roof blew off at Fukushima, that would not happen now because they have hydrogen venting and other things to prevent those sorts of things. They have learned from those past disasters and older designs.[57]

---

56 Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, p. 47.

57 Mr Geoff Dyke, Secretary, Victorian Branch of the CFMMEU, public hearing, Melbourne, *Transcript of evidence*, 25 June 2020, p. 5.

Furthermore, Mr Dyke believed that SMRs are well-suited to Australia's 'small-capacity grid in that you can size a generator to suit the grid'[58] and it could be more responsive to grid stability issues:

> If you lose a very big load out of a small system, potentially you could plummet the frequency and collapse the whole grid, so size is a consideration. Because they are modular they are potentially quick to manufacture and cheaper because they are manufactured in a factory and can be shipped over. Small modular reactors are estimated to be about the same price as wind, but they do not have the additional costs on the grid. When we talk about levelised cost, levelised cost is one thing, but total cost is what consumers pay. There has been heavy focus on levelised cost, but the focus needs to be on total cost of the system.[59]

Cost, modular design, reactor size, and safety were discussed by numerous stakeholders who argued that SMRs should be investigated by policymakers as a potential contributor to the energy mix.

Costs of SMRs

This section relates specifically to the costs of SMR technology comparative to large scale reactors. Detailed discussion of the costs of nuclear energy more broadly is in Chapter 5.

A point of contention throughout the evidence on SMRs was their expected commercial costs or economic viability. The Committee received varying estimates for SMRs which generally agreed that initial upfront costs for the technology are expensive but differed on the impact mass production of would have on overall costs. On this basis, as with costing nuclear energy in general, the Committee is unable to make any finding on the economic viability of SMR technology. Rather, the Committee believes that a business case conducted within a Victorian context is needed to fully understand the costs associated with developing this technology, however, that is unlikely to occur if prohibitions remain in place.

SMR Nuclear Technology, in its submission, discussed 'the economics of small modular reactors', some of the key points the submission raised were:

1. Current figures, such as the CSIRO's $16,000/kW overnight cost estimate for nuclear, is not appropriate when assessing the economic viability of SMRs[60]

2. Modern SMRs could be competitive with firmed variable renewable energy[61]

3. Accurate cost predictions for SMR deployment in Australia requires a feasibility study[62]

---

58 Ibid, p. 2.

59 Ibid.

60 SMR Nuclear Technology, *Submission 40*, p. 8.

61 Ibid, p. 9.

62 Ibid.

4. The generation costs of solar and wind are lower than nuclear energy, however, the cost to the overall power system is higher because:
    a. low capacity
    b. additional transmission costs
    c. firming costs.[63]

Mr Patrick Gibbons, Director, of the Minerals Council of Australia (MCA) acknowledged that initial costs for SMRs may be high but as they are able to mass produced, once they are commercially viable, the costs will significantly decrease the more they are built:

> It is about the fabrication process. What you are doing with it is that you are minimising the build risk, if you want, by producing them in a factory. So, think of it this way: it is analogous to, say, aircraft…
>
> So, the point I am trying to make here is that there is value in producing something in a factory, because you control the costs in the factory. This has always been part of projects when you build offsite or a one-of-a-kind. Power stations are a classic example of it, as are dams—anything—or roads for that matter. There are a whole lot of production costs that are involved when you are building something just as a one-off or a bespoke operation. Having the same design, like an aircraft or like a car, just coming off the production line, that is where you get the lower costs… they are first of a kind and will be more expensive, but equally once you start producing these relatively en masse the costs could go right down. This is what drives the economics of small modular reactors and it is also what drives what we are seeing as significant commercial interest in North America and Europe on this.[64]

6

This was echoed by Dr Mark Ho, President, Australian Nuclear Association, who gave the example of the NuScale reactor[65] to explain that the construction costs of an initial SMR design are high but fall once more are built because they are factory constructed:

> … for example, for the overnight cost of, say, the NuScale reactor, they are quoting first-of-a-kind plants at US$4350 per kilowatt of capacity, and that would be falling down to $3600 after many plants have been built. Because what people have to understand that the idea with SMRs – the reason why they would be lower cost – is that they would be factory constructed, and so therefore you can increase the quality and decrease the unit price from building many of them, similar to, say, in an aircraft industry.[66]

In his submission to this Inquiry, Professor John Quiggin stated that:

> [SMRs] are substantially more costly (per MWh of capacity) to construct and operate than large reactors which benefit from economies of scale. The promise of small *modular* reactors is that these higher costs may be more than offset by the construction

63 Ibid.

64 Mr Patrick Gibbons, Director, of the Minerals Council of Australia, public hearing, Melbourne, *Transcript of evidence*, 25 June 2020, p. 36.

65 A US SMR design currently seeking certification.

66 Dr Mark Ho, President, Australian Nuclear Association, public hearing, Melbourne, *Transcript of evidence*, 25 June 2020, p. 19.

> of large numbers of small reactors under factory conditions, with the parts being transported to the construction site for assembly. [emphasis in original][67]

Several other stakeholders discussed construction and operating costs of SMRs as one of its advantages compared to conventional reactors. The following excerpts taken from submissions show that many nuclear advocates who provided evidence to this Inquiry believed that SMRs would have lower costs suitable to the Australian market:

- 'Lower initial capital cost than a large reactor. Scalable—modules can be added as required.'[68]
- 'Modern SMRs could be the lowest cost generation available in Australia because of their contribution to power system reliability.'[69]
- 'The attractiveness of SMRs is in their modularity and lower capital costs per unit compared to large nuclear plants.'[70]
- 'lower upfront investment by comparison with larger units, easier to finance'.[71]

6

In contrast, several stakeholders opposed to expanding nuclear activities in Victoria argued that lower costs of SMRs are unproven because they have not been introduced commercially making market demand difficult to determine; and as the cost competitiveness of SMRs depends on many units being sold this could undermine claims that it is an economically viable option.

Friends of the Earth (FOE) Australia argued that there is no market for SMRs making it difficult to properly predict their commercial viability or investment requirements:

> … there is virtually no market for SMRs – hence the reluctance of industry and government to make the multi-billion dollar investments that would kick-start an SMR industry.[72]

Furthermore, FOE Australia went on to contend that:

> 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.[73]

Other stakeholders also argued there was no significant market interest in SMRs. Mr Noel Wauchope stated that:

> No company, utility, consortium or national government is seriously considering building the massive supply chain that is at the very essence of the concept of SMRs—mass,

67 Professor John Quiggin, *Transcript of evidence*, 14 August 2020, p. 9.
68 Tony Irwin, *Submission 38*, p. 4.
69 SMR Nuclear Technology, *Submission 40*, p. 2.
70 Bright New World, *Submission 74*, p. 19.
71 Barry Murphy, *Submission 27*, p. 3.
72 Friends of the Earth Australia, *Submission 22*, p. 13.
73 Ibid, p. 15.

> modular factory construction. Yet without that supply chain, SMRs will be expensive curiosities.[74]

Dr Jim Green of FOE Australia told the Committee that SMRs are an 'economic non-starter' based on figures from the CSIRO's GenCost report:

> [The report] gives a low estimate for small modular reactors based on heroic assumptions of A$129 per megawatt hour, and they compared that to solar PV and wind with 2 to 6 hours storage. This is the comparison: a small modular reactor, $129 per megawatt hour; renewables with 2 to 6-hour storage, $52 to $86 per megawatt hour. The CSIRO report also gives a high estimate for SMRs of $336 per megawatt hour, which is vastly greater than the high estimates of renewables with storage of $90 to $151 per megawatt hour.[75]

Mr Philip White, in his submission, believed that Australia should not be a lead purchaser of SMR technology because there are none currently commercially operating:

> In regard to small modular reactors (SMR) and 'Generation IV' (Gen IV) reactors in general, there are no commercially operating examples, even though the basic technology is not new. The hope that these reactors might one day become economical with modularisation and mass production must not form the basis for policy planning in Australia. Australian demand will never be sufficient to promote the formation of the infrastructure base to support mass production, so Australia should not consider being a lead purchaser of these technologies. There is no sense in committing to the installation of such a reactor until the supply chain is in place and prices come down.[76]

Engineers Australia believed that despite SMRs being 'promoted as the nuclear option that is most relevant to the Australian context because of expected improvements in safety, flexibility, scalability and cost-effectiveness', debates around SMR technology is lacking key information and gaps in understanding:

> The cost competitiveness of SMR technologies is unknown. This is because the technology has not yet been commercially deployed and there is no place for the technology to be systematically monitored and evaluated in the Australian context.[77]

The Committee has found that there is no clear consensus on the potential costs of developing SMR technology in Victoria which has been compounded by a lack of market interest or commercialisation in other jurisdictions. The lack of concrete and applicable data makes it difficult for the Committee to draw any conclusions on the costing of SMRs or if it would be a viable option for Victoria on this basis. A detailed business case and feasibility study would be needed to properly assess the commercial or economic viability of technologies such as SMRs, but as the Committee has mentioned already this is unlikely to be undertaken with current prohibitions.

---

74 Noel Wauchope, *Submission 25*, p. 4.

75 Dr Jim Green, Friends of the Earth Australia, public hearing, Melbourne, *Transcript of evidence*, 26 June 2020, p. 13.

76 Philip White, *Submission 17*, p. 10.

77 Engineers Australia, *Submission 63*, p. 5.

SMR design

Many pro-nuclear stakeholders who advocated for developing SMRs in Victoria argued that its modular design and reactor size is a key advantage. Modular means that an SMR's parts are assembled from parts (or modules) which could be mass-produced in factories once a design is approved. The Committee heard that the costs of SMRs will decrease once they are commercially released because they are able to be assembled in modular parts in factories, standardising the process.

The Hon. Peter Vickery QC, in his submission, explained what modular construction is:

> … modular construction is a method where building or engineering structures are first built off-site in a factory and then delivered to the location where they are assembled or completed for use. The construction on-site may be in the locality of the factory or remote, with completed modular components being shipped for installation, even internationally.[78]

He further described what he considered to be advantages of modular construction applicable to SMRs:

> Conventional wisdom tells us that modular construction can achieve cost savings of up to 50 per cent and project times accelerated by between 20–50 per cent.[79]

Further advantages discussed in his submission included:

- controlled factory environmental which can improve product quality
- loss of construction time is limited during modular construction phase and a more controlled construction program
- shorter construction time which could reduce site management and facilities costs
- savings in labour costs, more efficient work force, increased access to labour market, greater job security and savings, and other work force advantages.[80]

In his submission, Mr Barry Murphy described some of the benefits of the SMR modular design:

- modularity and simpler componentry, better quality control in manufacture
- standardised design, mostly factory construction —like aircraft
- transportable to point of assembly, faster and less expensive final construction.[81]

78 Hon. Peter Vickery QC, *Submission 33*, p. 12.

79 Ibid.

80 Ibid, p. 13.

81 Barry Murphy, *Submission 27*, p. 3.

This was iterated in several other submissions to this Inquiry as the following excerpts show:

- 'The reactor model is factory built, minimising on-site time and reducing risk of construction delays... Scalable-modules can be added as required...Compact, would fit on any existing power station site'[82]
- 'Modern SMRs will be factory-built and the complete reactor module is transported to site and installed with minimum on-site work. This reduces construction time and the risk of expensive delays.'[83]
- 'NuScale's plant ...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.'[84]

However, some anti-nuclear stakeholders contended that promises of shorter construction times and delays because of SMR modular design were unproven; and some argued were untrue.

FOE Australia, in its submission, stated that the benefits of SMRs, including predicted shorter construction times and less delays, were 'speculative'.[85] For example, the submission referenced the US AP1000[86] projects and China's HTGR[87] as an example where SMR projects had delays to building and engineering.[88]

Safety of SMRs

The Committee heard from several pro-nuclear stakeholders that SMR technology promises improved safety features compared to older and traditional nuclear technologies. In particular, it was argued that SMR technology is developing 'passive' safety features that would prevent accidents like those that occurred at Chernobyl or Fukushima-Daiichi. The passive safety features, it was claimed, would also reduce emergency planning zones and site boundaries meaning there could be more flexibility in siting reactors.[89]

Nuclear Now, in its submission, explained the difference between newer technologies, including SMRs, and traditional light water reactors:

> A fundamental change in many SMRs and Gen-IV designs when compared to traditional light water reactors is the presence of vastly improved passive safety or even full passive safety systems. Active safety systems of older designs are characterised on the

82 Tony Irwin, *Submission 38*, p. 4.

83 SMR Nuclear Technology, *Submission 40*, p. 10.

84 NuScale Power, *Submission 42*, p. 2.

85 Friends of the Earth Australia, *Submission 22*, p. 5.

86 AP1000 is a nuclear power plant designed and sold by Westinghouse Electric Company.

87 HTGR means high temperature gas-cooled reactor.

88 Friends of the Earth Australia, *Submission 22*.

89 Dr Mark Ho, *Transcript of evidence*, 25 June 2020, p. 25.

> reliance of functioning of engineered components during emergency situations. These new reactors feature passive safety systems that depend predominately on physical phenomena such as convection, gravity, negative reactivity coefficients or structural robustness at high temperatures, which is intrinsic to the reactor design and operation. For SMRs, which are designs whose generation capacity is less than 300 MWe, they have significant lower cooling requirements in case of emergency shutdown, such that many can be safely cooled by naturally circulating air without the need for operator intervention.[90]

Mr Patrick Gibbons, MCA, told the Committee that he considers SMRs to be:

> … walkaway safe. Take NuScale for example. This is a really interesting one. If you are talking large nuclear reactors, the exclusion zone around that reactor is usually pretty large – that is, a fence – and you have to be a fair way from the reactor. The NuScale one has got approval from the US where the exclusion zone is basically the fence around the property. It is small. These things are viewed as being safe.[91]

The claim that SMRs would be 'walkaway safe' was also contended in SMR Nuclear Technology's submission, it stated:

- Modern SMRs are designed to be inherently safe, avoiding Chernobyl-type or Fukushima-type accidents.
- SMRs can be installed below ground level. This protects them from external hazards and unauthorised access. The reactor building is able to withstand aircraft impact.
- The NuScale module sits in a large "swimming pool" enabling the reactor to be cooled indefinitely without attention.
- 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'.[92]

GE Hitachi Nuclear Energy's submission discussed the 'passive safety features' its BWRX-300, a water-cooled, natural circulation SMR, which is 'designed to eliminate loss-of-coolant accidents (LOCA) enabling simpler passive safety'.[93]

In his submission, Mr Tristan Prasser argued that reactors responsible for previous nuclear accidents are no longer available on the market, 'thus out-of-scope for consideration,' and that:

> 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. This makes the possibility of a Chernobyl-style event significantly reduced or simply physically impossible.[94]

90 Nuclear Now, *Submission 75*, p. 20.

91 Mr Patrick Gibbons, *Transcript of evidence*, 25 June 2020, p. 39.

92 SMR Nuclear Technology, *Submission 40*, p. 5.

93 GE Hitachi Nuclear Energy, *Submission 77*, p. 5.

94 Tristan Prasser, *Submission 80*, p. 3.

Engineers Australia stated that SMR technology could be a 'useful addition to Australia's technology toolkit for electricity generation'[95] because it has 'potential to strengthen the capacity to transition to a low carbon energy system.'[96] However, it made several caveats to this assertion, that:

- Debate on managing risks and safety of SMRs is hampered because there is 'no practical information available about requirements needed'.[97]
- Australia should not rush into developing SMR technology because it is still not 'commercially feasible'. Therefore, Australia should take the time to properly consider its position on SMR technology and what policy direction it intends to pursue.[98]

Some anti-nuclear stakeholders critiqued the assertions that SMRs will offer improved safety features, in particular the argument that they could be 'walk-away' safe. FOE Australia argued the claim that SMRs have improved safety can be made because the technology is still in the design phase and no prototype has reached commercial production:

> The hype surrounding SMRs also derives from their non-existence. They are just designs on paper (or computer screens) and thus any conceivable problem or objection can be easily resolved… with words. The term 'proliferation resistant' or 'proliferation proof' resolves concerns about proliferation. The term 'meltdown proof' does away with safety concerns.[99]

6

FOE Australia's submission provided a lot of excerpts from a variety of sources which argued against the development of SMR technology, including a quotation from Dr Ed Lyman (Union of Concerned Scientists) which described some of the potential safety issues for SMRs:

> - Potential fire and explosion hazards: below-grade facilities present unique challenges, such as smoke/ fire behaviour; design and operation of the HVAC system and removal of waste water.
> - Potential flooding hazards: below-grade reactors and subsystems raise concerns with regard to hurricane storm surges, tsunami run-up and water infiltration intro structures.
> - Limited access for conducting inspections of pressure vessels and components that are crucial for containing radiation, such as welds, steam generators, bolted connections and valves.[100]

95 Engineers Australia, *Submission 63*, p. 4.

96 Ibid.

97 Ibid, p. 5.

98 Ibid, p. 6.

99 Friends of the Earth Australia, *Submission 22*, p. 4.

100 Ibid, p. 48.

This was reiterated in the joint submission from the Australian Conservation Foundation, FOE Australia and Environment Victoria which believed that safety claims about SMRs are 'routinely overstated'.[101]

Dr Margaret Beavis, Medical Association for Prevention of War (Australia), told the Committee that assertions about increased safety measures in SMRs should be 'treated with some scepticism', as well as similar assertions made about other nuclear technologies.[102]

Case study: NuScale Power

The following subsection discusses an example of SMR technology: the NuScale Power SMR. The Committee has chosen this particular model because it was discussed explicitly by many stakeholders on both sides of the nuclear debate.

NuScale Plants use a modular design meaning they are smaller than traditional power plants and mostly factory-built. This reduces construction times with more emphasis on the assembly. Large portions of the plants are manufactured offsite and brought onsite for assembly only. NuScale reactors are approximately 1% of the size of a conventional nuclear plant generating around 60 megawatts of power.

It has a light water design for cooling and power generation similar to most conventional nuclear power plants. However, the size and instalment of improved passive safety features means NuScale plants could be more reliable, safe, carbon-free and economical than conventional plants. For example, the design eliminates the pumps and pipes that could fail in a conventional reactor and cause an accident.

In 2008, NuScale began seeking certification with the US NRC for its SMR technology. In 2017, the NRC began reviewing NuScale's design certification application, with phase one of the application approved in May 2018. It is expected that the final review will be completed by September 2020. Upon approval, Utah Associated Municipal Power Systems will own the first NuScale SMR plant which will be located at Idaho National Laboratory.

According to the NuScale website the features of a NuScale Power Module include:

- safer shutdown and cooling through non reliance on AC or DC power, creating simplified electrical systems and more reliable battery arrays
- use of Helical Coil Steam Generators (HCSG) provides increased heat transfer surface area
- high strength steel containment for reactor cooling and pressure control
- a containment vacuum to minimise reactor vessel heat loss, oxygen content and prevents component corrosion

---

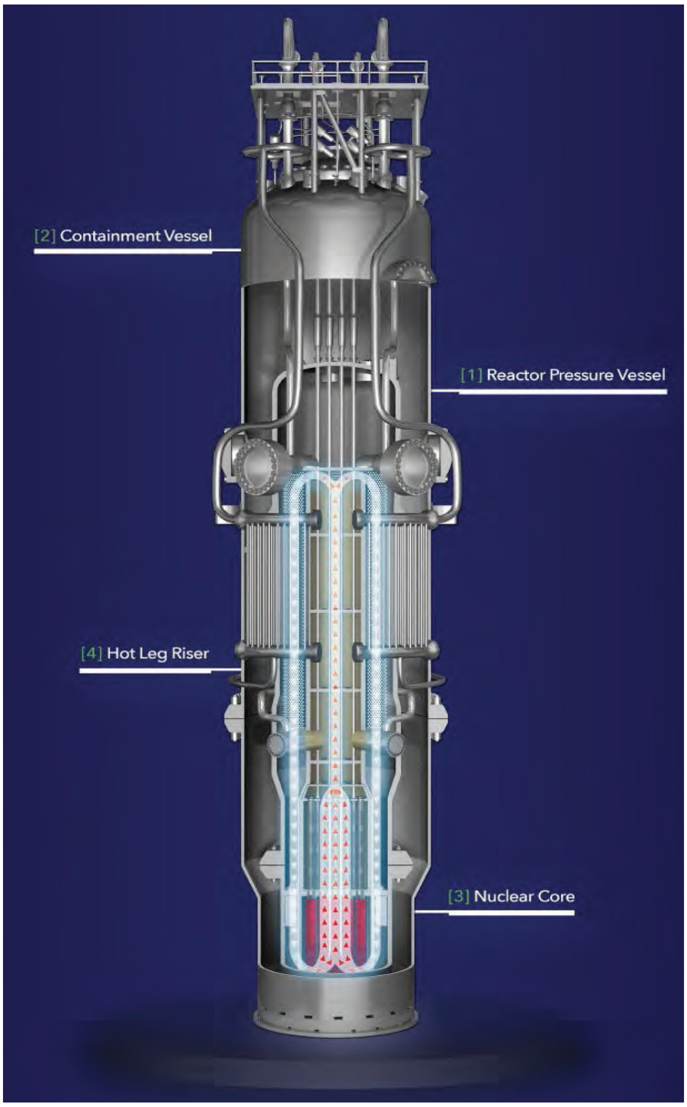
101 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, p. 28.

102 Dr Margaret Beavis, Medical Association for Prevention of War (Australia), public hearing, Melbourne, *Transcript of evidence,* 26 June 2020, p. 23.

- small and efficient design limited fuel damage in all design basis events including failure of all control rods to insert
- uses a single control room to monitor and control all plant systems which prevent against human error and hacking threats.

Figure 6.7 shows the NuScale Power Module which includes a reactor vessel, containment vessel, steam generators and pressuriser which NuScale's submission stated, 'eliminates reactor coolant pumps, large bore piping and other systems and components found in large conventional reactors.'[103]

Figure 6.7 NuScale Power Module



Source: NuScale Power, *Submission 42*, p. 8.

103 NuScale Power, *Submission 42*, p. 8.

6

At a public hearing, Mr Thomas Mundy, Chief Commercial Officer, NuScale explained to the Committee that he considers the NuScale SMR to be the industry's leading model because the program is no longer in early development unlike other SMR models:

> NuScale is best described as a nuclear technology development company specialising in the development of a 720 megawatt gross nuclear power plant on NuScale's small modular reactor, or SMR, technology. We are a leading SMR technology developer in terms of overall program maturity. That is, we are not in the early stages of conceptual design development but rather preparing our program for commercialisation involving the manufacture of equipment and the construction of our first commercial power plant—that will be located in the United States—with those activities commencing in just a couple of years.[104]

Mr Mundy argued that NuScale's SMR technology could:

> … provide safe, reliable base load electricity production that can be an integral part of the electricity power supply system. The NuScale SMR technology can also be operated as a dispatchable load-following source of electricity to complement and support power systems that have a high dependence on intermittent electricity generation. And lastly, NuScale's SMR is ideally suited to provide process heat for a variety of industrial applications, including district heating, desalination, hydrogen production and refinery operations, to name a few.[105]

Like the evidence discussed above on SMRs more generally, proponents of NuScale argued that the technology offers a number of benefits or solutions to issues existing for conventional nuclear reactors such as:

- lower overnight and annual operating costs on a dollar per MWh basis
- quicker construction times, largely in part to fully factory-fabricated elements of its modular design
- flexibility and suitability for diverse energy applications and delivery of high-capacity base load electricity
- scalable design allows generating capacity to be added as needed
- resistant to weather or man-made events that could damage nuclear facilities and improved electronic systems protecting against internet cyber-attacks
- the technology is complementary to an electricity grid that includes intermittent renewables such as wind or solar.[106]

During the public hearing, Mr Mundy also provided the Committee a number of estimated figures related to overnight costs, employment, levelised costs of electricity (LCOE) and decommissioning costs. These figures have been summarised by the Committee:

104 Mr Thomas Mundy, Chief Commercial Officer, NuScale Power, public hearing, Melbourne, *Transcript of evidence*, 14 August 2020, p. 1.

105 Ibid.

106 See: NuScale Power, *Submission 42*; Mr Thomas Mundy, *Transcript of evidence*; Hon. Peter Vickery QC, *Submission 33*.

- The overnight costs for a generic NuScale site are approximately US$2.97 billion, excluding contingency, fees, profit, interest, owner costs and several other factors.[107]
- The overnight costs including other factors such as contingency for a NuScale plant is conservatively estimated to be US$6.12 billion.[108]
- 300 direct job opportunities, mostly in operation and maintenance, for a 12-module NuScale facility.[109]
- An LCOE of US$65 per MWh in comparison to US$76 per MWh for ultra-supercritical coal, US$40 per MWh for offshore wind, US$122 per MWh for onshore wind and US$33 per MWh for solar PV.[110]
- The fund needed to decommission a NuScale plant would need to be approximately US$400–US$500 million.[111]

On the issue of overnight capital costs, Mr Mundy explained that whilst a NuScale SMR does have higher costs compared to some other technologies, the benefits the technology can provide to an electricity grid makes it more competitive:

6

> There is no question that there are other technologies on an overnight capital cost basis that do not cost as much as a NuScale power plant, but in the context of the customer's needs and their desire to possibly diversify their portfolio, the need for low carbon generation and an assortment of other considerations we are very competitive generally with combined cycle gas and coal on an overnight capital cost basis and on a levellised cost of energy basis.[112]

Several anti-nuclear stakeholders refuted many of the assertions made by NuScale and other SMR proponents, in particular the current industry estimates for capital costs and length of construction. FOE Australia's submission focused on discussing current literature on SMRs, the submission critiqued the fluctuating estimates of NuScale's SMRs:

> 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.
>
> …
>
> A report by WSP/ Parsons Brinckerhoff, commissioned by the Royal Commission, estimated levelized costs of electricity of A$225/ MWh (US$161/ MWh) based on the NuScale design…[113]

---

107 Mr Thomas Mundy, *Transcript of evidence*, 14 August 2020, p. 11.

108 Ibid.

109 Ibid, p. 8.

110 Ibid, p.6.

111 Ibid, p. 5.

112 Ibid.

113 Friends of the Earth Australia, *Submission 22*, pp. 14, 23.

In its submission, FOE Australia argued that cost estimates of NuScale SMR's are not inaccurate and that based on the current cost trajectory will significantly exceed current estimates:

> NuScale estimates that by the time it gets through the NRC licensing process, it will have spent US$1 billion overall (including government contributions). That's US$1 billion (possibly more) before the first concrete pour. NuScale will then face the problem that there is a long way from NRC certification to the completion of its first SMR, and further still from the first reactor to mass production for a mass market. One of many reality checks will be the eventual, inevitable acknowledgement that NuScale's estimate of "around $3 billion" for its first 684 MWe plant is ridiculous.
>
> ...
>
> A November 2018 US Department of Energy (DOE) report states that to make a "meaningful" impact, about US$10 billion of government subsidies would be needed to deploy 6 GW of SMR capacity by 2035. (For comparison, about 12.5 GW of new renewable energy capacity was installed in 2017 alone in the US, in addition to 3.5 GW of small-scale solar capacity).[114]

The joint submission by FOE Australia, Australian Conservation Foundation and Environment Victoria also refuted NuScale's construction cost estimates, the submission stated:

> The latest cost estimate for the two AP1000 reactors under construction in the US state of Georgia (the only reactors under construction in the US) is US$12.3–13.6 billion / GW.133 NuScale's target is just one-third of that cost—despite the unavoidable diseconomies of scale and despite the fact that every independent assessment concludes that SMRs will be more expensive to build (per GW) than large reactors. Further, modular factory-line production techniques were trialled with the AP1000 reactor project in South Carolina—a project that was abandoned after the expenditure of at least US$9 billion.[115]

At a public hearing, Mr Jim Green, of FOE Australia, told the Committee that some nuclear proponents have made the assessment that SMRs need to produce electricity at a cost competitive rate in order for there to be a market in Australia:

> It was noted yesterday, I think by [Minerals Council of Australia] that there will not be a market for SMRs unless they can produce power at something like A$60 to A$80 per megawatt hour. So let us use that as the benchmark. A study commissioned by the South Australian Nuclear Fuel Cycle Royal Commission and carried out by WSP Parsons Brinckerhoff did an economic assessment based on the NuScale design, and their estimate is A$225 per megawatt hour—so roughly three to four times too expensive to play any meaningful role in Australia.[116]

114 Ibid, p. 31.

115 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, p. 27.

116 Dr Jim Green, *Transcript of evidence*, p. 13.

6.3.2 Thorium

This section focuses on the use of thorium as an energy source. The Committee received evidence from numerous stakeholders which debated the viability of thorium as an energy source. Some stakeholders believed that Victoria could be a leading jurisdiction in the development of thorium-based fuel cycles for energy production because it hosts significant deposits of thorium. However, there were questions about the economic and technological viability of thorium energy production because there is no market for thorium resources and no thorium-based reactors are in the commercial phase.

At a public hearing, Mr Jeremiah Josey, Founder and Chief Executive Officer, The Thorium Network, explained the difference between uranium and thorium in terms of nuclear energy, he stated:

> Well, it is kind of like comparing a jet engine and an internal combustion engine—an engine in a car. Uranium systems tend to be very complex because of their safety requirements, whereas if you use thorium, the safety requirements are much less. You are using an atmospheric pressure vessel running through at high temperature—we are talking about a molten salt system – so you are able to get more energy from much, much less fuel.[117]

6

Mr Josey also calculated the estimated energy requirements for thorium versus coal in Australia:

> We [The Thorium Network] have calculated that the entire energy system requirement for Australia would be 100 tonnes of thorium per year. That is comparing the coal industry in Australia, which is 500 million tonnes per year.[118]

Some pro-nuclear stakeholders believed there were opportunities in Victoria to explore and mine thorium. In particular, The Thorium Network supported the exploration of thorium molten salt (TMS) as an energy source in Victoria due to the benefits it believed it offers, such as:

> … very high energy output and ultra low waste; it is 'walk-away safe and non-weaponisable; no water cooling is needed and above it all; has zero carbon production.
>
> Any associated risks are orders of magnitude lower than traditional uranium solid fuel systems.[119]

The Thorium Network recommended that Victoria research, develop and implement TMS reactors as part of its future energy production.[120]

117 Mr Jeremiah Josey, Founder and Chief Executive Officer, The Thorium Network, *public hearing, Melbourne, Transcript of evidence*, 25 June 2020, p. 42.

118 Ibid.

119 The Thorium Network, *Submission 79*, p. 3.

120 Ibid, p. 14.

Molten salt reactors use molten fluoride salts as the primary coolant and can use a variety of fuel sources. In the 1960s, the United States, as part of its Manhattan Project, developed the molten salt breeder reactor concept. The intention was to use it as the primary back-up option for fast breeder reactors leading to the construction of a small prototype 8 MWt Molten Salt Reactor Experiment which operated at Oak Ridge from 1965–1969.

Today, the nuclear industry has developed several molten salt reactor concept designs which use thorium to breed fissile U_{233} to be used for energy generation. However, despite several concepts existing the industry faces the challenge of commercialising reactors which use thorium as a fuel source. However, the Thorium Network believed that the abundance of thorium compared to uranium means it is important for the nuclear industry and policy-makers to look into ways it could play a part in the state's energy future.[121]

What is a thorium-based fuel cycle?

The thorium-based fuel cycle is very similar to the uranium fuel cycle, except that it requires an additional step of converting fertile Th_{232} into fissile U_{233}.[122] The Australian Institute of Physics (Victorian Branch) explained that thorium itself is not a fissile material and therefore needed to be processed to produce fuel that can be used for electricity generation:

> Thorium is only 'fertile', not fissile with thermal neutrons so it is not directly usable as a fuel for nuclear reactors. It requires breeding of from Thorium-232, uranium-233 can be made in a nuclear reactor, uranium-233 can extracted by reprocessing, it can then be made into fuel, but this takes place in a high radiation environment (due mainly to uranium-232 coproduction) and then used in a reactor designed for uranium-233 operation.[123]

This process can occur in either an open or closed fuel cycle, however, the process is slightly different depending on which fuel cycle is being used:

- **Open fuel cycle** requires irradiation of Th_{232} and in situ fission of U_{233}, without chemical separation.
- **Closed fuel cycle** requires reprocessing of irradiated thorium or thorium-based fuels for recovery of U_{233} and re-fabrication and recycling of U_{233} fuels.[124]

The Thorium Network further explained what happens in a thorium-based fuel cycle and how much of the energy contained in a thorium fuel load can be released as thermal energy from fissile U_{233}:

121 Ibid, p. 8.

122 International Atomic Energy Agency, *Thorium fuel cycle – Potential benefits and challenges*, May 2005, <https://www-pub.iaea.org/mtcd/publications/pdf/te_1450_web.pdf> accessed 31 July 2020.

123 Australian Institute of Physics, *Submission 67*, p. 2.

124 International Atomic Energy Agency, *Thorium fuel cycle – Potential benefits and challenges*.

> When bombarded with neutrons, the decay chain of Thorium moves into Uranium 233, a fissile material of superior energy-producing characteristics. Up to 99.5% of the energy contained in the Thorium fuel load can be released as thermal energy from the fission of U233.[125]

Arguments for thorium as an energy source in Victoria

The Committee received evidence from several pro-nuclear stakeholders which argued that thorium could be a useful energy source in Victoria, particularly because the State has significant deposits. These stakeholders contended that there were potential economic, environmental and safety benefits related to developing thorium-based nuclear activities in Victoria. Please see Chapter 10 for the Committee's view for thorium opportunities in Victoria.

The Hon. Peter Vickery QC, in his submission, discussed thorium-based nuclear fuel cycles stating:

> Use of low-radioactivity thorium instead of uranium may provide another breakthrough in safer nuclear power generation. Thorium reactors have the potential to provide the world with centuries of relatively safe carbon free electrical energy drawing upon a raw material which is abundant in the sands of India and Brazil, with Australia positioned in third place with resources amounting to about 595 000 tonnes.
>
> The potential of thorium to produce electricity in a safer nuclear process as an alternative to uranium is promising. Proponents of the thorium fuel cycle point to the prospect of meltdown being eliminated; problems of waste disposal being significantly reduced because thorium systems may be designed to consume by-products of the raw material in the energy production process; and any potential to use the system for the development of nuclear weapons is rendered unrealistic.[126]

He acknowledged that there were several challenges to address before a thorium-based fuel cycle could be commercially available, including:

- reactor designs are currently still in the development phase; with none yet to achieve working prototype status
- a number of countries, including India and China, are supporting projects which seek to develop a 'viable working plant'.[127]

He recommended that Victoria 'keep an open mind and prepare its population for technological developments in new generation nuclear as they are being invented and commercialised'.[128]

---

125 The Thorium Network, *Submission 79*, p. 7.

126 Hon. Peter Vickery QC, *Submission 33*, p. 16.

127 Ibid.

128 Ibid.

Mr Jeremiah Josey of The Thorium Network explained to the Committee why a thorium fuel cycle would contribute to creating a hydrogen economy:

> So you are burning thorium in a molten salt burner. Now, molten salt is running between 650 and 750 degrees Centigrade. So it is running at the same temperature as the inside of your car, in where the spark plugs are doing their thing, and that is a high temperature element all by itself. Hydrogen production needs high temperature. So basically you can couple the two together: you have got thorium production generating high heat. You can use that for hydrogen production and you can use it for electrical production as well. So it is a very, very good form of industrial heat to apply to many industrial processes.[129]

Mr Josey argued that thorium would have lower costs compared to uranium because it does not include costs incurred from using cooling water to control temperature. He stated:

> All of the costs associated with trying to contain high-pressure water in the traditional system do not exist. You end up with very, very low cost, and some at this stage are showing $1 million and $2 million per megawatt installed. That is comparable to everything else you have got. I concede prices for solar are now much less than that in the Middle East, but there are some different economic drivers on that. Comparing that to uranium solid fuel systems, which are going above $7 million per megawatt installed—so just because of the simpler technology require to contain the thorium while it is doing its stuff, it ends up being cheaper.[130]

At a public hearing, Dr Dragos Petrescu of The Thorium Network told the Committee that the environmental benefits of thorium would be:

> … that the technology is clean and green. There are no CO2 emissions, or at least the CO2 emissions are on par with the wind and solar. The other one would be the nuclear waste or the waste management.
>
> …
>
> Out of this 100 tonnes we only have half a tonne—500 kilograms— of waste. You think that from the whole Australia 500 kilograms – that would be a chest or container with the size of 35 x 35 x 35 centimetres, a bit over a cubic foot. So it is something very easy to manage, and its life to be managed is not thousands of years; it is about 300 years—and that in comparison with a plastic bag that degrades in the environment for about 1,000 years.[131]

In response to a question on what size a Victorian TMS reactor could be and how many jobs it could generate, Mr Josey used Canada as an example because he believed similar outcomes would be seen in an Australian context. He stated:

---

129 Mr Jeremiah Josey, *Transcript of evidence*, 25 June 2020, p. 45.

130 Ibid, p. 46.

131 Dr Dragos Petrescu, The Thorium Network, public hearing, Melbourne, *Transcript of evidence*, 25 June 2020, pp. 42–3.

> … 60 000 jobs in Canada and a $5 billion per year industry. That is what I said before. You can expect similar. In Canada they have a full spectrum of nuclear. They are also doing thorium molten salt as well. You can expect similar ramification ns in Australia. Canada and Australia are very similar in size, logistics and things like that.[132]

The Committee notes that these figures relate to Canada's entire nuclear industry, not just from thorium-related nuclear activities. In July 2020, the World Nuclear Association updated its website with new figures for Canada's nuclear industry based on estimates from the Canadian Nuclear Association. The figures showed:

- approximately 30,000 people were employed directly; and 30,000 people were employed indirectly through contracting
- industry generates revenue of $6.6 billion.[133]

Arguments against thorium as an energy source in Victoria

Some stakeholders from both sides of the nuclear debate argued against using thorium as an energy source in Victoria, namely because its commercial viability is unproven and there was a belief that there would not be a substantial market for thorium in the short to medium term.

In its submission, ANSTO acknowledged that whilst a thorium-based fuel cycle could be used to generate electricity there was not enough evidence to suggest it could be economically viable.[134] The submission stated:

> … there is limited evidence to suggest that the required significant investments to make thorium technologies commercially viable would be an improvement on the well-established reactor technologies and systems using uranium-based fuels.
>
> As the South Australian Nuclear Fuel Cycle Royal Commission found, 'Energy generation technologies that use thorium as a fuel component are not commercial and are not expected to be in the foreseeable future. Further, with the low price of uranium and its broad acceptance as the fuel source for the most dominant type of nuclear reactor, there is no commercial incentive to develop thorium as a fuel.'[135]

The joint submission from FOE Australia, Australian Conservation Foundation and Environment Victoria challenged the assertion that a thorium-based fuel cycle would not be suitable for making nuclear weapons, stating that 'the proliferation risks associated with thorium fuel cycles can be as bad as—or worse than—the risks associated with conventional uranium reactor technology.'[136]

---

132 Mr Jeremiah Josey, *Transcript of evidence*, 25 June 2020, p. 47.

133 World Nuclear Association, *Nuclear Power in Canada*, July 2020, <https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/canada-nuclear-power.aspx> accessed 04 August 2020.

134 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 10.

135 Ibid, p. 8 (with sources).

136 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, p. 37.

In her submission, Ms Rosamund Krivanek listed what she believed were several disadvantages of using thorium as an energy source:

- breeding process is slow and requires extensive reprocessing
- requires significant testing, analysis and licensing in the first phase which can be expensive and needs business and government support
- higher costs for fuel fabrication and reprocessing
- irradiation process can create dual purpose fuel; for energy generation and weapons manufacturing.[137]

FINDING 7: Until there is a change in the Commonwealth position, detailed discussions about emerging technologies in Victoria related to the nuclear fuel cycle and power generation are unlikely to advance.

137 Rosamund Krivanek, *Submission 65*, p. 8.

7 Nuclear energy issues: security and safety

7.1 Introduction

This Chapter canvasses evidence received relating to nuclear security, health and safety. The Committee has not sought to undertake a detailed analysis of the merits or otherwise of the various cases put to it, rather it seeks to encapsulate the arguments.

7.2 Security and weapons non-proliferation

7.2.1 Australian settings

Since 1970 Australia has had a consistent position of not pursuing a nuclear weapons capability when it signed the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), of which it is one of the world's strongest proponents. The NPT seeks to curb the proliferation of nuclear weapons to other states and to commit nuclear weapon states to work towards disarmament. It also promotes the peaceful uses of nuclear energy and technology, including in human health, agriculture and food security, water and the environment. Australia's compliance with the NPT is verified through its application of International Atomic Energy Agency (IAEA) safeguards to all nuclear activities.

Australia is involved in several international measures to promote the importance of nuclear security, including as a founding member of the Global Initiative to Combat Nuclear Terrorism, a member of numerous IAEA bodies concerned with nuclear security and a regular contributor to the IAEA Nuclear Security Fund.[1]

In 2012, 2014, 2016 and 2018, the Nuclear Threat Initiative[2] ranked Australia first in the world in its biennial assessment of security measures that countries have in place to protect significant holdings of nuclear materials and nuclear facilities.[3]

---

1 Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, Government of South Australia, South Australia, 2016, p. 145.

2 The Nuclear Threat Initiative is an independent non-government organisation that works to reduce global threats from nuclear, biological and chemical weapons.

3 Australian Nuclear Science and Technology Organisation, *Submission 62*, pp. 49–50.

A number of Commonwealth Acts interact with Australia's international treaty obligations to govern its policy on nuclear security and non-proliferation, including:

***Nuclear Non-proliferation (Safeguards) Act 1987* (Cth)**

This Act provides the legislative basis for Australia's safeguards system. The objects under section 3 of the Act are to give effect to Australia's obligations it has as a party to:

- the Treaty on the Non-Proliferation of Nuclear Weapons (NPT)
- the Agreement between Australia and the IAEA on the Application of Safeguards in connection with the NPT
- Supplementary Agreements with the IAEA
- prescribed international agreements (including agreements with various countries on the transfer of nuclear material, equipment and technology)
- the Convention on the Physical Protection of Nuclear Material (CPPNM) (and its 2005 amendment)
- the International Convention for the Suppression of Acts of Nuclear Terrorism.

Commitments under these international treaties are managed through a system of permits issued by the Australian Safeguards and Non-Proliferation Office (ASNO) for the possession of nuclear material, equipment and technology. The Act regulates the possession, transport and communication of nuclear material, and associated material, facilities, equipment and technology, as well as arrangements for the physical protection of nuclear material and facilities.

***South Pacific Nuclear Free Zone Treaty Act 1986* (Cth)**

Implements Australia's obligations under the South Pacific Nuclear-Free Zone Treaty of Rarotonga, which prohibits the manufacture, possession and testing of nuclear weapons, and research and development relating to the production of nuclear weapons in Australia.

***Comprehensive Nuclear Test-Ban Treaty Act 1998* (Cth)**

Implements Australia's obligations under the Comprehensive Nuclear-Test Ban Treaty, which prohibits the conduct of nuclear weapon test explosions, or any other nuclear explosions.

Australian Safeguards and Non-Proliferation Office

The ASNO is a division within the Commonwealth Department of Foreign Affairs and Trade. It is responsible for ensuring that Australia's international obligations are met under NPT, as well as Australia's NPT safeguards agreement with the IAEA, the CPPNM, and Australia's various bilateral safeguards agreements.

ASNO has four main responsibilities in the nuclear area:

1. the application of safeguards in Australia;
2. the physical protection and security of nuclear items in Australia;
3. the operation of Australia's bilateral safeguards agreements; and
4. contribution to the operation and development of IAEA safeguards and the strengthening of the international nuclear non-proliferation regime.

ASNO follows internationally respected rules and guidelines set out by the IAEA as its basis for national regulation, which is implemented through the *Nuclear Non-proliferation (Safeguards) Act 1987* (Cth). Among other things, ANSO licenses and inspects uranium mines, the OPAL research reactor at Lucas Heights, and other possessors of nuclear material including government departments, CSIRO, universities and industry.[4]

Uranium export monitoring

As noted in Chapter 3, Australian uranium is exported in-line with Australia's NPT obligations and only to countries and parties with which Australia has a bilateral nuclear cooperation (safeguards) agreement. Australia currently has 25 safeguards agreements in force covering 43 countries, in addition to an Exchange of Notes constituting an Agreement with Singapore Concerning Cooperation on the Physical Protection of Nuclear Materials.[5]

An export licence is necessary for the export of radioactive material (including refined uranium, plutonium and thorium).[6] Export applications are subject to assessment by the Department of Resources, Energy, and Tourism and ASNO to ensure that Australian uranium is only exported for peaceful, non-explosive purposes under the network of bilateral safeguards agreements.

Australia's uranium export policy[7] provides assurances that exported uranium and its derivatives cannot benefit the development of nuclear weapons or be used in other military programs. This is done by precisely accounting for amounts of Australian-Obligated Nuclear Material (AONM) as it moves through the nuclear fuel cycle. In summary, this policy stipulates that:

- Australian uranium may only be exported for peaceful purposes under a nuclear cooperation agreement that provides for:
  - coverage by IAEA safeguards

4 Dr John Kalish, Assistant Secretary, Australian Safeguards and Non-Proliferation Office, public hearing, Melbourne, *Transcript of evidence*, 12 March 2020, p. 1.

5 Department of Foreign Affairs and Trade, *Australia's network of nuclear cooperation agreements*, <https://dfat.gov.au/international-relations/security/non-proliferation-disarmament-arms-control/policies-agreements-treaties/nuclear-cooperation-agreements/Pages/australias-network-of-nuclear-cooperation-agreements.aspx> accessed 19 August 2020.

6 *Customs (Prohibited Exports) Regulations 1958* (Cth) reg 9.

7 Department of Foreign Affairs and Trade, *Australia's Uranium Export Policy*, <https://www.dfat.gov.au/international-relations/security/non-proliferation-disarmament-arms-control/policies-agreements-treaties/Pages/australias-uranium-export-policy> accessed 19 August 2020.

  - fallback safeguards in the event that IAEA safeguards no longer apply
  - prior Australian consent for any transfer of AONM to a third party for enrichment or reprocessing
  - physical security requirements.
- Australia may be selective in concluding safeguards arrangements with other countries
- Customer countries must be a party to the NPT[8]
- NPT Non-Nuclear Weapon State customer countries must, at a minimum, be a party to the NPT and have concluded a full scope safeguards agreement with the IAEA
- Nuclear weapon state customer countries must provide an assurance that AONM will not be diverted to non-peaceful or explosive uses and accept coverage of AONM by IAEA safeguards
- Commercial contracts for uranium exports should include a clause noting that the contract is subject to the relevant bilateral nuclear cooperation agreement
- The Australian Government has further tightened Australia's export policy by making an Additional Protocol with the IAEA (providing for strengthened safeguards) a pre-condition for the supply of Australian obligated uranium to all states.

At a public hearing, Dr John Kalish, Assistant Secretary, ASNO, expanded on ASNO's role in relation to uranium export and how it ensures destination countries abide by the terms of bilateral agreements in their use of Australian uranium. He told the Committee:

> We also work closely with our nuclear cooperation agreement counterparts in other countries—counterpart agencies and departments in other countries—to verify the amount of nuclear material that is present in those countries that is what we call Australian obligated nuclear material, or AONM. When we send uranium ore concentrate to another country, we call that Australian obligated nuclear material, and that country picks up an obligation to report in relation to the disposition of that material, including the form that it is in and where it is located within their nuclear infrastructure. We get those data in annual reports, and those annual reports are reflected in the Australian Safeguards and Non-proliferation Office annual report. We seek to, on many occasions, corroborate the information that is sent to them by having bilateral meetings with those countries in relation to the disposition of that nuclear material. I should mention that you can get that information from our annual report, as I mentioned, and that can be found at www.dfat.gov.au/asno. Then if you look for annual reports, you can find that information.[9]

---

8 In the case of India an exception has been granted on the basis of the 2008 decision of the Nuclear Suppliers Group, the application of International Atomic Energy Agency safeguards to India's civil nuclear facilities and separation of the Indian civilian and military nuclear programs.

9 Dr John Kalish, *Transcript of evidence*, pp. 5–6.

Nuclear safeguards and security

In relation to nuclear safeguards, ASNO is responsible for Australia's state system of accounting for and control of nuclear material, established under IAEA guidelines, which includes inspections of nuclear facilities in Australia and areas that hold the material. ASNO also facilitates inspections conducted by the IAEA in Australia and engages in other verification activities in relation to IAEA obligations. [10]

Dr Kalish told the Committee:

> One of the things that Australia has achieved through this series of nuclear safeguards is what is known as the broader conclusion, and that is in relation to the IAEA's criteria on the peaceful use of nuclear material. What this does is it verifies that all nuclear material and facilities in Australia are being used for peaceful purposes and there is no diversion of nuclear material. It also confirms that our declarations that we make annually are correct and complete. That is the nuclear safeguard side of things.

ASNO engages with nuclear facilities on security requirements using a risk-based, graded approach to prevent and mitigate threats. There are two main threats that ASNO considers in relation to nuclear materials and facilities: [11]

- nuclear sabotage leading to a possible release of radioactive material
- theft of nuclear material for the purposes of constructing a nuclear explosive device.

Australian Nuclear Science and Technology Organisation (ANSTO)

ANSTO undertakes research in the principal areas of nuclear security, including nuclear forensics and border security technology development. It also represents Australia as a participant in the Global Initiative to Combat Nuclear Terrorism steering group and the implementation and assessment group, has chaired the nuclear forensics working group, and participated in two other working groups.[12]

ANSTO's nuclear forensics laboratory provides Australia with the necessary tools and expertise to aid in the prevention of and response to domestic and international nuclear security threats.[13]

ANSTO also engages actively in domestic and international discussions regarding emerging cyber security threats.[14]

10 Ibid, p. 2.

11 Ibid.

12 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 50.

13 Ibid.

14 Ibid.

7.2.2 Nuclear security

Nuclear security focuses on the prevention of, detection of, and response to, criminal or intentional unauthorised acts involving or directed at nuclear and other radioactive material, associated nuclear facilities, or associated nuclear activities. Individual nation states are entirely responsible for their nuclear security, including responsibility to provide for the security of nuclear material, facilities and activities to:

- ensure the security of nuclear material in use, storage, or transport
- combat illicit trafficking and the inadvertent movement of such material
- be prepared to respond to a nuclear security event.[15]

The extent to which the nuclear fuel cycle gives rise to nuclear security risks relates to the potential production of weapons-usable material. Nuclear weapons require either highly enriched uranium (HEU), or plutonium. While nuclear fuel cycle activities do not ordinarily produce HEU or plutonium with a composition for use in weapons, the basic capability to produce such materials is possible through uranium enrichment and fuel reprocessing technologies, making those activities of greatest concern to the non-proliferation regime. Such activities are therefore subject to a range of measures that seek to limit the risks.[16]

Other stages of the nuclear fuel cycle can also give rise to proliferation concerns, albeit to a lesser extent, including:

- uranium mining and conversion
- storage and disposal of low- and intermediate- and high-level waste
- the storage and disposal of used fuel
- nuclear power plants.[17]

Views on nuclear security and weapons proliferation risks

The Committee received evidence on a number of issues relating to nuclear security and weapons proliferation concerns associated with the nuclear fuel cycle and nuclear power generation.

Dr Tilman Ruff AO from the Medical Association for Prevention of War (MAPW) (Australia) argued that there was no way to separate the potential capability to produce weapons grade materials from the capacity to run nuclear reactors, noting if you could enrich uranium for use in a reactor, then you had everything necessary to enrich it a little further for use in nuclear weapons.[18]

---

15 International Atomic Energy Agency, *Objective and Essential Elements of a State's Nuclear Security Regime*, Nuclear Security Series no. 20, Vienna, 2013, p. 1.

16 Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, p. 146 (with sources).

17 Ibid, p. 147 (with sources).

18 Dr Tilman Ruff AO, Medical Association for Prevention of War (Australia), public hearing, Melbourne, *Transcript of evidence*, 26 June 2020, p. 22.

Dr Ruff also highlighted concerns arising from theft, trafficking and malicious use of nuclear materials. In response to a question on notice he informed the Committee that, in 2018, 156 incidents of nuclear theft were identified across 23 countries, and that recent information published by the IAEA indicated that 290 incidents of trafficking or malicious use occurred between 1993 and 2019, including 12 involving enriched uranium and two involving plutonium.[19]

Similar points were highlighted in the submission from the MAPW (Australia), which also drew attention to the potential for catastrophic release of radiation into the environment in the event a nuclear facility was successfully targeted in a terrorist attack.[20]

In their joint submission, Friends of the Earth (FOE) Australia, Australian Conservation Foundation and Environment Victoria considered the major security risks associated with civil nuclear programs included military strikes on nuclear sites, attacks on or theft from nuclear facilities and transports by individuals and non-state actors, theft and smuggling of nuclear material, and sabotage and insider threats.[21] The joint submission stated:

> The weapons proliferation risks associated with civil nuclear programs are well understood and 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, and power reactors have been used to produce plutonium for weapons in most or all of the other five nation-states (the 'declared' nuclear weapons states).[22]

The joint submission also included a critique of the assertion that a thorium-based fuel cycle would not be suitable for making nuclear weapons, stating that 'the proliferation risks associated with thorium fuel cycles can be as bad as—or worse than—the risks associated with conventional uranium reactor technology.'[23] This echoed comments from some other stakeholders, including Ms Rosamund Krivanek who noted in her submission that thorium irradiated for use in reactors could be altered to make U_{233}, which is used in nuclear weapons.[24]

However, Dr Dian Kemp, Nuclear Chemical Engineer, The Thorium Network, argued that while U_{233} could be used for nuclear weapons, to do so would be very difficult and very expensive to the point that this would be unlikely to occur in reality as there were other nuclear materials that could be used to make bombs 'far cheaper, far easier [and] with far less hassle.'[25]

---

19 Dr Tilman Ruff AO, response to questions on notice received 6 July 2020.

20 Medical Association for Prevention of War (Australia), *Submission 34*, pp. 1, 5, 14.

21 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, p. 66.

22 Ibid, p. 67 (with sources).

23 Ibid, p. 37.

24 Rosamund Krivanek, *Submission 65*, p. 7.

25 Dr Dian Kemp, Nuclear Chemical Engineer, The Thorium Network, public hearing, Melbourne, *Transcript of evidence*, 25 June 2020, p. 45.

This view was echoed by Mr Robert Parker, Vice President of the Australian Nuclear Association, who told the Committee:

> On nuclear proliferation and the used fuel from nuclear power plants, there is no record out of these pressurised water reactors and boiling water reactors of the type of fuel being used. If one wants to build a bomb, there are much easier ways of doing it. We must be mindful that all nuclear plants are signatories to the IAEA and are subject to continued inspections at any time of the day, anywhere, and ANSTO undergoes this in Australia. These things are sealed units, and IAEA inspectors can come in at any time. The fuel out of those is a terrible way to try to go towards weapons manufacture. There are other simpler, direct ways that people who want to go down that route go.[26]

In relation to uranium exports to India, the Uniting Church of Australia (Synod of Victoria and Tasmania) expressed doubts in its submission that that Australian uranium and nuclear technology was only used for civilian purposes.[27] It argued that:

> Uranium trade with India undermines a fundamental principle of the global non-proliferation and disarmament regime. This is the principle that only signatories to the NPT can engage in international nuclear trade for their civilian nuclear programs. The precedent set by nuclear trade with India increases the risk of other countries pulling out of the NPT, and building nuclear weapons with the expectation that civilian nuclear trade would continue.[28]

Dr Margaret Beavis from the MAPW (Australia) drew attention to the dangers of cyber attack. In response to a question on notice she informed the Committee:

> The cyber threat has expanded dramatically in recent years, with a series of damaging, high-profile attacks that have made headlines around the world. Nuclear facilities and critical command and control systems are not immune to cyber-attack—such an attack could facilitate the theft of weapons-usable nuclear materials or a catastrophic act of sabotage.

In contrast to many of the security and proliferation concerns raised by some stakeholders, the Australian Workers' Union (AWU) argued that much of the anxiety in this area was caused by anti-nuclear advocates 'fanning public indignations towards nuclear science' by linking nuclear power generation to the threat of nuclear armament. Further, the AWU submitted that Australia would not need to build a nuclear power plant if it really wanted to develop nuclear weapons.[29]

---

26 Mr Robert Parker, Vice President of the Australian Nuclear Association, public hearing, Melbourne, *Transcript of evidence*, 25 June 2020, p. 19.

27 Uniting Church in Australia (Synod of Victoria and Tasmania), *Submission 70*, pp. 4–10.

28 Ibid, p. 8.

29 Australian Workers' Union, *Submission 71*, pp. 3, 4.

7.2.3 Expansion of nuclear activities in Victoria and Australia

Addressing capacity of any future Victorian nuclear framework to govern regulatory settings around nuclear security, ANSTO submitted:

> The IAEA has developed a range of standards and conventions regarding the security of nuclear facilities and nuclear material that would be applied in the event that nuclear power plants or other fuel cycle facilities/activities were introduced in Victoria.[30]

While Dr Kalish (ASNO) told the Committee that any expansion of Victoria's nuclear footprint, including for energy generation and related activities in the event existing prohibitions were lifted, would result in increased rates of inspections by both ASNO and the IAEA.[31] Furthermore, he said that existing legislated security and safeguards aspects of the current Australian regulatory framework had the capacity to regulate a nuclear power facility, although he noted it could be enhanced with some refinement, and would require an increase in ASNO's human resources capability to effectively undertake the resulting expansion in its activities.[32]

In considering whether Victoria specifically, and Australia more generally, are capable of ensuring international best practice in respect of nuclear security, the Committee notes of the Report of the South Australia Nuclear Fuel Cycle Royal Commission (SANFCRC), which states:

> If Australia were to widen its involvement in nuclear activities, it would need to be proactive in assuring other countries that it remains committed to its international and domestic non-proliferation obligations. Several means of doing so are already in train.[33]

The Committee recognises there are legitimate concerns regarding threats to nuclear security that must be taken seriously, both in the context of the existing safeguards framework and in the event of any expansion of Victoria's, and indeed Australia's, nuclear activities. However, the Committee is also confident that Australia is served well by a robust and effective framework that is capable of being adapted and refined to effectively cater for any future expansion in the domestic nuclear environment.

7.3 Health and safety

This section examines health and safety issues linked with nuclear plants, energy production and accidents. The first sub-section examines public health issues related to nuclear energy production, in particular the effects of radiation exposure from nuclear materials and facilities. The second sub-section focuses specifically on nuclear accidents, presenting stakeholders views on the likelihood of accidents and the health and safety consequences when they occur. The sub-section provides three case studies, from, arguably, the most well-known nuclear accidents:

- Three Mile Island (United States of America)

30 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 49.

31 Kalish, *Transcript of evidence*, p. 5.

32 Ibid, p. 7.

33 Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, p. 146.

- Chernobyl (Ukraine)
- Fukushima Daiichi (Japan).

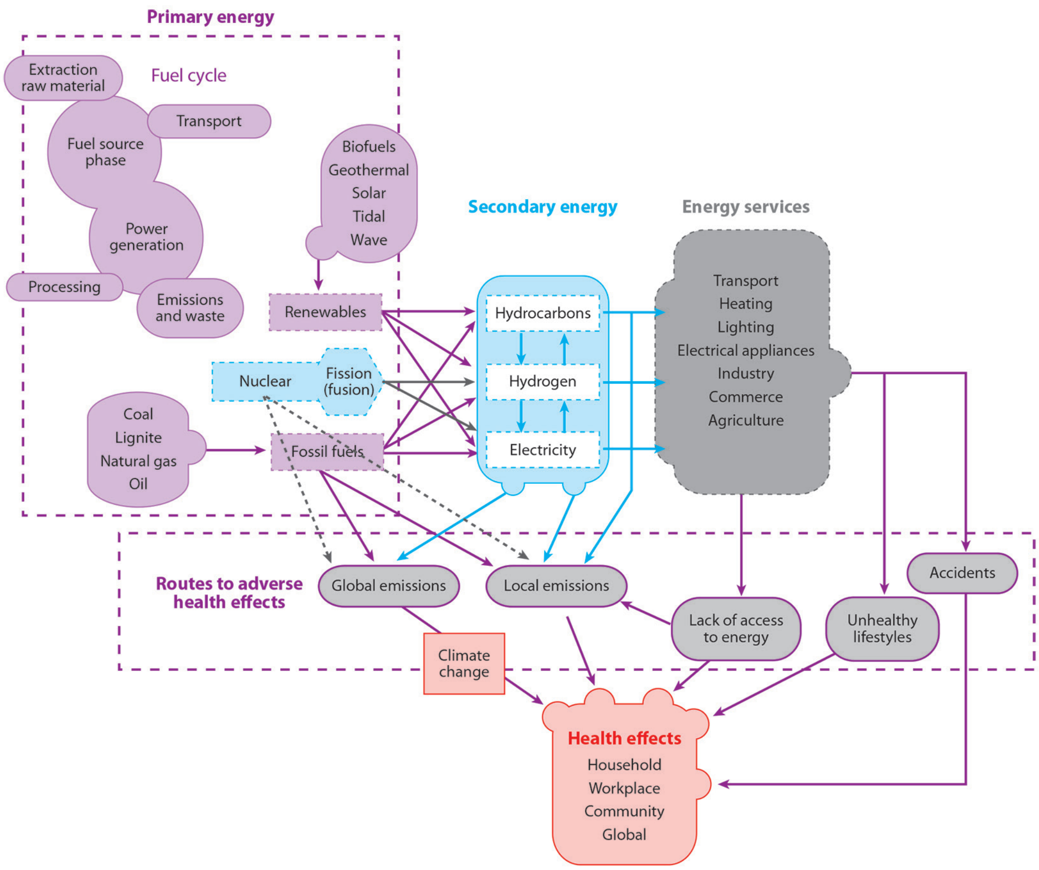
These case studies were selected partly because they are well known by the wider public but also because many stakeholders, on both sides of the nuclear debate, discussed these nuclear accidents in their submissions or evidence.

7.3.1 Public health

Every step of nuclear energy production, from mining to disposal, has radioactive emissions and waste streams. The main risk associated with nuclear energy is radiation exposure, which can cause numerous ill-health effects ranging from skin burns to radiation-induced cancer.[34] The Committee notes that exposure to low-level radiation does not cause immediate ill-health effects, however, some stakeholders argued it could increase the risk of cancer over a person's lifetime. Figure 7.1 shows the potential routes to adverse health effects from energy sources.

7

Figure 7.1 Pathways linking energy and health



Source: Kirk Smith, et. al, 'Energy and Human Health', *Annual Review of Public Health*, vol. 34, 2013.

34 Kirk Smith and et. al, 'Energy and Human Health: Annual Review of Public Health', vol. 34, 2013, p. 69.

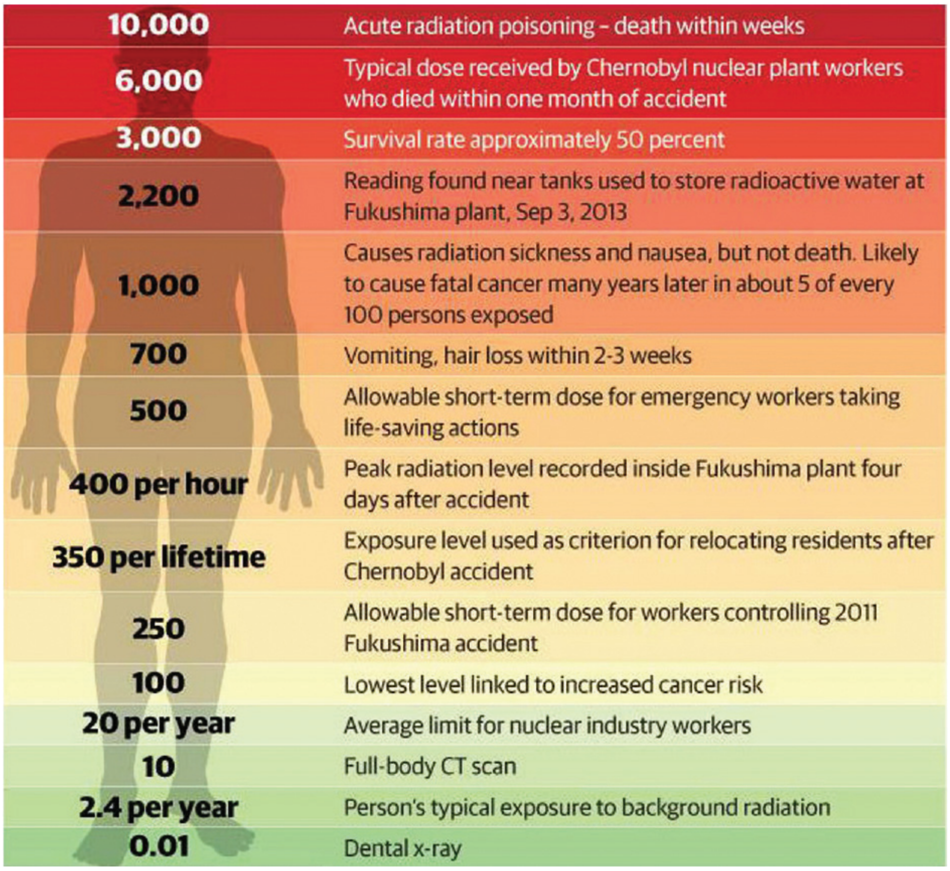
Mr Barrie Hill, in a submission, explained where radiation exposure can arise and compared average background radiation with public exposure from nuclear power generation:

> The radioactivity of uranium has potential health impacts when it is used to produce electricity. Ionising radiation is produced when the nucleus of an atom disintegrates, releasing energy in the form of an energetic particle wave of electromagnetic radiation. Radiation exposure can arise from sources outside the body (external exposure) or from radioactive material inside the body (internal exposure). Radioactive material can enter the body by inhalation or ingestion in water or food. Some parts of the body are more sensitive to the effects of radiation than others, and some types of radiation are inherently more dangerous than others, even if they deposit the same level of energy…
>
> People are continuously exposed to natural background radiation and this may vary substantially from place to place. The worldwide average is 2.4 mSv/year with maximums above 12 mSv/year depending on local geology and altitude. There is no evidence that this variation leads to any differences in terms of human health. Evidence is emerging that the small background radiation exposure we experience may have an overall beneficial effect. The dose rate estimated for individual members of the public from nuclear power generation is very low, on average 0.005 mSv/year for people resident within 50 km of a pressurised water reactor power station. To place radiation exposure to the public in perspective, a person taking a return flight from Melbourne to London would receive the same dose (approximately 0.25 mSv) as someone living fifty years in the vicinity of such a power reactor.[35]

In response to a question on notice on the health risks from low dose radiation, the Australian Nuclear Association provided a graphic (Figure 7.2) which showed the associated health effects for people when they are exposed to a specific dose of radiation.

35 Barrie Hill, *Submission 47*, pp. 26–7.

Figure 7.2 Comparison of effects of varying levels of ionising radiation in millisieverts (mSv)



10,000	Acute radiation poisoning - death within weeks
6,000	Typical dose received by Chernobyl nuclear plant workers who died within one month of accident
3,000	Survival rate approximately 50 percent
2,200	Reading found near tanks used to store radioactive water at Fukushima plant, Sep 3, 2013
1,000	Causes radiation sickness and nausea, but not death. Likely to cause fatal cancer many years later in about 5 of every 100 persons exposed
700	Vomiting, hair loss within 2-3 weeks
500	Allowable short-term dose for emergency workers taking life-saving actions
400 per hour	Peak radiation level recorded inside Fukushima plant four days after accident
350 per lifetime	Exposure level used as criterion for relocating residents after Chernobyl accident
250	Allowable short-term dose for workers controlling 2011 Fukushima accident
100	Lowest level linked to increased cancer risk
20 per year	Average limit for nuclear industry workers
10	Full-body CT scan
2.4 per year	Person's typical exposure to background radiation
0.01	Dental x-ray

Source: Attributed to IAEA and World Nuclear Association. Taken from Mr Robert Parker, Vice President, Australian Nuclear Association, Inquiry into nuclear prohibition hearing, response to questions on notice received 17 July 2020, p. 1.

The Australian Nuclear Association explained that Australia's average background radiation exposure is approximately 1.5 mSv, when medical exposure is excluded.[36] This largely can be considered a low dosage of radiation and does not have any associated ill-health effects. The International Commission for Radiological Protection has established guidelines for radiation safety standards which are used by the nuclear industry to monitor radiation exposure from nuclear power plants for the general public and those employed in the industry.

The recommended limits for ionising radiation exposure above background levels are:

- 1 mSv/ year for public exposure[37]
- 20 mSv/ year, averaged over 5 years (i.e. a limit of 100 mSv in 5 years) for occupational exposure.[38]

The Minerals Council of Australia's submission discussed the findings of the 2019 Australian National Radiation Dose Register which showed that uranium workers'

36 Mr Robert Parker, *Transcript of evidence*, 25 June 2020, p. 1.

37 ICRPaedia, *Dose Limits*, June 2019, <http://icrpaedia.org/Dose_limits> accessed 24 August 2020.

38 Ibid.

radiation exposure was lower than aircraft crew (3.5 mSv) and well below the maximum dose permitted (20 mSv) with exposure being estimated at approximately 1 mSv per year.[39]

Dr Angie Bone, Deputy Chief Health Officer, Environment, Department of Health and Human Services, explained to the Committee that:

> … the risk to health [from radiation] really depends on the dose that you get and over the time period that you get it as well. So a very acute injury could be a massive dose very quickly, which could cause acute radiation sickness and death, as you would have seen in atomic bombs or at Chernobyl, for example, versus the longer term risks of small amounts of radiation exposure, which over many years perhaps can increase the risk of certain types of cancer and some, what we call, heritable mutations. But it is very dose dependent.[40]

Dr Bone further clarified that:

> Workers will be people who will be more at risk than the general population because they will be having a greater exposure, and the risk around sites is usually considered to be related to the density of the population and how close that population is living to them.[41]

In their submission, Terje Petersen also contended that the harm of radiation is entirely dependent on the amount a person is exposed to:

> If a radioactive material is ingested, then the harm will depend on how long it resides in the body. Many materials will only reside in the body for a matter of days and may not be there long enough to cause harm. The harm will also depend on the quantity consumed.
>
> …
>
> The risks from radiation should not be downplayed excessively. However nor should they be over played as some commentators seek to do. Just as we manage the risks of electricity, by isolating it with insulation and other appropriate techniques, so also can radiation risks be managed. Nuclear energy should not be held to a higher standard than other parts of the energy sector.[42]

In his submission, Mr Tristan Prasser contended that ‘exposure to radiation remains one of the principle [sic] concerns people have when discussing nuclear energy.’ He believed that this concern stemmed from a lack of knowledge within the public on the real effects of radiation exposure. Mr Passer further stated that:

> Without downplaying the seriousness of radiation exposure, it should be noted that the use of nuclear energy does not lead to significant radiation exposure for members of the

39 Minerals Council of Australia, *Submission 78*, p. 8.

40 Dr Angie Bone, Deputy Chief Health Officer, Environment, Department of Health and Human Services, public hearing, Melbourne, *Transcript of evidence*, 12 March 2020, p. 13.

41 Ibid.

42 Terje Petersen, *Submission 3*, p. 3.

> public. In the cases of Three Mile Island and Fukushima no radiation deaths have been attributed to these accidents. It should also be noted that radiation plays a significant role in saving lives and curing disease through nuclear medicine, in which Australia is a world leader.[43]

In contrast, anti-nuclear stakeholders largely believed that any exposure to radiation has associated ill-health effects. With some stakeholders touching on the concept of the 'linear no-threshold' which contends that there is no limit below where there are no risks from radiation. Dr Ruff, MAPW (Australia) explained to the Committee the concept of the 'linear no-threshold' in relation to the health effects of radiation exposure:

> The studies of medical radiation exposure have really transformed our understanding of radiation and confirmed that at any dose there are health impacts. Obviously the more you get, the worse it is, but there is no level below which there are no impacts. That is absolutely clear now and that has been the logical, prudent basis for regulatory standards in just about every country, including Australia, that so-called linear no-threshold – that there is no threshold below which there is no risk and the risk is proportional to the dose. So the more you get, the worse it is, and the younger you are when you get it, the worse it is.[44]

He further explained an acute dose of radiation does not require a significant amount of energy:

> To give you some sense of the particular ability of ionising radiation to cause harm, an example is that the amount of energy in what would be a lethal dose of acute radiation for you or I—that would kill us reliably within a couple of weeks—can be no more than the amount of heat in 3 millilitres of water at 80 degrees. So a sip of coffee, in the heat that it contains, is the amount of energy that is in a lethal dose of radiation. So it is not that it is an extraordinary amount of energy; it is particularly biologically damaging.[45]

In its submission, the MAPW (Australia) listed the what it believed were the various radiation-related health risks linked to the civilian nuclear industry, these included:

- increased cancer risks for children
- higher risk of childhood leukaemia in areas closer to nuclear power plants
- thyroid abnormalities
- cardiovascular and respiratory disease.[46]

---

43 Tristan Prasser, *Submission 80*, p. 5.

44 Dr Tilman Ruff AO, *Transcript of evidence*, p. 25.

45 Ibid, p. 20.

46 Medical Association for Prevention of War (Australia), *Submission 34*.

The Association argued that the understanding of radiation and health is still evolving, but consistent trends over time indicate that 'the more we know about radiation effects, the greater those effects appear to be.'[47] The submission also described the various health effects of the 1986 Chernobyl accident and the 2011 Fukushima Daiichi accident, the Committee has summarised this discussion in Table 7.1 below.

Table 7.1 Health effects from Chernobyl (1986) and Fukushima (2011) according to the Medical Association for Prevention of War (Australia)

Chernobyl (1986)	• 40,000 excess fatal cancers by 2065 • 6,000 additional thyroid cancer cases have occurred • Increasing rates of leukaemia • Increases in nervous-system birth defects • Increasing rates of breast cancer • Psychological effects of dislocation for citizens forced to evacuate due to radioactive contamination
Fukushima (2011)	• Lack of comprehensive health screening or follow ups • Evidence of an epidemic of thyroid cancer (based on periodic screening of thyroid glands in children less than 18 years that lived in the Fukushima prefecture at time of the accident)

Source: Medical Association for Prevention of War (Australia), *Submission 34*, pp. 12–13.

7

In his submission, Mr Philip White discussed the issue of public health by using the Fukushima Daiichi accident as an example of the various public health impacts of a nuclear accident:

> It is first necessary to distinguish between the health effects of acute radiation exposure and exposure to lower levels of radiation. In the case of acute radiation exposure, for example the workers who died as a result of the JCO accident, it is clear that death or injury was caused by radiation. However, for the lowers levels of exposure experienced as a result of the Fukushima nuclear accident, it becomes a matter of probability – so-called 'stochastic effects'. Cancers and some other health problems may arise many years later. No one person's disease can be directly attributed to radiation, but, based on epidemiological studies, people exposed to more radiation are expected to have a higher chance of contracting certain conditions, especially cancer.[48]

Of particular interest to the Committee and the Inquiry's stakeholders was the issue of workplace health and safety for people employed in a civilian nuclear power industry. This was a significant point of contention across the evidence received by the Committee, with pro-nuclear advocates contending to there is nil to minimal health risks for workers in the industry because of its strong safety culture and regulations. However, this was largely refuted by anti-nuclear stakeholders who suggested there were significant industry-specific occupational risks for workers in the industry.

---

47 Ibid, p. 11.

48 Philip White, *Submission 17*, pp. 6–7.

In its submission, ANSTO stated that civilian nuclear activities garner 'significant public interest' in particular:

> … there is significant concern about the risks of nuclear fuel cycle activities (and their consequences) stemming from human exposure to ionising radiation – including the pathways and controls that are established to ensure the safety of radiation workers and members of the public.[49]

Mr Geoff Dyke from the Construction, Forestry, Maritime, Mining and Energy Union, argued that there are numerous health risks across all industries, using coal mining and stonemasonry as examples. Mr Dyke stated:

> Look, there are a number of health risks in all industries. Black lung is a problem that has been in underground coal mining and it is preventable with proper safety standards and processes. We have seen the same with the stonemasons and the kitchen benchtops – a lot of deaths in there with serious lung failure, and all of that is preventable.[50]

Dr Jo Lackenby Women in Nuclear (WiN) Australia contended that the health and safety risks for nuclear were the same ones posed by other industries because the industry is tightly regulated to protect workers and the public from major radiation risks:

> It is extremely safe; I mean, the workers get exposed to such low levels of radiation. The major hazards are not from radiation. I feel sorry for the electrical workers. In every job that they do, if something goes wrong, there is a risk of electrocution. So most of the hazards and risks at nuclear plants are more likely to be – what do you call it? Conventional work health and safety hazards pose a bigger risk – slips, trips and falls, which every other industry has to deal with.[51]

Mr Parker (Australian Nuclear Association) stated that there are strong safety procedures in place within the industry to protect workers from unsafe radiation exposure:

> Within a nuclear power plant the workers are continually monitored; they wear monitors which are checked at monthly, weekly, intervals. There is a significant database on the actual radiation that workers in nuclear power plants receive. It happens that workers in nuclear power plants are probably exposed to less radiation inside the power plants than people outside. They are incredibly well shielded, and it is an incredibly tightly regulated industry.[52]

Furthermore, Mr Parker explained to the Committee that he believed that:

> … there is no evidence that one can see of any long-term health exposure due to working in the nuclear industry. There are very well-regulated levels of radioactive absorption that those workers cannot exceed, and should someone reach a higher level, they would depart the industry and would be looked after. But that does not occur, and

---

49 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 53.

50 Mr Geoff Dyke, Secretary, Victorian District Branch, Construction, Forestry, Maritime, Mining and Energy Union *Transcript of evidence*, public hearing, Melbourne, 25 June 2020, p. 9.

51 Dr Jo Lackenby, WiN Australia, public hearing, Melbourne, *Transcript of evidence*, 25 June 2020, p. 13.

52 Ibid.

> I have looked at the industry, particularly France, where I looked at the regimes there. There is no long-term health impact for workers in the nuclear power industry. It may be different, of course, in defence industries and other things, but they are not aligned to the civil nuclear power industry.[53]

In contrast, Mr Trevor Gauld, National Policy Officer, Electrical Trades Union (Victorian branch) expressed concern about the potential long-term health impacts of a nuclear industry which was based on his experiences of the Ranger uranium mine (Northern Territory):

> Absolutely it might deliver a sugar rush of construction jobs and a small number of operation jobs, but what are the long-term effects? We have seen long-term health effects from other industries—you know, all those Telstra workers now who are all retired who are contracting mesothelioma from asbestos exposure. The difficulty here is that often the exposures in this industry are not felt until long after the worker has left the industry, and so the capacity of the employer to deny that there is a workforce causation to it is entirely problematic. Certainly, I had personal experience of representing workers up at the Ranger uranium mine more than a decade ago, and the safety standards on that site were atrocious. Guys were wearing lapel monitors to monitor their exposure to uranium; they had a number of issues where there were spikes. So the company stopped providing them their daily doses and moved to a monthly averaging exercise. So there are issues about how transparent the industry is about this, but there is also overwhelming evidence that there are long-term health effects from this industry. I guess it comes back to the point that there are long-term health effects in other industries. The point is: we do not need nuclear. Like I said, there is no intractable policy problem that nuclear is the only answer to. So we have got an industry without long-term health effects or a proposed industry with long-term health effects. Why choose that one when you have already got one that does not?[54]

In his submission, Mr Frank Simpson argued that there are occupational risks throughout the nuclear fuel cycle, particularly risks associated with ionising radiation:

> We acknowledge that nuclear power reactors operate within a nuclear fuel chain that commences with mining of uranium and ends with decommissioning of nuclear reactors, with occupational risks at every step. The long association with uranium mining and lung cancer is unequivocal, due to radon gas exposure. Recent evidence points to radon gas being twice as hazardous as first thought. There is also increasing evidence of an increased rate of solid cancers in nuclear industry workers throughout the nuclear fuel chain proportional to their radiation dose.[55]

In the Committee's view, the safety of workers and the general public should be paramount in any consideration of introducing a nuclear industry or expanding activities in Victoria. It acknowledges that a relatively unique risk of the nuclear industry is harmful exposure to radiation and that the ill-health effects of exposure are wide

53 Mr Robert Parker, *Transcript of evidence*, p. 22.

54 Mr Trevor Gauld, National Policy Officer, Electrical Trades Union (Victorian branch), public hearing, Melbourne, *Transcript of evidence*, 26 June 2020, p. 6.

55 Frank Simpson, *Submission 24*, p. 5.

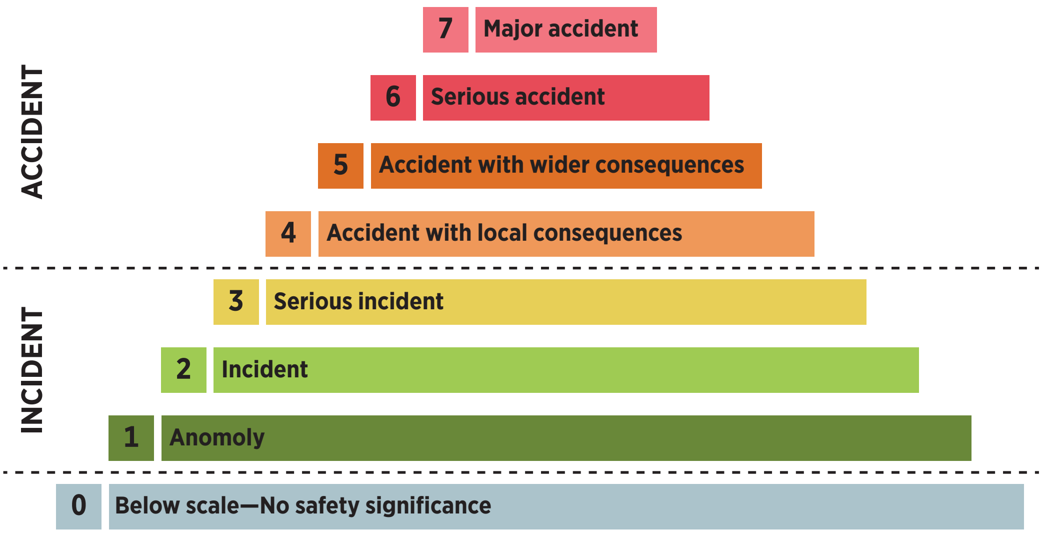
ranging and dose specific. Harmful effects from radiation can include skin burns to acute radiation sickness causing death.

The Committee notes that stakeholders throughout the Inquiry provided differing accounts of the effectiveness of the safety culture and practices of the international nuclear industry. Therefore, it believes that more consideration of this issue would need to occur as part of any feasibility or business case study, for any proposed activities across the whole nuclear fuel cycle, including an examination of the existing best practice regulations and standards across the entire energy industry. There should also be consideration of the industry-specific risks linked to nuclear power generation and whether risks can be minimised to such an extent that nuclear activities could be reasonably considered in a business case.

7.3.2 Nuclear plant safety and accidents

The IAEA defines a nuclear or radiation accident as 'an event that has led to significant consequences to people, the environment or the facility'.[56] Examples of events which constitute a nuclear accident include lethal effects to the public, large radiation release to the environment or reactor core melt.[57] The IAEA has established the International Nuclear and Radiological Event Scale (INES) to rate nuclear events, the term 'accident' is used to describe events at level 4 or above. Figure 7.3 is a pyramid chart of the INES.

Figure 7.3 The International Nuclear and Radiological Event Scale (INES)



Source: Adapted from IAEA, *The International Nuclear and Radiological Event Scale: User's Manual 2008 Edition*, online, 2008, p. i.

Since 1952, there have been over 100 nuclear accidents around the world and many more events which did not reach the level of 'accident' according to the INES. This

56 International Atomic Energy Agency, *INES: The International Nuclear and Radiological Event Scale User's Manual: 2008 Edition*, Vienna, March 2013, p. 183.

57 Ibid.

subsection addresses the three major global nuclear accidents that occurred: Three Mile Island (1979), Chernobyl (1986) and the Fukushima Daiichi (2011). All three of these accidents involved large-scale nuclear meltdowns at civilian nuclear power plants where there was significant damage to the core and radiation was leaked into the environment. However, there have been other serious incidents where there have been core meltdowns, for example at the Saint-Laurent Nuclear Power Plant in France (1980).[58]

At a public hearing, Mr Ian Hore-Lacy, Senior Adviser, World Nuclear Association categorised the takeaways of the three major nuclear accidents, in particular Fukushima Daiichi:

> There have been three significant accidents with nuclear reactors in 60 years of experience. Three Mile Island—destroyed the reactor, nobody got a significant dose of radiation from it, and a lot was learned from that. A great deal was learned from that accident in 1979. Chernobyl, nothing much was learned from it, except that that was a reactor that should never have been operating in any country and could have only been licensed in the Soviet Union. The remaining reactors of that kind have been very heavily modified, frankly, to the extent that I would be happy to live next to one. That was 1986.
>
> And then you have got the Fukushima accident. You got a tsunami which killed upwards of 15 000 to 19 000 people, and nobody was hurt from radiation from a very, very major accident, which was caused by the fact that the backup power was not available because they had reserve generators in the basement instead of up the hill.[59]

Throughout the evidence received by the Committee, there was considerable debate amongst stakeholders on the likelihood of future accidents on the same scale as those discussed below and what the health and safety consequences of nuclear accidents are. The Proforma A submission stated that it is impossible for nuclear power plants to be completely accident-proof:

> All human made systems fail. When nuclear power fails it does so on a massive scale. The human, environmental and economic costs of nuclear accident like Chernobyl and Fukushima have been massive and continue.[60]

In its submission, the MAPW (Australia) refuted that there was only a small probability of nuclear accidents occurring and that the risk has 'increased significantly' as more reactors are built and operated:

> Given that, in the history of nuclear energy, hundreds of reactors have operated for a total of 14,400 years (counting each year of operation by one reactor as a reactor-year), a core-damage accident has happened once every 1,309 years of operation with a total of 12 core melts. With approximately 400 reactors operating worldwide, the rate would

---

58 PowerTechnology, 'The world's worst nuclear power disasters', *PowerTechnology*, <https://www.power-technology.com/features/feature-world-worst-nuclear-power-disasters-chernobyl> accessed 26 February 2020.

59 Mr Ian Hore-Lacy, *Transcript of evidence*, 14 August 2020, p. 53.

60 *Submission Proforma A*, p. 2.

> yield a core melt an average of once every three calendar years, and an even more disastrous accident with release of radioactivity once every 9 years.[61]

In contrast, pro-nuclear stakeholders believed that the risk of serious nuclear accidents, such as those that occurred at Chernobyl and Fukushima Daiichi, has significantly decreased due to improved safety culture, standards and technology across the industry. Dr Jo Lackenby (WiN Australia) argued that:

> nuclear is one of the most heavily regulated industries worldwide, probably right up there with the airline industry. It is really important to get safety right, because one accident in one country affects the whole nuclear regime in another country.[62]

These views are discussed in more detail below for each specific case study.

Three Mile Island (1979)

The Three Mile Island nuclear accident in 1979 is the United States' most significant accident involving a commercial nuclear power plant. The accident resulted in a partial core meltdown in Three Mile Island's reactor 2 and subsequent radiation leaks to surrounding populations.

In the aftermath of the accident, several agencies, including the US Nuclear Regulatory Commission (NRC), US Environment Protection Agency, US Department of Health and the Commonwealth of Pennsylvania, conducted studies into the health impacts of radiation exposure from Three Mile Island. According to the NRC, possible adverse effects on people, animals and ecosystems surrounding the plant could not be directly correlated to the accident. Rather, only very low levels of radiation were attributed to the accident.[63] The NRC estimated that people nearby only received approximately 1 millirem above the average background dose, it argued that the dose had 'negligible' impacts on public health.[64]

---

61 Medical Association for Prevention of War (Australia), *Submission 34*, p. 15.

62 Dr Jo Lackenby, *Transcript of evidence*, p. 13.

63 United States Nuclear Regulatory Commission, *Backgrounder on the Three Mile Island Accident*, June 2018, <https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html#impact> accessed 02 September 2020.

64 Ibid.

BOX 7.1: Three Mile Island (Pennsylvania, United States)

On 28 March 1979, a cooling malfunction at the Three Mile Island nuclear power plant caused part of the core to melt in reactor 2 (TMI-2). As a result, TMI-2 was destroyed. In the days following the accident some radioactive gas was released into the atmosphere and across surrounding areas. However, according to the World Nuclear Association the amount of radiation released was not enough to cause dosage levels above normal background levels. There are no reported injuries or health issues linked to the Three Mile Island accident.[a]

At 4am on 28 March, the plant experienced a failure in the secondary, non-nuclear section of the plant which prevented the main feedwater pumps from sending water to the steam generators that remove heat from the reactor core. This resulted in the shutdown of the turbine generator and the TMI-2 reactor increasing pressure in the primary system. To alleviate the pressure build up the pilot-operated valve was opened and became stuck. Plant operators were unaware that steam was pouring out of the valve and that the plant was experiencing a loss of coolant. The stuck valve combined with staff uncovering the reactor core led to coolant pumps being turned off, this caused the reactor core to overheat. Ultimately, resulting in radiation being released into the atmosphere.[b]

Both the World Nuclear Association and the US NRC argued the cause of the accident was a combination of:

- personnel error—including inadequate emergency response training
- design deficiencies—including deficient control room instrumentation
- component failures.[c]

The clean-up process for TMI-2 took approximately 12 years and cost approximately US$973 million. The clean-up was challenging both technically and radiologically, because:

- Plant surfaces required decontamination.
- Water used and stored had to be processed.
- Approximately 100 tonnes of damaged uranium fuel had to be removed from the reactor vessel without causing risks to workers or the public.[d]
- The TMI-2 reactor has remained out of operation since the accident. The TMI-1 reactor re-opened in 1985, following an unrelated decommission.

(continued)

7

BOX 7.1: *(continued)*

In response to the accident, the industry conducted an initial inquiry which introduced a number of reforms to prevent future accidents occurring especially around personnel training.[e] Training became centred around maintaining and protecting a nuclear plant's cooling capacity. Furthermore, safety guides and procedures became 'symptom-based' involving a set of yes and no questions to allow staff to quickly identify and respond to plant malfunctions. The accident at Three Mile Island also led to the establishment of the Institute of Nuclear Power Operations and its National Academy for Nuclear Training.[f]

a. World Nuclear Association, *Three Mile Island Accident*, January 2012, <https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/three-mile-island-accident.aspx> accessed 24 February 2020.

b. Nuclear Regulatory Commission, *Backgrounder on the Three Mile Island Accident*, June 2018, <https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html> accessed 24 February 2020.

c. World Nuclear Association, *Three Mile Island Accident*.; Nuclear Regulatory Commission, *Backgrounder on the Three Mile Island Accident*.

d. World Nuclear Association, *Three Mile Island Accident*.

e. Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, p. 43.

f. World Nuclear Association, *Three Mile Island Accident*.

In its submission, ANSTO explained that Three Mile Island was the first major incident at a civilian nuclear power plant and that several studies of the incident have showed that the radiation leak was 'effectively contained'. No deaths or injuries have been attributed to workers or the general public.[65]

Mr Barrie Hill's submission explained that the Three Mile Island accident is the only 'significant PWR [pressurised water reactor] incident' and that it 'caused only minor release of fission products from the core as a result of the inherent safety features of the PWR design.'[66] Mr Hill further contended that:

> After extensive expert review, no measurable impact on health was found. It demonstrated the robustness of the PWR design and the value of containment structures required in all Western power plants.[67]

In his submission, Mr Bart Wissink contended that even though a partial core meltdown occurred only a minimal amount of radiation was released into the surrounding population.[68]

65 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 49.

66 Mr Barrie Hill, *Submission 47*, p. 10.

67 Ibid, p. 27.

68 Mr Bart Wissink, *Submission 29*, p. 520.

According to Nuclear for Climate Australia's submission:

> … the collective dose equivalent resulting from the radioactivity released [from Three Mile Island] was so slow that the estimated number of excess cancer cases to be expected, if any were to occur, would be negligible and undetectable.[69]

Mr Dayne Eckermann, General Manager, Bright New World argued that the legacy of Three Mile Island is that it showed 'that when one plant has an accident, they share that experience with everyone, so everyone who has that same sort of reactor technology understands what the problem was and can do things to prevent that.'[70]

Chernobyl (1986)

The 1986 Chernobyl nuclear accident is considered the worst nuclear accident in history and the first accident which rated at a seven (maximum severity) on the INES; only two nuclear accidents have rated this high, with the other being the 2011 Fukushima Daiichi nuclear accident. Some stakeholders contended that the introduction of legislative prohibitions for nuclear fuel cycle activities were a direct response to the Chernobyl disaster as public and political opinion shifted to anxiety about the safety of the nuclear industry.[71]

In 1986, in response to Chernobyl, the New South Wales Parliament passed the *Uranium Mining and Nuclear Facilities (Prohibition) Act 1986*. During the second reading debate of the Bill, the Honourable Peter Francis Cox, former New South Wales Minister for Energy and Technology, stated that:

> What makes an accident in a nuclear power station uniquely dangerous is the potential release into the environment of highly poisonous radioactive elements which can contaminate large areas of land and make them unhabitable for thousands of years. What makes an accident seem inevitable is the human factor… While some might argue that only the most highly qualified and experienced persons would be employed in a nuclear power plant, I doubt the victims of Chernobyl, a disaster for which the full ramifications are still not known, or any of those threatened by the Three Mile Island incident, would be consoled by such claims.
>
> …
>
> …the recent disaster at Chernobyl was evidence that Murphy's law was still applicable to every aspect of human technology, including the nuclear industry.[72]

The New South Wales prohibition was followed by a federal prohibition in 1998. Please refer to Chapter 2 for discussion on the national prohibitions for nuclear fuel cycle activities.

---

69 Nuclear for Climate Australia, *Submission 44*, p. 8.

70 Mr Dayne Eckermann, General Manager, Bright New World, public hearing, Melbourne, *Transcript of evidence*, 14 August 2020, p. 25.

71 Dr John Patterson, *Submission 28*, p. 1.; Bart Wissink, *Submission 29*, p. 576.

72 New South Wales, Legislative Assembly, December 1986, *Parliamentary debates*, p. 7364.

7

BOX 7.2: Chernobyl (Pripyat, Ukraine)

On the 26 April 1986, the Chernobyl nuclear power plant experienced a large-scale nuclear accident as a result of significant damage in the reactor which occurred because of a failed safety system test.[a] The accident resulted in the immediate deaths of two plant workers, and the deaths of 28 people within a few weeks of the accident. Those who died in the aftermath of the accident passed away due to acute radiation poisoning.[b]

The Chernobyl nuclear power plant used the Soviet-designed RBMK, or light water graphite, reactor design, a water-cooled reactor with individual fuel channels that used graphite as a moderator. The use of a water-cooled reactor and graphite moderator is found in no other nuclear reactors anywhere in the world. The Chernobyl nuclear accident showed that several components of the RBMK reactor design were unsafe, such as the control rod.[c]

On 25 April, the crew responsible for Chernobyl 4 initiated safety tests on the reactor prior to a routine shutdown. The test aimed to assess how long turbines would continue supplying power following a loss of main electrical power. However, a series of operating errors during the 25 April test (including the disablement of automatic shutdown mechanisms) meant the 26 April test was conducted in very unstable conditions. As a result, a dramatic surge of power resulted in a dangerous interaction of very hot fuel with cooling water leading to fuel fragmentation, rapid steam production and an increase in temperature. This caused significant damage to three or four fuel assemblies ultimately destroying the reactor. Two explosions occurred as a consequence of the damage with two workers dying as a result.[d]

The two explosions resulted in a fire which burned for 10 days, releasing large amounts of radiation into the atmosphere. According to the Nuclear Energy Institute, of the 190 metric tons of uranium dioxide fuel and fission product contained in the Chernobyl 4 reactor approximately 13–30% of it escaped into the atmosphere.[e] In the aftermath of the accident, both Soviet and western scientists analysed the movement of the radiation estimating that approximately 60% of the contamination was received by Belarus. Large areas in the Russian Federation and northwest Ukraine were also contaminated.[f]

In response to the large amounts of radiation leaking into the atmosphere, Soviet authorities evacuated people in the areas surrounding Chernobyl within 36 hours of the explosions; approximately 220, 000 people were evacuated as a result of the accident. Resettlement is still ongoing and in 2011 Chernobyl was declared a tourist attraction.[g]

(continued)

BOX 7.2: *(continued)*

An important legacy of the Chernobyl nuclear accident is the establishment of the Convention on Nuclear Safety which came into force in 1994. The Convention enshrines fundamental principles for protecting individuals, the environment and communities from the effects of ionising radiation. The Convention has 152 member states, including Australia, which are required to establish local regulations for nuclear power safety.

a. World Nuclear Association, *Chernobyl Accident 1986*, February 2020, <https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/chernobyl-accident.aspx> accessed 24 February 2020.

b. Ibid.

c. World Nuclear Association, *RBMK Reactors - Appendix to Nuclear Power Reactors*, July 2019, <https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/appendices/rbmk-reactors.aspx> accessed 2 September 2020.

d. World Nuclear Association, *Chernobyl Accident 1986: Appendix 1: Sequence of Events*, June 2019, <https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/appendices/chernobyl-accident-appendix-1-sequence-of-events.aspx> accessed 24 February 2020.

e. Nuclear Energy Institute, *Chernobyl Accident and Its Consequences*, May 2019, <https://www.nei.org/resources/fact-sheets/chernobyl-accident-and-its-consequences> accessed 24 February 2020.

f. Ibid.

g. World Nuclear Association, *Chernobyl Accident 1986*.

In 2002, the Chernobyl Forum was established to assess the health and environmental consequences of the Chernobyl nuclear accident which involved organisations such as the IAEA, the World Health Organization and the World Bank, among others. Three population categories were exposed to radiation that leaked from Chernobyl:

- emergency and recovery workers who were at the plant site and exclusion zone (liquidators)
- citizens living in evacuated areas
- citizens from contaminated areas that were not evacuated.[73]

Table 7.2 shows the number of people from each population category and the estimated dose levels of radiation they may have been exposed to from Chernobyl.

73 Chernobyl Forum, *Chernobyl's Legacy: Health, Environmental and Socio-economic impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine*, International Atomic Energy Agency, online, 2006.

Table 7.2 Summary of average accumulated doses to affected populations from Chernobyl fallout

Population Category		Number of People	Average Dose
Liquidators (1986–1989)	Immediately after accident	1,000	2 to 20 Gy
	Total	600,000	100 mSv
Evacuees from highly contaminated areas (1986)		116,000	33 mSv
Residents of 'more contaminated' zones[a] (1986–2005)		270,000	Under 50 mSv
Residents of 'contaminated' areas[b] (1986–2005)		5,000,000	10–20 mSv

a. 'More contaminated' are areas classified by Soviet Union authorities as areas requiring strict radiation control.

b. 'Contaminated' are areas that were contaminated with radionuclides due to the Chernobyl accident, including Belarus, Russia and Ukraine.

Source: Legislative Council Environment and Planning Committee. Data extracted from Chernobyl Forum, *Chernobyl's Legacy: Health, Environmental and Socio-economic impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine*, 2nd ed, International Atomic Energy Agency, N.D., <https://www.iaea.org/sites/default/files/chernobyl.pdf> accessed 14 September 2020.

The Chernobyl Forum's 2006 revised report explained that claims of high death tolls from Chernobyl were found to be 'highly exaggerated' because 'in the years since 1986, thousands of emergency and recovery operation workers as well as people who lived in 'contaminated' territories have died of diverse natural causes that are not attributable to radiation.'[74] The report found that:

- 28 emergency workers died from acute radiation sickness in 1986
- 2 workers died from injuries unrelated to radiation
- 1 worker died from a coronary thrombosis
- between 1987 to 2004, 19 workers died of various causes, however not all of their deaths could be directly attributed to Chernobyl
- no deaths from acute radiation sickness occurred in the general population.[75]

On cancer mortality, the Chernobyl Forum believed that it is 'impossible to assess reliably, with any precision, numbers of fatal cancers caused by radiation exposure due to Chernobyl accident.' The report discussed the findings of an international expert group who produced a rough estimate of possible cancer-related deaths from Chernobyl, the report stated:

> The international expert group predicts among the 600 000 persons receiving more significant exposures (liquidators working in 1986–1987, evacuees, and residents of the most 'contaminated' areas), the possible increase in cancer mortality due to this radiation exposure might be up to a few per cent. This might eventually represent up to four thousand fatal cancers in addition to the approximately 100 000 fatal cancers to be expected due to all other causes in this population. Among the 5 million persons

---

74 Chernobyl Forum, *Chernobyl's Legacy: Health, Environmental and Socio-economic impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine*, p. 14.

75 Ibid, pp. 14–5.

> residing in other 'contaminated' areas, the doses are much lower and any projected increases are more speculative, but are expected to make a difference of less than one per cent in cancer mortality.[76]

According to ANSTO's submission:

> The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has found there are generally positive prospects for the future health of most members of the public in the affected area. However, 220,000 people were displaced from their homes and there have been undoubted long-term psychosocial effects.[77]

As part of its investigation the SANFCRC examined the causes or contributing factors leading to the Chernobyl accident. The Commission determined:

- The design of the reactor, a Russian RBMK, which was unique to the Soviet Union was prone to unstable operation under certain conditions.
- The accident was a result of reactor instability combined with significant deficiencies in safety culture, operator inexperience and management capability.
- The experimental tests conducted in Chernobyl 4 did not receive full authorisation and bypassed essential safety systems. Leading to the core becoming unstable and increased fission heat production to dangerous levels.[78]

According to the World Nuclear Association's website, several lessons have been learnt by the global nuclear industry because of Chernobyl, such as:

- development of a strong safety culture fostered by collaboration between the West and East
- the RBMK reactor design has been improved to prevent a similar accident occurring
- introduction of twinning arrangements between the Western and Eastern nuclear industries, most of which are under the World Association of Nuclear Operators
- the initiation of IAEA safety review projects aimed to safety improvement for nuclear reactors.[79]

---

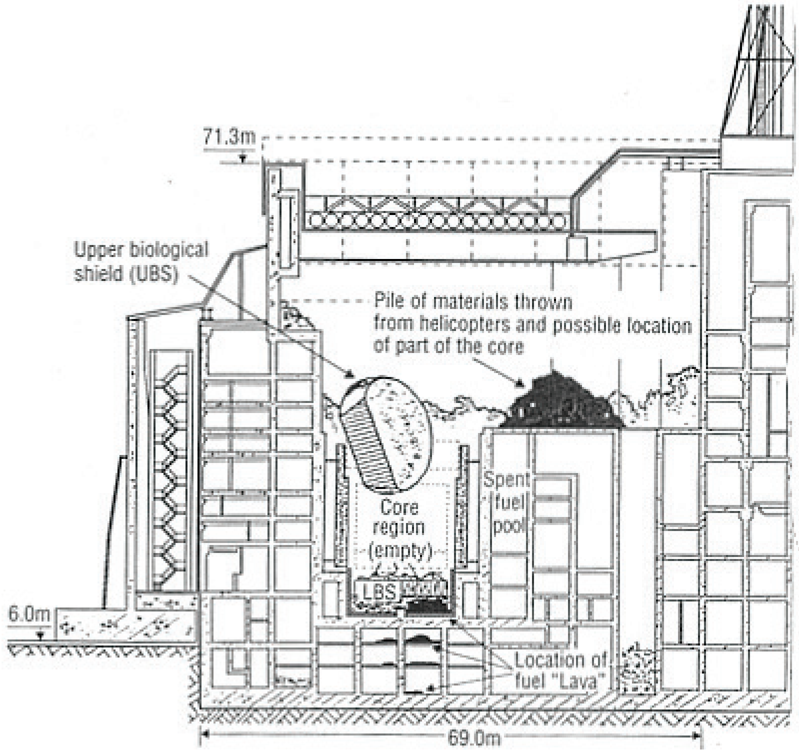
76 Ibid, pp. 15–6.

77 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 50.

78 Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, pp. 43–4.

79 World Nuclear Association, *Chernobyl Accident 1986*.

Figure 7.4 Damage in the Chernobyl 4 reactor building



Source: World Nuclear Association, *Chernobyl Accident 1986*, February 2020, <https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/chernobyl-accident.aspx> accessed 24 February 2020.

7

The assertion that the Chernobyl disaster was primarily caused by reactor design and a poor safety culture was raised by several pro-nuclear stakeholders.[80] There was a general belief that Chernobyl-like nuclear accidents are no longer possible because of widespread improvements in reactor design and safety standards. Moreover, that the reactor design used by the Chernobyl site at the time of the accident is no longer operating with the same technology. Rather, modifications have been made to improve operating safety such as:

- improvement in response efficiency of emergency systems
- prevention of emergency systems to be bypassed while the reactor is operating
- improvements in subcooling at the core inlet.[81]

Nuclear Now's submission stated that:

> The Chernobyl disaster was caused primarily by an inadequate and poor reactor design that was operated by equally inadequately trained personnel. A steam explosion and subsequent fire resulted in a substantial radiological release into the surrounding environment… About 6000 cases of thyroid cancer have been observed in the region to date in those that were around during the accident, and fifteen of these cases have

80 For example: Forestry Construction, Maritime, Mining and Energy Union, *Submission 20*.; Bart Wissink, *Submission 29*.; Hon. Peter Vickery QC, *Submission 33*.; Nuclear Now, *Submission 75*.

81 World Nuclear Association, *RBMK Reactors - Appendix to Nuclear Power Reactors*.

> proved fatal by 2005. The UNSCEAR says that apart from these increased cases of thyroid cancer "there is no evidence of a major public health impact attributable to radiation exposure 20 years after the accident".[82]

Some anti-nuclear stakeholders believed that the nuclear industry has dismissed the Chernobyl accident as a specific consequence of the Soviet's RBMK nuclear reactor.[83]

Dr Ruff, MAPW (Australia), criticised the agencies responsible for investigating the health consequences of major nuclear accidents, such as Chernobyl:

> WHO puts it name to reports led by the International Atomic Energy Agency on Chernobyl that claimed that 34 workers died of acute radiation sickness were all of the casualties from Chernobyl. IARC [International Agency for Research on Cancer] studies since, repeatedly, carefully, have estimated that, no, the best case is probably around 30 000 to 40 000 fatal cancers across Europe from Chernobyl.[84]

FOE Australia, in response to a question on notice, discussed the various death tolls which could or have been attributed to Chernobyl:

> Claims that the Chernobyl death toll was <100 have no basis in scientific evidence. United Nations in 2005/06 estimated up to 4,000 eventual cancer deaths among the higher-exposed Chernobyl populations (emergency workers from 1986–1987, evacuees and residents of the most contaminated areas) and an additional 5,000 deaths among populations exposed to lower deaths in Belarus, the Russian Federation and Ukraine.
>
> The estimated death toll rises further when populations beyond those three countries are included… That 16,000 figure is the lowest of the pan-European estimates of the Chernobyl cancer death toll.[85]

Several stakeholders discussed the economic impact of the Chernobyl nuclear accident. At a public hearing, Dr Green (FOE Australia) estimated that the costs in the wake of Chernobyl are in the 'ballpark of A$1 trillion–$1000 billion Australian dollars.'[86] It was contended by John Poppins, in his submission, that Chernobyl, and Fukushima, are 'continuing disasters' with significant risks, costs and clean-up difficulty.[87] The ongoing fallout of major nuclear accidents was also discussed in the Civil Society Statement on Domestic Nuclear Power which stated that 'When nuclear power fails it does so on a massive scale. The human environmental and economic costs of nuclear accidents like Chernobyl… have been massive and continue.'[88]

---

82 Nuclear Now, *Submission 75*, pp. 11–2.

83 For example: Philip White, *Submission 17*, p. 5.

84 Dr Tilman Ruff AO, *Transcript of evidence*, p. 4.

85 Dr Jim Green, National Nuclear, Friends of the Earth Australia, Inquiry into Nuclear Prohibition hearing, response to questions on notice received 02 July 2020, p. 1.

86 Dr Jim Green, *Transcript of evidence*, 26 June 2020, p. 15.

87 John Poppins, *Submission 51*, p. 1.

88 Joint Civil Society Statement, *Submission 55*, p. 3.

Dr Helen Caldicott argued that there was a significant public health fallout from the Chernobyl nuclear accident linked to the radiation leaks from the site to surrounding areas and countries.[89] Dr Caldicott listed various health impacts connected to Chernobyl, such as:

- abnormalities and deformities, particularly in infants
- genetic abnormalities to people and plant life
- increased rates of cancer, such as leukaemia or thyroid cancer
- radiation in food and waterways
- deficient mental development for infants in utero.[90]

In her evidence, Dr Caldicott criticised the findings of the Chernobyl Forum which she argued 'did not measure the doses' rather only estimated the level of radiation that leaked and the dosage.[91] She went onto say that the book *Chernobyl* published by the New York Academy of Sciences was a better study into the health impacts of the Chernobyl accident because it was conducted by medical professionals on the ground at exposure sites. At a public hearing, Dr Caldicott stated:

> This book, *Chernobyl*, published by the New York Academy of Sciences, is a collation of 5000 papers from Russia, Belarus and Europe. Now, it is not all statistically absolutely spot on according to the way Americans do studies, but it is a study on the ground by physicians, by doctors, by epidemiologists, of their patients. The Chernobyl Forum that you quote has never been to examine patients on the ground in Russia or Belarus or anywhere else.[92]

Pro-nuclear stakeholders maintained that it was unlikely a nuclear accident similar to Chernobyl would occur again. Stakeholders pointed to improvements in reactor design, safety and personnel training that came out of lessons learned from Chernobyl and Fukushima Daiichi as reasons why similar accidents are unlikely. Mr Tristan Prasser maintained that the significant improvements to safety in reactor design and training means that the 'possibility of a Chernobyl-style event are significantly reduced or simply physically impossible.'[93]

In his submission, Mr Barrie Hill stated that after the Chernobyl accident an international nuclear safety regime was introduced to prevent similar accidents occurring again:

> This regime is based on binding international conventions, internationally accepted safety standards, and an extensive system of peer reviews. IAEA safety standards are periodically revised and updated to reflect the state of the art for nuclear safety, and to include new areas, such as the nuclear fuel cycle; modern techniques such as human/machine interaction, and assessment of the probability of occurrence of certain

89 Dr Helen Caldicott, *Transcript of evidence,* 28 August 2020, p. 2.

90 Ibid, pp. 2–10.

91 Ibid, p. 8.

92 Ibid.

93 Tristan Prasser, *Submission 80*, p. 3.

> postulated accidents. These standards are now accepted worldwide and although not obligatory, have been adopted by several countries on a voluntary basis, and are used as the basis of national regulations in numerous other member states.[94]

Some pro-nuclear stakeholders expressed concern that recent pop-culture interest in the Chernobyl accident has reignited debate about the safety record of the nuclear industry, such as the recent Netflix television miniseries *Chernobyl*.[95] The Committee received evidence which suggested that there is still a lot of negative bias against the nuclear industry which may have been facilitated by dramatisations of nuclear accidents.[96]

In his submission, Mr Prasser contended that the popular culture references like *Chernobyl*, *The Simpsons* and *The China Syndrome* have reinforced concerns about the safety of nuclear power plants and ensured that accidents 'remain high in the public imagination'.[97]

Fukushima Daiichi (2011)

In March 2011, the Tōhoku earthquake and tsunami caused a large-scale nuclear accident at the Fukushima Daiichi nuclear power plant in Ōkuma, Fukushima prefecture. The nuclear accident registered at a 7 on the INES for only the second time in the history of nuclear power. Table 7.3 shows the event sequence of the nuclear accident at Fukushima Daiichi.

94 Barrie Hill, *Submission 47*, p. 28.

95 Marcos Fernandes, *Submission 64*, p. 9.

96 Ibid.; Terje Petersen, *Submission 3*, p. 3; Barrie Hill, *Submission 47*, p. 27.

97 Tristan Prasser, *Submission 80*, p. 3.

7

BOX 7.3: Fukushima Daiichi (Ōkuma, Japan)

On 11 March 2011 the Great East Japan earthquake caused a 15-metre tsunami which flooded the Fukushima Daiichi site, this caused power to be disabled in three reactors and reactor cores to cool. This resulted in a large-scale loss-of-coolant accident[a] where all three affected reactor cores melted within three days of the event.[b] To minimise adverse health effects from radiation to nearby citizens, Japanese authorities evacuated over 100,000 people to prevent radiation exposure.[c] Immediately following the accident there was no reported deaths or cases of radiation sickness linked to the accident. However, in 2018 the Japanese Government attributed the death of a man in his 50s, who worked at the site monitoring radiation after the accident, to radiation exposure from Fukushima Daiichi.[d]

According to the World Nuclear Association, the earthquake did not cause serious damage to the reactors, but they were automatically shut down in line with the emergency response systems at Fukushima Daiichi. However, the two tsunamis following the earthquake caused significant structural damage especially to the reactors' cooling systems. This resulted in fuel melting and fission product being released. Furthermore, the generation of hydrogen gas parallel to the loss-of-coolant accident caused chemical explosions that damaged the structure of the plant's buildings.[e]

The nuclear power plant included numerous tsunami countermeasures that were designed and sited in the 1960s. However, at least 18 years prior to the accident in 2011 new evidence emerged on the likely impact of a large earthquake and tsunami at the Daiichi site. Despite this, the plant's operator Tepco and Japan's nuclear regulatory body the Nuclear & Industrial Safety Agency elected not to implement new tsunami countermeasures that would have been in accordance with IAEA guidelines, such as moving backup generators further up the hill, sealing lower parts of the building, or having back-up for seawater pumps.[f]

In the aftermath of the accident various agencies determined there were a number of operation deficiencies which contributed to the accident, including:

- critical weaknesses in plant design and emergency preparedness—such as an insufficient high flood wall, emergency power supplies vulnerable to flooding and limited primary containment compared to modern reactors
- lack of regulatory independence and multiple decision-makers which obscured lines of responsibility
- absence of an appropriate safety culture—low preparedness by plant operators for severe accident scenarios and extreme conditions.[g]

(continued)

BOX 7.3: *(continued)*

In September 2012, the IAEA Director General initiated an inquiry into the Fukushima Daiichi accident. The inquiry released its final report, *The Fukushima-Daiichi accident: Report by the Director General*, in October 2015. The report identified five key lessons that the global nuclear industry should take away from Fukushima and previous nuclear accidents:

1. Design of power plants and their safety systems
2. Radiation containment
3. Need to properly prepare for multiple external hazards in simultaneous or sequential scenarios
4. Need to strengthen regulatory oversight and assessment of plants
5. Need to establish strong safety cultures in which industry stakeholders are able to question basic assumptions and continuously improve operational safety.[h]

a. A loss-of-coolant accident is a mode of failure for a nuclear reactor; if not managed effectively, the results of a loss-of-coolant accident could result in reactor core damage. Each nuclear plant's emergency core cooling system exists specifically to deal with a loss-of-coolant accident.

b. World Nuclear Association, *Fukushima Daiichi Accident*, February 2020, <https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-daiichi-accident.aspx> accessed 25 February 2020.; Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, p. 44.

c. World Nuclear Association, *Fukushima Daiichi Accident*.

d. Motoko Rich, 'In a first, Japan says Fukushima Radiation Caused Worker's Cancer Death', *The New York Times*, 05 September 2018, <https://www.nytimes.com/2018/09/05/world/asia/japan-fukushima-radiation-cancer-death.html> accessed 18 September 2020.

e. Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, p. 44.

f. World Nuclear Association, *Fukushima Daiichi Accident*.

g. Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, p. 44.

h. International Atomic Energy Agency, *The Fukushima Daiichi Accident*, report prepared by the Director General, 2015.; Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, p. 45.

Similar to Chernobyl, many stakeholders pointed to flaws in the reactor design as a significant factor which led to the accident at Fukushima Daiichi. In particular, there were concerns about the location of the reactor site with some stakeholders suggesting that if it was located further up the hill the reactors might not have been impacted by the earthquake or tsunami in such a catastrophic way.

At a public hearing, Mr Ian Hore-Lacy, Senior Advisor, World Nuclear Association stated that:

> If the Fukushima power plant had been built 5 metres further up the hill, probably no-one here would have heard of it. So there was nothing much wrong with the reactor intrinsically, it is just that the backup power was removed by the tsunami.[98]

Professor Stephen Wilson, Energy Economist, believed that the Fukushima Daiichi accident demonstrated the strong safety of nuclear energy and that the accident was attributable to poor site planning:

> I am fairly confident I understand what happened at Fukushima, and I have come to the view that it is actually a stunning demonstration of the safety of nuclear energy. The magnitude of the earthquake was much larger than the engineers designed for, for example, and it withstood that very well. They put the backup generators in the wrong place. The story I heard is that the Americans put them in the basement because they were building reactors in Tornado Alley in the US and they did not really want to change the blueprints. The Japanese engineers knew they should have been up on the hill but did not have in the 1960s and early 70s the courage to tell the Americans what to do. And of course the consequences of Fukushima from a nuclear accident point of view are tiny, negligible—almost nothing—compared with the actual tsunami disaster itself.[99]

7

Other stakeholders believed that the seawall at the Fukushima site was not high enough to properly protect the plant from the impacts of a tsunami. In its submission, Bright New World compared the seawall levels at Fukushima Daiichi and Onagawa nuclear power plants which were both impacted by the Tōhoku earthquake and tsunami. Bright New World stated that:

> Onagawa was located closer to the epicentre of the Tōhoku earthquake and received beyond design basis ground acceleration twice than that experienced at Fukushima-Daiichi. Both plants were assessed after prior earthquakes and found to have no damage.
>
> …
>
> The difference between the two plants was the design of the sea wall to prevent water intrusion. At Onagawa the designers pushed for a 14.8m seawall as opposed to the drafted 12m seawall. Fukushima-Daiichi's was designed to 5.7m and the tsunami that inundated the plant was estimated to be 14m.[100]

98 Mr Ian Hore-Lacy, *Transcript of evidence*, p. 53.

99 Professor Stephen Wilson, *Transcript of evidence*, 11 September 2020, pp. 7–8.

100 Bright New World, *Submission 74*, p. 18.

Table 7.3 Event sequence following earthquake (Fukushima Daiichi, 11 March 2011)

	Unit 1	Unit 2	Unit 3
Loss of AC power	+51 min	+54 min	+52 min
Loss of cooling	+1 hour	+70 hours	+36 hours
Water level down to top of fuel[a]	+3 hours	+74 hours	+42 hours
Core damage starts[a]	+4 hours	+77 hours	+44 hours
Reactor pressure vessel damage[a]	+11 hours	Unknown	Unknown
Fire pumps with fresh water	+15 hours	—	+43 hours
Hydrogen explosion	+25 hours (service floor)	+87 hours[b] (suppression chamber)	+68 hours (service floor)
Fire pumps with seawater	+28 hours	+77 hours	+46 hours
Off-site electrical supply	+11–15 days	+11–15 days	+11–15 days
Fresh water cooling	+14–15 days	+14–15 days	+14–15 days

a. According to 2012 MAAP analysis.

b. Not confirmed.

Source: World Nuclear Association, Fukushima Daiichi Accident, February 2020, <https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-daiichi-accident.aspx> accessed 25 February 2020

7

Dr Margaret Beavis, MAPW (Australia) at a public hearing argued that accidents, like Fukushima Daiichi, are an inevitability for the nuclear industry because the 'technology will inevitably fail at some point'. Dr Beavis described the events of Fukushima Daiichi and what factors she believed contributed to it:

> Fukushima happened after a major earthquake and nine years later it is still leaking radiation. The former Prime Minister, Naoto Kan, said that there was a real possibility of requiring the evacuation of Tokyo because the 35 million residents there were subject to fallout if the wind had been in the wrong direction. As dumb luck had it, the wind was actually offshore after the Fukushima accident, but otherwise the evacuation of Tokyo had been a real possibility.
>
> Both these reactor meltdowns happened because of cost cutting and poor regulation. Prior to the accident there were two separate models saying that higher seawalls and better protections were needed for tsunamis, and these were not undertaken for cost reasons. In fact the formal investigation by the Japanese diet found that there was a combination of inadequate safety culture, mismanagement and deception on the part of both regulators and operators that caused that event.[101]

Japan has experienced some difficulty in clearly tracking and assessing the level of radiation released into the atmosphere as a result of the accident. The World Nuclear Association explained:

> A significant problem in tracking radioactive release [at Fukushima Daiichi] was that 23 out of the 24 radiation monitoring stations on the plant site were disabled by the

101 Dr Margaret Beavis, *Transcript of evidence*, 26 June 2020, p. 23.

> tsunami. There is some uncertainty about the amount and exact sources of radioactive releases to air.
>
> Japan's regulator, the Nuclear & Industrial Safety Agency (NISA), estimated in June 2011 that 770 PBq (iodine-131 equivalent) of radioactivity had been released, but the Nuclear Safety Commission (NSC, a policy body) in August lowered this estimate to 570 PBq. The 770 PBq figure is about 15% of the Chernobyl release of 5200 PBq iodine-131 equivalent. Most of the release was by the end of March 2011.[102]

Mr Steven McIntosh, Senior Manager, Government and International Affairs, ANSTO told the Committee that radioactive substances decay over time and that the radioactivity from the iodine isotopes emitted from Fukushima Daiichi have likely disappeared. Furthermore, Mr McIntosh went on to explain that the 'isotopes of current most concern have half-lives of around 30 years, which means that 30 years after the accident, even if no clean-up was done, it is only half as radioactive as it was before.'[103]

Several pro-nuclear stakeholders contended that despite harmful radiation leaking from the accident into the atmosphere there has been minimal harmful physical effects amongst workers or citizens exposed to radiation at the time.[104]

The following excerpts are taken from several submissions:

- 'The Fukushima nuclear accident caused great economic loss and evacuation of large numbers of people. Nevertheless, there is no clear evidence of any deaths attributable to the emission of radiation from the accident that occurred at Fukushima. Radiation doses to the public were ten times lower than the dose at which any direct health impacts become evident.'[105]
- 'The Fukushima incident was instigated by a natural disaster-in this case an earthquake and tsunami that tragically killed almost 1600 people. Of those lives lost, zero deaths were attributed to the resulting nuclear accident.'[106]
- 'There was an observed significant radiological release into the environment. Despite this, there were no deaths or serious injuries due to radioactivity, though 19,000 were killed by the tsunami and fatalities were recorded due to evacuation of the area.'[107]
- 'Although tragically 16,000 deaths were attributed to these natural disasters, there we no deaths from radiation exposure in the immediate aftermath.'[108]

This was contested by some anti-nuclear stakeholders who believed that a lack of comprehensive health studies in the immediate aftermath or in the years following the accident meant that there was inadequate data to make this claim. Furthermore, a few

---

102 World Nuclear Association, *Fukushima Daiichi Accident*.

103 Mr Steven McIntosh, *Transcript of evidence*, 28 August 2020, p. 41.

104 For example see: Bart Wissink, *Submission 29*.

105 Australian Nuclear Association, *Submission 50*, p. 5.

106 Australian Workers' Union, *Submission 71*, p. 33.

107 Nuclear Now, *Submission 75*, p. 12.

108 Minerals Council of Australia, *Submission 78*, p. 8.

of these stakeholders suggested that the periodic studies which are taking place in the Fukushima prefecture into rates of thyroid cancer are finding early indications of increased thyroid cancer in the region.[109]

The MAPW (Australia), in its submission, found in relation to child thyroid cancer in Fukushima prefecture that:

- To September 2016, the number of reported cases was 145
- The rates of thyroid cancer detected initially in Fukushima were between 20 and 50 times higher than the Japanese national average
- Among the cancers diagnosed on a second ultrasound screening, two years after the first, the rate is still 20 to 38 times the national average, likely too great a difference to be explained by active screening alone.[110]

Dr Helen Caldicott expressed concern that current studies into Fukushima are only focusing on thyroid cancer even though 'all cancers can be caused by radiation.'[111]

The joint submission from FOE Australia, Australian Conservation Foundation and Environment Victoria critiqued assertions that there will be no cancer related deaths from the Fukushima accident. It pointed to figures from the World Health Organization which suggested there could be increased risks of some cancers for people in the most contaminated areas in the Fukushima prefecture.[112]

Dr Jim Green, National Nuclear, FOE Australia explained to the Committee that the:

> … World Health Organization has estimated increases in a range of different cancers arising from radiation exposure from Fukushima fallout, but the World Health Organization does not give an estimated death toll. But others have. For example, British radiation biologist Dr Ian Fairlie gives an estimate of 5000 cancer deaths from Fukushima fallout.[113]

In response to a question taken on notice, FOE Australia provided the Committee estimated risks for all solid cancers for citizens in contaminated areas of the Fukushima prefecture at the time of the nuclear accident. The response stated:

> [From Fukushima] the estimated increased risk of all solid cancers will be around 4% in females exposed as infants; a 6% increased risk of breast cancer for females exposed as infants; a 7% increased risk of leukaemia for males exposed as infants; and for thyroid cancer among females exposed as infants, an increased risk of up to 70% (from a 0.75% lifetime risk up to 1.25%).[114]

---

109 Medical Association for Prevention of War (Australia), *Submission 34*, p. 13.

110 Ibid.

111 Dr Helen Caldicott, *Transcript of evidence*, p. 8.

112 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, p. 61.

113 Dr Jim Green, *Transcript of evidence*, p. 15.

114 Dr Jim Green, response to questions on notice, p. 2.

The Committee notes that in 2018 the Japanese Government attributed the death of nuclear power plant worker to radiation exposure linked to Fukushima Daiichi.[115] According to media reports, the man, who died of lung cancer as a result of radiation exposure, measured radiation levels in the immediate aftermath of the accident. The Japanese Government has also acknowledged that radiation exposure has caused illness in four workers from the plant.[116] An online article from the *New York Times* discussed the radiation dose the man was exposed to over his career in the nuclear industry and how much of that likely came from the Fukushima Daiichi site after the accident:

> According to the government, the man was responsible for measuring radiation at Fukushima Daiichi and wore a protective jumpsuit and a full face mask while working. The ministry said he had been exposed to a lifetime dose of 195 millisieverts of radiation after working at Fukushima and other plants.
>
> Safety regulators say workers can be safely exposed to up to 50 millisieverts a year, but if a worker with an accumulated 100 millisieverts develops an illness after five years of exposure, that can be ruled an occupational injury. According to an expert cited by the Mainichi Shimbun, a daily newspaper, the man had been exposed to 74 millisieverts at the Fukushima plant since the accident.[117]

In 2015, a clean-up crew worker at Fukushima Daiichi was awarded compensation by the Japanese Government to cover medical treatment for cancer very likely contracted because of radiation exposure at the site. The successful compensation claim was the first time Japanese authorities attributed the nuclear accident to a case of cancer. According to media reports, the worker was exposed to approximately 15.7 mSv of radiation over 14 months at the site.[118]

Stakeholders from both sides of the nuclear debate acknowledged the psychosocial impacts of displacement that occurred for many residents living near the site at the time of the nuclear accident. In its submission, ANSTO suggested that the 'displacement of households and fears about the effects of radiation have resulted in significant social and mental health impacts'.[119] The effect of social dislocation was also brought up by the Australian Institute of Physics (Victorian branch) who believed it was an 'overwhelming source of detriment'.[120]

Many anti-nuclear stakeholders expressed concern about the environmental impacts of the Fukushima Daiichi nuclear accident contending that considerable damage was

---

115 Eli Meixler, 'Japan Acknowledges the First Radiation-Linked Death From the Fukushima Nuclear Disaster', *Time*, 5 September 2018, <https://time.com/5388178/japan-first-fukushima-radiation-death> accessed 17 September 2020; BBC, 'Japan confirms first Fukushima worker death from radiation', *BBC News*, <https://www.bbc.com/news/world-asia-45423575> accessed 17 September 2020.

116 BBC, 'Japan confirms first Fukushima worker death from radiation'.

117 Motoko Rich, 'In a first, Japan says Fukushima Radiation Caused Worker's Cancer Death'.

118 Jonathan Soble, 'Japan to Pay Cancer Bills for Fukushima Worker,' *The New York Times*, 20 October 2015, <https://www.nytimes.com/2015/10/21/world/asia/japan-cancer-fukushima-nuclear-plant-compensation.html> accessed 18 September 2020.

119 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 40.

120 Australian Institute of Physics (Vic Branch), *Submission 67*, p. 4.

caused to surrounding eco-systems, food sources and waterways along with the release of large amounts of radiation into the atmosphere.

Dr Caldicott told the Committee that:

> … at Fukushima 400 tonnes of highly radioactive water is emitted into the Pacific every day since the accident, and those elements – caesium, strontium, iodine; you name it – concentrate hundreds of times in the algae, hundreds or thousands more times in the crustaceans, then in the little fish, then the big fish…[121]

The MAPW (Australia) also discussed the damage to waterways from the damaged power plant and spent fuel ponds which are still 'leaking and dangerous'. Meaning that the amount of contaminated water is still increasing, requiring ongoing clean-up work and exposure to radioactive materials for clean-up workers.[122]

In the wake of the Fukushima Daiichi, Australian uranium, which was being used in the reactors at the time, experienced 'soften[ed]' commodity prices because of the accident.[123] Table 7.4 provides an overview of Australian uranium between 2010–11 to 2019–June 2020 and Table 7.5 is a closer snapshot of the Australian uranium market in the year of the Fukushima Daiichi nuclear accident.

7

Table 7.4 Overview of Australian Uranium industry (export volume and price) from 2010–11 to 2019–June 2020

			Export volume			
	Production (tonnes)	Export volume (tonnes)	Nominal value (AUD$ million)	Real value (AUD$ million)	Average price (AUD$ million)	Real price (AUD$ million)
2010-11	7,069	6,950	610	630	87.7	90.6
2011-12	7,645	6,917	607	654	87.8	94.6
2012-13	8,918	8,391	823	885	98.1	105.5
2013-14	5,548	6,701	622	652	92.8	97.4
2014-15	6,496	5,515	532	548	96.4	99.4
2015-16	7,623	8,417	940	976	111.7	115.9
2016-17	7,295	7,081	596	621	84.2	87.8
2017-18	7,521	7,343	575	672	80.0	82.8
2018-19	7,618	7,571	734	748	96.9	98.8
2019-20[a]	7,329	7,270	650	650	89.4	89.4

a. Estimate.

Source: Legislative Council Environment and Planning Committee. Data taken from the Department of Industry, Science, Energy and Resources' *Resources and Energy Quarterly* publications from 2010 to June 2020.

121 Dr Helen Caldicott, *Transcript of evidence*, 28 August 2020, p. 3.

122 Medical Association for Prevention of War (Australia), *Submission 34*, p. 13.

123 World Nuclear Association, 'Australia's Uranium,' January 2020, https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/australia.aspx, last accessed 16 September 2020.

In 2019, Small Caps, an online news source on ASX-listed small cap and micro cap companies, published an article on 'Uranium stocks on the ASX: The Ultimate Guide' which looked at the impact of Fukushima on Australian uranium prices. The article stated that:

> After Fukushima, uranium prices entered a period of steady decline until the price fell below US$18/lb in late 2016.
>
> The price then hovered between US$20/lb and US$25/lb for about 18 months, before rising steadily in the last six months of 2018 to end the year at US$28.50/lb.[124]

Mr Dave Sweeney, Nuclear Free Campaigner, Australian Conservation Foundation, explained to the Committee that the Australian uranium industry was affected in the fallout of Fukushima Daiichi:

> This uranium sector has been hard hit by the Australian uranium fuel Fukushima accident, and the market fallout from that has seen the commodity price go from US$120 per pound pre-Fukushima to $30 at best now. A 75 per cent reduction has seen the world's largest dedicated uranium producer, Cameco, which owns the two largest deposits not developed in Western Australia, shelve those projects.[125]

Figure 7.5 Australian uranium market figures in the year of Fukushima Daiichi

	March 2011	June 2011	September 2011	December 2011
Mine production (tonnes)				
Uranium Oxide	1,685	1,202	2,124	2,055
Uranium (U content)				
• South Australia	989	949	944	869
• Northern Territory	439	70	856	873
• Australia	1,429	1,019	1,801	1,742
Exports (tonnes)				
Uranium Oxide	1,810	1,118	2,197	1,503
Value (AUD$ million)				
Uranium Oxide	181	90	162	153
Prices				
Uranium Oxide				
• Industry Spot[a] (USD$ per pound)	68	56	51	52
• Australia[b] (AUD$ per kilogram)	100	80	74	102

a. Cameco Corporation.

b. Average export unit value.

Source: Department of Industry, Science, Energy and Resources, 'Historical Data', *Resources and Energy Quarterly – June 2020*, 2020, <https://publications.industry.gov.au/publications/resourcesandenergyquarterlyjune2020/index.html> accessed 16 September 2020.

124 Small Caps, 'Uranium stocks on the ASX: The Ultimate Guide,' 09 January 2019, <https://smallcaps.com.au/uranium-stocks-asx-ultimate-guide> accessed 16 September 2020.

125 Mr Dave Sweeney, *Transcript of evidence*, 26 June 2020, p. 14.

In the Committee's view, accidents like the one that occurred at Fukushima Daiichi should be taken very seriously by the industry and governments which may be interested in investing in nuclear technology. Whilst no deaths occurred immediately following the nuclear accident, the significant amounts of radiation leaked is of concern. The Committee believes the Fukushima Daiichi site and accident should continue to be investigated for potential harmful effects of radiation to people, ecosystems, food sources and waterways. However, the Committee was told by ANSTO that the most serious levels of radiation have already occurred and that levels of radiation are declining.[126] The Committee acknowledges this claim was strongly disputed by other witnesses. Despite this, the Committee acknowledges that long-term impacts are difficult to identify and quantify.

The Committee has found that reactor design and siting can play a significant role in the overall safety of a nuclear power plant or facility, however, it is also important to acknowledge the role human error or safety culture can have on accident management and response. Personnel response in the immediate and shortly following nuclear accidents can be a critical factor in minimising potential harms from radiation to people (both workers and the general public) and the environment. Any consideration of expanding nuclear activities needs to properly consider the appropriate safety mechanisms, processes and training needed to protect against human error, technical failures or natural disasters all of which have the propensity for causing a nuclear accident.

126 Mr Steven McIntosh, *Transcripts of evidence*, 28 August 2020, p. 41.

8 Nuclear energy issues: waste management and the environment

8.1 Introduction

This Chapter canvasses evidence received relating to nuclear waste and environmental issues. The Committee has not sought to undertake a detailed analysis of the merits or otherwise of the various cases put to it, rather it seeks to encapsulate the arguments.

8.2 Waste and waste management

An overview of radioactive waste, in particular relating to high-level waste (HLW) generated as part of the nuclear fuel cycle, was covered in Chapter 6. This section covers radioactive waste management in Australia and looks at the arguments relating to waste management and disposal canvassed during the Inquiry.

8.2.1 Radioactive waste management in Australia: current approach

Australia's radioactive waste is generated in a variety of medical, industrial, research and agricultural practices, including the Open Pool Australian Lightwater (OPAL) research reactor at Lucas Heights.

Australia produces mostly low-level waste (LLW) and some intermediate-level waste (ILW). No high-level radioactive waste is stored or disposed of in Australia.[1] Spent fuel from the OPAL reactor is sent overseas as HLW for reprocessing. The reprocessed material that is returned to Australia falls within the intermediate-level waste classification. [2]

Australia maintains a legislative and regulatory framework governing the safety of spent fuel and radioactive waste management in accordance with its obligations as a party to the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management.[3]

At a national level, Australian Radiation Protection and Safety Agency (ARPANSA) is the primary authority on radiation protection and nuclear safety. It is responsible for developing codes, standards, guides and advice on radiation protection throughout

---

1 ARPANSA, *Radioactive waste safety in Australia*, <https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/radioactive-waste-safety> accessed 16 March 2020.

2 Dr Carl-Magnus Larsson, CEO and Deputy CEO, Australian Radiation Protection and Safety Agency, public hearing, Melbourne, 12 March 2020, *Transcript of evidence*, p. 22.

3 ARPANSA, *Radioactive waste safety in Australia*.

Australia, including radioactive waste management. ARPANSA also fulfils Australia's reporting obligations under the Convention on Nuclear Safety and Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management.[4]

The Australian classification scheme for disposal of radioactive waste is based on the safety of disposal pathways, taking into account the radioactivity level and the time it will take for the radioactivity to decay (half-life).[5] Radioactive waste classification within Australia is set out in Table 8.1 below.

Table 8.1 Radioactive waste classification in Australia

Exempt Waste (EW)	Contains very low levels of radioactivity where safety measures are not required. Can be safely disposed of in the same way as non-radioactive waste.
Very Short Lived Waste (VSLW)	Contains very short-lived radioactivity. Can be safely stored for short time periods and then disposed of the same way as non-radioactive waste.
Very Low Level Waste (VLLW)	Contains low levels of short-lived radioactivity. Can be safely disposed of in existing industrial or commercial landfill-type facilities with limited regulatory control.
Low Level Waste (LLW)	Contains higher levels of short-lived radioactivity and low levels of long lived radioactivity. Can be safely disposed of in an engineered near-surface (3–10 metres) facility.
Intermediate Level Waste (ILW)	Contains higher levels of long-lived radioactivity. Can be safely disposed of at greater depths (up to a few hundred metres).
High Level Waste (HLW)	Contains levels of radioactivity high enough to generate significant amounts of heat during the radioactive decay process. Disposal in deep, stable geological formations (several hundred metres below the surface) is recognised as the safest disposal pathway.

Source: ARPANSA, *Radioactive waste safety in Australia*, <https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/radioactive-waste-safety>, accessed 16 March 2020.

States and Territories are responsible for the management of LLW produced from hospitals, universities, and nuclear medicine and scientific research facilities. Each has its own legislation regulating waste management and establishing a regulatory body for radiation protection. In Victoria, the governing legislation is the *Radiation Act 2005* (Vic). The Radiation Team in Department of Health and Human Services (DHHS) is responsible for regulatory compliance relating to the disposal of radioactive material under the Act, including authorising the disposal, export and long-term storage of radioactive materials.[6]

4 Dr Carl-Magnus Larsson, *Transcript of evidence*, p. 20.

5 ARPANSA, *Radioactive waste safety in Australia*.

6 Mr Noel Cleaves, Manager, Environment Health Regulation and Compliance, Department of Health and Human Services, public hearing, Melbourne, 12 March 2020, *Transcript of evidence*, pp. 11, 7.

Mr Noel Cleaves, Manager Environmental Health Regulation and Compliance, DHHS, explained to the Committee where Victoria's radioactive waste goes:

> So in Victoria we would licence someone to store the material, and that might be long-term storage. We also approve the export of radioactive material. Often it goes back to the manufacturer. That is part of the usual process of approval: people supply information to say that the company in Canada that they are buying the material from has agreed to take it back at the end of its life. But there are some sources, particularly legacy sources, where there is no long-term disposal pathway currently. That is when we would licence someone to store it. We will ensure that it is stored in a secure facility, and those are things that we would inspect from time to time because we regard those as being, again, of a higher risk than a dentist with intra-oral X-ray unit.[7]

Australia has accumulated almost 5,000 cubic metres of radioactive waste (excluding uranium mining waste, which is disposed of at mine sites),[8] stored in more than 100 locations around the country.[9] The South Australia Nuclear Fuel Cycle Royal Commission (SANFCRC) assessed the current inventory of Australian Government radioactive waste (Table 8.2, below).

Table 8.2 Current inventory of Australian Government radioactive waste

Waste type	Current storage location	Volume of waste (m^3)
Lightly contaminated soil, a legacy waste from ore processing research in the 1950s–60s	Woomera Prohibited Area, SA	2,100
Operational waste from the Australian Nuclear Science and Technology Organisation (ANSTO)	ANSTO, Lucas Heights, NSW	1,936
Defence waste: electron tubes, instrument dials, sealed sources, etc	Department of Defence	12

Source: Adapted from Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, Government of South Australia, South Australia, 2016.

The majority of Australia's ILW is stored at Australian Nuclear Science and Technology Organisation (ANSTO) facilities at Lucas Heights in storage casks that require to be recertified every 10 years.[10] ANSTO is also currently constructing the world's first industrial-scale facility to use the 'Synroc'[11] process to treat waste generated from the operation of its new nuclear medicine production facility.[12] ANSTO submitted:

7 Ibid., p. 11.

8 Sophie Power, 'Radioactive waste management', *Parliamentary Library, Parliament of Australia*,, <https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook45p/RadioactiveWaste> accessed 06 April 2020.

9 Department of Industry, Science, Energy and Resources, *Managing radioactive waste*, <https://www.industry.gov.au/strategies-for-the-future/managing-radioactive-waste> accessed 6 April 2020.

10 Dr Carl-Magnus Larsson, *Transcript of evidence*, pp. 22–3.

11 Synroc is a techno-process for the containment of radionuclides, invented at the Australian National University in 1978, and subsequently was progressed by ANSTO. Synroc mimics the ability of natural rock forms to bind radioactive atoms in a crystalline structure through the application of heat and pressure. It presents significant advantages over vitrification and cementation, including the capacity for higher waste loadings, reduced volume, greater durability, and greater proliferation resistance.

12 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 42.

> With the establishment of this demonstration facility potentially will come opportunities for commercialisation in foreign markets, including for the management of historically intractable radioactive waste streams, strengthening nuclear non-proliferation objectives and protection of the environment.[13]

Proposed National Radioactive Waste Management Facility (NRWMF)

The *National Radioactive Waste Management Act 2012* (Cth) sets out the process for selecting and establishing a NRWMF for the long-term disposal and storage of Australia's radioactive waste. The facility will be used to permanently dispose of Australia's LLW and temporarily store its ILW, with a separate process to be developed for a permanent ILW disposal facility. Under the Australian Radioactive Waste Management Framework, the national facility will primarily be used for waste generated by Commonwealth entities.[14]

Following a number of previous, unsuccessful attempts to site a national waste repository, including near Woomera in South Australia and Muckaty in the Northern Territory (due to community concern, and resistance from State and Territory governments and affected local and Indigenous communities),[15] in January 2020 the Federal Government identified Napandee, near Kimba in South Australia, to host the facility.[16] The National Radioactive Waste Management Amendment (Site Specification, Community Fund and Other Measures) Bill 2020 was subsequently introduced and passed in the House of Representatives; the Bill was before the Senate for consideration at the time of writing.[17]

Dr John Kalish, Assistant Secretary, Australian Safeguards and Non-Proliferation Office (ASNO) explained to the Committee the responsibilities ASNO may have if a NRWMF was constructed in Australia:

> We would play a role in the facility to the extent that the facility contained or would be likely to contain in the future nuclear material. There is a specific definition of 'nuclear material', and that would include things that contain uranium, thorium and plutonium. Based on discussions that have been going on it is almost certain that this facility would include some nuclear material with a low level of radioactivity. And that material in the facility would be subject to international atomic energy safeguards and verification activities such as inspections. ASNO would play a role in ensuring that that material

---

13 Ibid.

14 Department of Industry, Innovation and Science, *Australian Radioactive Waste Management Framework*, Australian Government, Canberra, April 2018, p. 4.

15 Sophie Power, 'Radioactive waste management'.

16 Department of Industry, Science, Energy and Resources, *Managing radioactive waste*.

17 Parliament of Australia, *National Radioactive Waste Management Amendment (Site Specification, Community Fund and Other Measures) Bill 2020*, 2020, <https://www.aph.gov.au/Parliamentary_Business/Bills_Legislation/Bills_Search_Results/Result> accessed 20 October 2020.

> was adequately safeguarded so it could not be diverted and that it was also subject to adequate levels of physical protection. It would also work with the IAEA to facilitate inspections in addition to any inspections that we might organise on our own behalf.[18]

Dr Carl‑Magnus Larsson, CEO and Deputy CEO, ARPANSA told the Committee that if Australia were to introduce nuclear into its energy mix the proposed NRWMF would not be able to accommodate the HLW. Dr Larsson stated that as the waste management processes and facilities for spent fuel and HLW are a different system than the one proposed for the NRWMF, there would need to be a separate policy decision on its waste management. [19]

Women in Nuclear (WiN) Australia argued that if Victoria introduced a 'nuclear energy program' the Victorian Government would either need to work with the Federal Government on transporting its waste to this facility or 'adopt its own waste disposal facility'.[20] WiN Australia recommended that:

> Victoria should consider adopting existing solutions for nuclear waste management which are sophisticated and effective. The Committee should consider the relatively small risks associated with radioactive waste management, transportation and storage arising from nuclear power technology, compared to imminent and potentially devastating effects of climate change.[21]

Anti‑nuclear stakeholders argued that the NRWMF could result in the 'disempowerment and dispossession'[22] of Aboriginal peoples, especially if policy‑makers do not conduct thorough and ongoing community consultation. The joint submission from Friends of the Earth (FOE) Australia, Australian Conservation Foundation and Environment Victoria contended that:

> … the National Radioactive Waste Management Act dispossesses and disempowers Traditional Owners in many respects: the nomination of a site for a radioactive waste dump is valid even if Aboriginal owners were not consulted and did not give consent; the Act has sections which nullify State or Territory laws that protect archaeological or heritage values; including those which relate to Indigenous traditions; the Act curtails the application of Commonwealth laws including the Aboriginal and Torres Strait Islander Heritage Protection Act 1984 and the Native Title Act 1993 in the important site‑selection stage; and the Native Title Act 1993 is expressly overridden in relation to land acquisition for a radioactive waste dump.[23]

18 Dr John Kalish, Assistant Secretary, Australian Safeguards and Non‑Proliferation Office, public hearing, Melbourne, 12 March 2020, *Transcript of evidence*, p. 3.

19 Dr Carl‑Magnus Larsson, *Transcript of evidence*, p. 24.

20 Women in Nuclear (WiN) Australia, *Submission 36*, p. 18.}

21 Ibid., p. 22.

22 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, p. 7.

23 Ibid.

Other concerns that were raised by anti-nuclear stakeholders about establishing a NRWMF, included:

- 'the movement of materials over very long distances would be responsible for increased carbon emissions from the largely carbon-based transport fleet'[24]
- 'proposed national radioactive waste facility would be attractive to terrorists wanting to make a 'dirty bomb', a radioactive weapon delivered by conventional means.[25]

8.2.2 Potential high-level waste management in Australia and Victoria

Some pro-nuclear stakeholders believed that Australia was uniquely placed to take advantage of potential opportunities of establishing a permanent waste management repository:

- Storage of spent fuel from geographically smaller nations could form a significant contribution of Australia toward addressing carbon emissions reductions.[26]
- Australia has large uranium reserves and an ideal waste-storage environment with many dry, remote and geologically stable areas.[27]
- Australia's stable democracy and geological footprint makes it ideally suited to build storage for both Australia and other nations and global partners.[28]

Addressing the issue of potential HLW management in Australia, Dr Carl-Magnus Larsson, CEO, ARPANSA spoke to the need to consider and decide on an approach to spent fuel management well in advance of any future participation in the nuclear fuel cycle. He told the Committee:

> [...in relation to] the management of high-level waste...Australia would have to take a decision on what the policy should be for the management of the spent fuel, and if the policy would be to dispose of the high-level waste in Australia, then of course this would not be accommodated in the national radioactive waste management facility which is now under consideration. That would be a completely different system that had to be put in place for the management of the spent fuel.
>
> This would also go into the area of funding because the back end of the nuclear fuel cycle requires funding. The usual internationally acknowledged principle for doing that is that you set aside the money as the reactors are operating and actually revenue-generating and make sure that you have enough funds so that you can take care of the back end of the nuclear fuel cycle when that time comes. What we have seen

24 Rosamund Krivanek, *Submission 65*, p. 3.

25 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, p. 70.

26 Nuclear for Climate Australia, *Submission 44*, p. 12.

27 Mr Geoff Dyke, Secretary, Victorian Branch, Construction, Forestry, Maritime, Mining and Energy Union, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 1.

28 Mr Daniel Walton, National Secretary, Australian Workers Union, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 30.

> in many countries, of course, is that the back end is considered a little bit too late. Many countries are now busily looking at solutions for the high-level waste and the spent fuel, and they are taking different approaches. But I would in that case probably suggest that Australia would take a different approach and consider the back end already at the beginning.[29]

Further, ANSTO submitted that if Victoria were to introduce nuclear fuel cycle activities relating to radioactive waste, a consideration of the appropriateness of current regulatory structures would be needed. Depending on the scale of any future activities, Victoria may need to significantly strengthen the capacity and capability of its regulators, and/or the jurisdiction of ARPANSA may need to be broadened.[30]

8.2.3 Views about waste management and disposal

This section of the Report discusses many of the views and arguments put forward to the Committee regarding the effectiveness and safety of nuclear waste management and disposal, particularly relating to nuclear power generation. Related issues and arguments concerning social licence and community consent are discussed in Chapter 9.

The issue of HLW from nuclear power generation and the waste management credentials of the nuclear energy industry is highly contested. The Committee received conflicting evidence from proponents and opponents of nuclear power over the course of the Inquiry.

A common theme raised in favour of nuclear power generation was its potential to address climate change through the provision of stable, zero emission and large-scale power generation. Dr Jo Lackenby, President, WiN Australia presented this argument to the Committee in the context of nuclear waste management, stating:

> Do we think that putting nuclear waste safely underground for long-term storage is a bigger risk than the risk that we are facing from climate change? That is the question we need to ask ourselves, and for me it is quite clear that climate change is a much more imminent and much, much bigger risk to civilisation, to the environment, to animals, to everything on earth than safely disposing of nuclear waste underground, even if it is for thousands of years. We have the technology to do this, and Sweden and Finland are currently building their waste disposal facilities. It comes down to risk—what you think is a bigger risk, and what you are willing to accept. Because, for me, I would much rather accept disposing of waste underground than I would accept a world that is 3 degrees or 4 degrees warmer than what we currently have.[31]

---

29 Dr Carl-Magnus Larsson, *Transcript of evidence*, p. 24.

30 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 28.

31 Dr Jo Lackenby, President, Women in Nuclear (WiN) Australia, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, pp. 13–4.

Pro-nuclear stakeholders told the Committee that Nuclear power is a tightly regulated industry that accounts for the very small quantities of waste it produces. Bright New World submitted:

> Nuclear power has one of the lowest materials input per unit of energy and is the only power generation source that fully encapsulates its waste stream. It is the only generation source that has established industries to recycle wastes from generation (spent nuclear fuel) and facilities to dispose of the material that has no further use.[32]

This point was echoed by many other stake holders, including WiN (Australia),[33] which also argued that perceptions that there were no effective solutions to managing radioactive waste were incorrect. [34]

A substantial portion of pro-nuclear evidence provided to the Committee made the following points regarding the issue of waste management:

- The amount of waste produced is miniscule relative to coal and solar energy generation.[35]
- Waste management processes and hazards are well developed, understood and managed and consequently pose negligible risk to the public.[36]
- Nuclear waste has been handled and stored safely for more than 50 years.[37]
- In over 40 years of nuclear waste transportation there have been no accidents that caused a significant release of radiation or harm to the environment.[38]
- There is proven scientific consensus of the safe management and disposal of waste.[39]
- Spent fuel from current generation reactors may be a future source of fuel for advanced, next generation reactors as the technology develops.[40]
- As a major supplier of fuel for nuclear reactors, Australia shares responsibility for waste generated from exported uranium.[41]

In contrast, opponents of nuclear power remain unconvinced by claims that the issue of permanent and safe nuclear waste management has been resolved. A joint civil society statement signed by more than 50 Australian-based groups and organisations

8

32 Bright New World, *Submission 74*, p. 9.

33 Women in Nuclear (WiN) Australia, *Submission 36*, p. 12.

34 Ibid.

35 Terje Petersen, *Submission 3*, p. 18.

36 Bright New World, *Submission 74*, pp. 10, 1.

37 Mr Ian Hore-Lacy, Senior Adviser, World Nuclear Association, public hearing, Melbourne, 14 August 2020, *Transcript of evidence*, p. 49; Mr King Lee, Director, Harmony Programme, World Nuclear Association, public hearing, Melbourne, 14 August 2020, *Transcript of evidence*, p. 53.

38 Bright New World, *Submission 74*, p. 11.

39 Mr King Lee, *Transcript of evidence*, p. 53.

40 Dr Jo Lackenby, *Transcript of evidence*, p. 18.

41 Azark Project, *Submission 21*, p. 3.

in response to the 2019 federal *Inquiry into the pre-requisites for nuclear power in Australia*, and subsequently provided to this Inquiry, states in relation to nuclear waste:

> Nuclear reactors produce long-lived radioactive wastes that pose a direct human and environmental threat for many thousands of years and impose a profound inter-generational burden. Radioactive waste management is costly, complex, contested and unresolved, globally and in the current Australian context. Nuclear power cannot be considered a clean source of energy given its intractable legacy of nuclear waste.[42]

In response to claims that nuclear power was a genuine source of low and zero emissions electricity, Mr Trevor Gauld, National Policy Officer, Electrical Trades Union (ETU) (Victoria) told the Committee:

> … in their emissions discussions, and what we see from the nuclear lobbyists, is that when they try and compare like for like they almost universally leave waste management and storage out of their emissions profiles.[43]

Many other stakeholders argued that waste management continues to be a problem the nuclear industry has failed to address in any meaningful or permanent manner, pointing to the fact that the entirety of HLW produced since nuclear energy generation began continues to reside in temporary storage around the world as it continues to accumulate.

Dr Tilman Ruff AO from the Medical Association for Prevention of War (MAPW) (Australia) noted that more than 70 years into the nuclear age no country had yet established a functioning repository.[44] Similarly, in a submission to the Inquiry, Mr Philip White highlighted the failure of the industry to implement permanent disposal solutions:

> … so far no SNF [spent nuclear fuel] or HLW has been permanently and safely disposed of. Nuclear energy programs were approved and implemented without first ensuring that there was a solution to the problem of this extremely hazardous radioactive waste. To the extent that the economic viability of these programs was assessed, it was assessed with totally inadequate consideration of the cost of disposing of this waste, or of the cost of decommissioning in general.[45]

Even if deep geological repositories were in operation, many opponents remained unconvinced that the issue of nuclear waste could be resolved with such extraordinarily long timescales involved for safe disposal. Addressing the challenges of managing nuclear waste over such protracted time periods, the MAPW (Australia) submitted:

> High level waste…requires permanent storage in deep geological formations for a few hundred thousand years. Due to the complexity of the problem and the long time periods considered, the ability of a repository to retain radioactivity has a significant

---

42 Joint Civil Society Statement, *Submission 55*, p. 2.

43 Mr Trevor Gauld, National Policy Officer, Electrical Trades Union, public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 8.

44 Dr Tilman Ruff AO, Medical Association for Prevention of War (Australia), public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 22.

45 Philip White, *Submission 17*, pp. 3–4.

> degree of uncertainty. Furthermore, similar assumptions usually based on insufficient or absent data are made to simulate the behaviour of a repository over an arc of time orders of magnitude beyond that of recorded human history.[46]

Several stakeholders cited safety failures at other disposal facilities around the world, including the Waste Isolation Pilot Plant in New Mexico, USA[47] (a waste disposal repository for ILW) as evidence that the ongoing safety of long-term waste storage could not be guaranteed. At a public hearing, Dr Jim Green, National Nuclear Campaigner, FOE Australia argued that the New Mexico incident was indicative of a broader failure to ensure long-term safety of underground storage. He told the Committee:

> … the waste isolation pilot plant…started up in 1999 with great fanfare and great promises about how this would safely contain waste for literally thousands of years. But within a few years of the commencement of operation of that repository, safety standards fell dramatically and layers of regulation were stripped away. The end result of that was a chemical explosion in an underground waste barrel in 2014, which closed the repository for three years and the direct and indirect costs associated with that accident amounted to about US$2 billion. So I would ask you to reflect on that. We are being told that nuclear waste can be safely contained for hundreds of thousands of years, and yet the practical experience of the only deep underground repository anywhere in the world is that safety standards fell away dramatically in the space of just a few years.[48]

Mr White contended that obtaining approval for a geological repository was not proof that waste be safely disposed of. Rather, it only demonstrated that procedural hurdles had been cleared and it would be impossible to know if these projects were successful until thousands of years had elapsed.[49]

Similar concerns were submitted by the Uniting Church in Australia (Synod of Victoria and Tasmania) in which expressed its 'anxiety' for the dangers of nuclear waste products such as plutonium and believed that present-day generations have no right to impose the enormous burden of care for the waste and obsolete installations on future generations, and the continuing risks this involves.[50]

8.2.4 The Committee's view

The Committee notes there is no repository for the long-term disposal for HLW in Australia. Further, it acknowledges that broad public acceptance and social license to operate is a key factor in the issue of nuclear waste management and disposal. This is discussed in more detail in Chapter 9.

---

46 Medical Association for Prevention of War (Australia), *Submission 34*, pp. 17–8.

47 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, pp. 45–6; Philip White, *Submission 17*, pp. 3–4 (with sources).

48 Dr Jim Green, National Nuclear, Friends of the Earth Australia, public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 18.

49 Mr Philip White, *Submission 17*, p. 3 (with sources).

50 Uniting Church in Australia (Synod of Victoria and Tasmania), *Submission 70*, p. 11.

Sifting through debates surrounding radioactive waste management is a complex task owing to the broad spectrum of and strongly held views of so many individuals, informed by many and varied backgrounds and experiences. The Committee notes that while technical solutions and scientific consensus is essential for the successful and safe management of nuclear waste, it is just as important to genuinely engage with and respect the concerns regarding risks to human health and the environment, both real and perceived.

FINDING 8: The success of any radioactive waste strategy relies on a level of acceptance and confidence across government, industry and the broader community of its legitimacy, effectiveness and integrity in its ability to deal with all facets of waste management, storage and disposal, including the long-term health and safety of workers, affected communities, particularly First Nations Peoples, and the environment.

FINDING 9: Those who propose a policy shift have not presented any argument, data or proof in support of their position that cannot be nullified by those arguing against. Any advantages are speculative in nature, and do not outweigh the identified and proven risks.

8.3 Environmental impacts of nuclear energy

One of the key drivers for a shift away from fossil fuels, and in particular coal, has been concerns about the impact of carbon emissions on the climate. Climate change is considered to be a fundamental challenge globally and high carbon emitting energy generation is seen to be one of the factors that exacerbates global warming.

As stated in previous sections, a move to renewable energy with its low carbon emissions has been seen to be one of the most effective ways of slowing or reducing the impact of climate change. A significant emphasis has been placed on a shift to renewable energy in all of the policy settings across Australian governments.

During the course of the Inquiry, it has been clear that one of the key arguments put forward to support a shift to nuclear energy, or at least to include nuclear power in the energy mix, has been the fact that nuclear power does not emit carbon and is therefore a ‘clean’ energy source. Proponents of nuclear energy, both those with a commercial investment in the technology and those who simply consider it to be an efficient energy source, all reference the mitigating effects of it on climate change as one of the great advantages of the technology.

Notwithstanding claimed environmental benefits put forward by nuclear proponents, issues such as the need for substantial amounts of water, a potentially difficult issue in the driest continent in the world, were raised by those concerned about any potential shift towards putting nuclear power into the energy mix.

In this section, some of the significant arguments put to the Committee are canvassed. Again, the Committee is not attempting to undertake a detailed technical analysis of nuclear power, nor does it seek to mount an argument for or against putting nuclear power into an energy mix. Rather, the intention is to highlight some of the questions that would need to be asked should a nuclear prohibition be lifted at any point and therefore making nuclear power a viable option.

8.3.1 Low or no emission technology

Many stakeholders discussed environmental factors connected with the nuclear fuel cycle; throughout the evidence there was debate about whether nuclear energy generation would assist in addressing climate change concerns or introduce new environmental issues to the State, particularly the issue of nuclear waste management This section focuses on discussions around nuclear's emissions and carbon footprint, it does not engage in the debate in the environmental or health impacts of nuclear energy. Instead the section focuses on presenting both sides of evidence the Committee received about whether nuclear energy is a zero-emissions technology that should contribute to Victoria's emissions targets and climate change reduction goals. For a more fulsome discussion of environmental considerations related to nuclear energy, particularly waste management, see Section 8.2.3.

Several pro-nuclear stakeholders argued that nuclear power, once contributing to Victoria's energy mix, would be a zero-emission technology, with CO2 emissions only being generated during the construction phase. Furthermore, some stakeholders contended that construction emissions would be on par with solar and wind. Mr Terje Petersen, in a submission, provided a table (Table 8.3) from the Intergovernmental Panel on Climate Change (IPCC) 2014 Climate Change Report which shows lifecycle emissions of different energy generation technologies.

Table 8.3 Lifecycle Emissions (including albedo effect) of different energy technologies

Technology	Median value gCO2eq/ kWh
Wind—onshore	11
Wind—offshore	12
Nuclear	12
Hydropower	24
Concentrated solar power	27
Geothermal	38
Solar PV—rooftop	41
Solar PV—utility	48
Biomass—dedicated	230
Gas—combined cycle	490
Biomass—cofiring	740
Coal—PC	820

Source: Terje Petersen, *Submission 3*, p. 5.

8

NuScale Power, a US small modular reactor (SMR) technology development company and America's leading SMR developer, suggested in its submission to the Inquiry that its SMR will be as clean as renewables and certainly cleaner than fossil fuels, have a smaller environmental footprint as the site for any nuclear power plant will be smaller than a renewable energy facility and will enable growth in renewables as it will provide supplementary and complementary power.

It has been suggested that the prohibition of nuclear activities was brought into effect before there was any imperative to reduce emissions. According to a submission by Nuclear for Climate, when the legislation banning nuclear activity was introduced, the public was not yet aware of the need for emissions reductions and climate change action was not on the agenda. In their view, the impact of the *Nuclear Activities (Prohibitions) Act 1983* (Vic) has been to prevent adoption of the most effective tool to address climate change. [51]

In his submission, Mr Bart Wissink stated that:

> A nuclear power industry in Australia would greatly reduce our green house gas emissions and provide us with a reliable power source which can be readily expanded, to accommodate a growing industry and population.[52]

---

51 Nuclear for Climate Australia, *Submission 44*, p. 2.

52 Bart Wissink, *Submission 29*, p. 6.

A lot of other pro-nuclear stakeholders also discussed the benefits of nuclear power is its low emissions and carbon-footprint throughout its lifecycle. The following are excerpts taken from submissions and transcripts showing some of the assertions made by stakeholders:

- 'the critical advantage of nuclear power plants in addressing climate change is that they are greenhouse gas emission free'[53]
- 'Nuclear fission does not produce any carbon dioxide or greenhouse gases. The emissions from other parts of the fuel cycle (e.g. mining of uranium and enrichment of uranium are less than 2% of those from using coal…'[54]
- 'Nuclear power reactors generate electricity with zero CO2 emissions, and 12 kg/MWh whole of life cycle emissions, the same as wind and less than solar PV…'[55]
- 'Nuclear energy provides 10 per cent of the world's electricity. Without it, global CO2 emissions would be 2.2 billion tonnes higher.'[56]
- 'Most of the countries that do have zero emissions are basically all hydro and nuclear, and all the major developed countries use nuclear as a fuel source.'[57]

8

The Australian Nuclear Association in its submission, stated that nuclear energy plays a key role in lowering carbon emissions from the energy sector in many countries. The submission claimed that the carbon emissions for the whole nuclear fuel cycle are very low and of the order of 40 grams CO2/kWh. This low carbon emission is similar to emissions from wind and hydro per unit of electricity produced and slightly less than solar PV. [58]

Mr Ian Hore-Lacy, in his submission, argued that nuclear 'causes virtually no CO2 emissions from the full fuel cycle.'[59]

Mr Robert Parker, Vice-President, Australian Nuclear Association, compared the emissions intensity of France and Germany, finding:

> Day by day, week by week and for the last 40 years we have seen the French emissions intensity set at around about 30 to 40 grams of carbon dioxide per kilowatt hour. Their near neighbour in Germany formerly was a nuclear enthusiast but now they are winding back their plants. Despite that, and despite spending €125 billion up until 2015—and they are now going to be in debt to the tune of €520 billion by 2025—their emissions intensity as they attempt to use variable wind and solar replacement is actually not

---

53 Hon. Peter Vickery QC, *Submission 33*, p. 11.

54 Women in Nuclear (WiN) Australia, *Submission 36*, p. 12.

55 Tony Irwin, *Submission 38*, p. 4.

56 Mr Patrick Gibbons, Minerals Council of Australia, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 34.

57 Mr Geoff Dyke, *Transcript of evidence*, p. 5.

58 Australian Nuclear Association, *Submission 50*, p. 3.

59 Ian Hore-Lacy, *Submission 32*, p. 1.

> achieving the types of results they had hoped. They steadfastly keep their emissions high at around about to 300 to 400 grams, or around 10 times that of the French system.[60]

Another submission that supported the introduction of nuclear energy, from Terrestrial Energy, suggested that a comparison between Canadian province Ontario and Victoria showed the lower emissions provided by a jurisdiction powered significantly by nuclear energy. It stated that:

> We draw the committee's attention to the contribution of the Victorian energy sector to global climate change – 100 MtCO2e per year from a population of 6.4 million people. We draw attention to the Canadian province of Ontario of 14.57 million people, with greenhouse gas emissions from the energy sector of 4,5 MtCO2-e per year. The Victorian power sector is responsible for 15.7 tCO2e per capita. The power sector of Ontario is responsible for 0.3 tCO2e per capita. The power sector of Ontario has the benefit of a large hydropower resource, and is also gets over 60% of its electricity supply from nuclear energy.[61]

This comparison illustrates the low emissions of nuclear energy when compared with those of a fossil fuel-based energy source. It is comparing a jurisdiction with nuclear power to one that generates the majority of its power from coal, not from renewable energy. It is not a comparison between nuclear power and renewable energy.

Dr Sarah Lawley, in her submission, argued that Victoria should adopt a 'technology neutral stance on reducing emissions in the electricity sector.'[62] In her view, this would mean not focusing solely on a renewables-only approach but looking at a multitude of energy options which could assist with emission reductions. If nuclear was found to be a needed contributor to these goals, Dr Lawley suggested a Victorian nuclear industry should adopt circular economy principles.[63]

Dr Jo Lackenby, President, WiN Australia, told the Committee that there is plenty of evidence suggesting that nuclear energy, along with hydropower, is successful in significantly reducing carbon emissions. Dr Lackenby also explained that:

> The countries that have a lot of renewables installed absolutely have less carbon emissions than the countries that mostly have fossil fuel generation. However, what you will see on [electricityMap] is that you can get massive swings in the carbon intensity from those sources depending on whether the wind is blowing or the sun is shining. So you can have very low emissions from those places with renewable generation or very high emissions if they are relying on fossil fuel backups to coincide with their renewable generation.[64]

---

60 Mr Robert Parker, Vice President, Australian Nuclear Association, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 17.

61 Terrestrial Energy, *Submission 76*, p. 5.

62 Dr Sarah Lawley, *Submission 49*, p. 3.

63 Ibid.

64 Dr Jo Lackenby, *Transcript of evidence*, p. 11.

Mr Geoff Dyke, Secretary, Victorian District Branch, Construction, Forestry, Maritime, Mining and Energy Union, supported the introduction of nuclear activities in Victoria because it is a low-emission energy alternative which is also dispatchable:

> … a reliable electricity grid requires dispatchable power to exactly match supply with demand to maintain system frequency at 50 hertz. The current dispatchable generation sources within the national electricity market are gas, coal and hydro.
>
> …
>
> The CFMMEU's preferred option for dispatchable power is high-efficiency, low-emissions coal-fired power with carbon capture and storage.
>
> …
>
> However, if none of that is viable, we believe the only cost-effective and viable source of power would be nuclear.[65]

While the lower emissions of nuclear power are not seriously disputed, there is considerable debate about whether the use of nuclear power is the only way to reduce emissions to meet current targets.

In evidence at a public hearing, Mr Simon Holmes a Court, a researcher with the Energy Transition Hub at Melbourne University, told the Committee that the energy market operator, Australian Energy Market Operator (AEMO), put out a second revision of its integrated system plan in which it estimated that in a 'least cost scenario' (i.e. no additional policies) Victoria could reach 76% of renewables in 2042 with no additional gas and a sharp reduction in baseload generation, to as much as 96% in a 'step-change scenario' with no baseload generation.

Further, Mr Holmes a Court suggested that in the step-change scenario which is closest to meeting the Paris target, the Integrated System Plan estimates the National Energy Market would reach 96% renewable energy. Mr Holmes a Court suggested that there is a good reason to believe that this scenario will be achieved. It will involve no baseload generation in Victoria and the grid will be cleaner than France's grid is now. He said that the AEMO has simulated scenarios on an hour-by-hour basis and that under the scenario he discussed, 'the lights stay on, emissions fall and the costs are close to business as usual.'[66]

However, some anti-nuclear stakeholders did refute the assertion that nuclear energy was a zero-emission energy source, pointing to emissions generated during mining and construction as evidence that claims of 'zero' emissions were untrue.

In its submission, the MAPW Australia stated that nuclear proponents overlook the whole nuclear fuel chain, and that 'mining, milling, fuel fabrication, enrichment, reactor construction, decommissioning and waste management all use fossil fuels.'[67]

65 Mr Geoff Dyke, *Transcript of evidence*, p. 1.

66 Mr Simon Holmes a Court, Energy Transition Hub, public hearing, Melbourne, 11 September 2020, *Transcript of evidence*, p. 14.

67 Medical Association for Prevention of War (Australia), *Submission 34*, p. 18.

Furthermore, in questioning the accuracy of the claims that nuclear has no emissions, MAPW Australia argued that 'depending on your choice of analysis, nuclear power can be viewed as almost as emissions-intensive as gas.'[68] Its submission compared two sets of figures from both sides of the nuclear debate to demonstrate that different conclusions can be drawn depending on the perspective of a researcher:

> Several analyses by researchers who are independent of the nuclear industry have found that total CO2 emissions depend on the grade of uranium ore mined and milled. The lower the grade, the more fossil fuels are used, and so the higher the resulting emissions.
>
> In one such study, the nuclear physicist (and nuclear energy advocate) Manfred Lenzen found that CO2 emissions from the nuclear fuel cycle increase from 80 grams per kilowatt-hour (g/ kWh) where uranium ore is high-grade, to 131 g/ kWh where the ore grade declines to low grade.
>
> Other experts, such as nuclear energy critics Jan Willem Storm van Leeuwen and Philip Smith, using assumptions less favourable to nuclear energy, have reported an increase in emissions from 117 g/ kWh for high-grade ore to 436 g/ kWh for low-grade ore.[69]

Dr Tilman Ruff AO, of MAPW, refuted that nuclear was a zero-emission technology when in operation, stating:

> But even the normal operation of those facilities generates large amounts of radioactive materials, some of which are inevitably released into the environment through gaseous emissions, through liquid emissions into soil, into cooling water.[70]

Despite criticism of the zero-emission assertion, there was general consensus among stakeholders across the Inquiry that once nuclear was operating it had no emissions and would contribute to the rapid decarbonisation of Australia's energy grid.

As stated earlier, it is not seriously disputed that nuclear power has low carbon emissions. The contention surrounds whether other factors of nuclear energy make it more or less attractive than other low emission power sources, such as renewable energy.

8.3.2 Nuclear risks a much lesser evil than climate change

The imperative of addressing emissions levels to mitigate the impact of climate change over the coming decades has led to support for nuclear power among a number of submitters and witnesses to the Inquiry. The risks of nuclear power plants are seen by some as the lesser of two evils, when compared to the potential devastation that climate change threatens without mitigation.

WiN Australia focused its submission and its evidence on support for including nuclear power in the energy mix as a way of reducing emissions and thereby ameliorating the

68 Ibid.

69 Ibid.

70 Dr Tilman Ruff AO, *Transcript of evidence*, p. 21.

impact of climate change, which will adversely affect women and children, particularly in poorer countries disproportionately. In its submission, WiN Australia told the Committee that it sees nuclear energy technology as a key part of the solution in the fight against climate change.[71]

In 2015, WiN Global produced a document known as the "Women in Nuclear Declaration for the Earth Climate". The document acknowledges:

- That the world's population should reach 10 billion people and electricity demand should double by 2050.
- That if the world is to limit global warming to a maximum of 2°C by 2050, over 80% of electricity will need to come from all available low carbon technologies.[72]

In its submission, WiN suggested Victoria should consider adopting existing solutions for nuclear waste management which are sophisticated and effective. The submission stated that:

> The Committee should consider the relatively small risks associated with radioactive waste management, transportation and storage arising from nuclear power technology, compared to the imminent and potentially devastating effects of climate change.[73]

In evidence in a public hearing, Ms Jasmine Diab of WiN Australia emphasised this point and told the Committee that "… Australia has signed up to the UN sustainable development goals and the UN acknowledges that women and children are more gravely affected by poverty, natural disasters, climate change and inequality."[74] Further, she said:

> … energy needs to not only be sustainable but also reliable. With around 1 billion people worldwide still without access to electricity, there is much work to be done. We would like the committee to note that nuclear energy is a proven, reliable low emissions technology with advanced safety management.[75]

The theme of climate change being a greater risk to populations and the environment than nuclear energy was further explored by a group called Nuclear for Climate, which submitted to the Inquiry. In its submission, it suggested that no nation has achieved emissions reductions of the level required to address climate change using predominantly wind and solar.[76] In addition to climate change, the submission suggests that air pollution around the world was also a significant killer and that the use of low emissions nuclear power had the potential to massively reduce the direct impact of such pollution.

---

71 Women in Nuclear (WiN) Australia, *Submission 36*, p. 4.

72 Ibid.

73 Ibid., p. 17.

74 Ms Jasmin Diab, Vice-President, Women in Nuclear (WiN) Australia, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 7.

75 Ibid.

76 Nuclear for Climate Australia, *Submission 44*, p. 3.

The submission quotes former NASA scientist and climate change scientist, Dr James Hansen, and his colleague Pushker A. Kharechai:

> Because nuclear power is an abundant, low-carbon source of base-load power, it could make a large contribution to mitigation of global climate change and air pollution. Using historical production data, we calculate that global nuclear power has prevented an average of 1.84 million air pollution-related deaths and 64 giga-tonnes of CO2-equivalent (GtCO2-eq) greenhouse gas (GHG) emissions that would have resulted from fossil fuel burning. On the basis of global projection data that take into account the effects of the Fukushima accident, we find that nuclear power could additionally prevent an average of 420 000–7.04 million deaths and 80–240 GtCO2-eq emissions due to fossil fuels by mid-century, depending on which fuel it replaces.[77]

The fear of nuclear power compared with the concerns about climate change was also addressed in a submission from Dr Sarah Lawley. In her view the fear of nuclear technology was more dangerous and limiting than the 'nuclear fuel cycle will ever be.'[78]

Dr Lawley said in her submission that far more people will be impacted by climate change than by nuclear energy production. She said:

> ... whether a person resides in Victoria, in Lucas Heights, New South Wales or in France the risk that the person will be harmed by radiation from a nuclear reactor or from the nuclear fuel cycle remains so small as to be approximately zero. Conversely, the risk that someone who lives in Victoria will be impacted significantly by climate change in their lifetime is so high as to be close to 100%. Furthermore, the risk that fragile ecosystems in Australia and marine ecosystems off the coast of Australia, will be impacted negatively by climate change is so high as to be approximately 100%.[79]

The significance of climate change as a direct threat was a common theme from submissions and nuclear power was seen as a way of mitigating its effects by a number of people who provided the Committee with evidence. One submission suggested that climate change and its potential impacts are not fully understood and that decisions about the use of nuclear energy are extremely important. Mr Adam Corrie said in his submission that:

> This is a global catastrophe, which is leading to the 6th global mass extinction in earth's history. This will change the global environment far greater than what we have ever seen. Unless a significant change is made, my generation and each and every generation therefore after are going to face dire living situations as a direct consequence to this decision.[80]

The view was expressed to the Committee in a submission that the legislation that currently prohibits nuclear activity is in fact likely to be an obstacle to mitigation of climate change. Hon. Peter Vickery QC told the Committee in his submission that the

---

77 Ibid.

78 Dr Sarah Lawley, *Submission 49*, p. 4.

79 Ibid.

80 Adam Corrie, *Submission 68*, p. 3.

fundamentals which Victoria and Australia need to address to deal with climate change are staring us in the face, and may be condensed into three basic propositions:

- first, the threat is grave and needs to be urgently addressed
- second, a key human activity which significantly contributes to climate change is the generation of electricity energy sourced from fossil fuels
- third, Victoria and Australia are going to need a lot more energy and a lot more fresh water to deal with climate change in the foreseeable future.[81]

He suggested that legislation currently in force has inhibited the development of the nuclear option to combat climate change which he suggests is potentially critical to the future of Australia.[82]

Mr Vickery further identified the fact that the Victorian legislation (*Climate Change Act 2017*), includes a challenging target of achieving net zero greenhouse gas emissions by year 2050 and recognises and supports the Paris Agreement on climate change target of holding the increase in global average temperature to well below 2°C above pre-industrial levels.[83]

He said that:

> … in order to meet the 2050 target, and the 2030 interim target, a nuclear option needs to be opened up for consideration to supplement renewables such as wind, solar and pumped hydro.[84]

Mr Daniel Walton, National Secretary, Australian Workers' Union argued that current legislative bans against nuclear inhibits real exploration of solutions to reducing emissions and our carbon footprint. Mr Walton believed that a solution to reducing our carbon footprint is the introduction of nuclear energy but this would require removal of prohibitions so it could be properly explored as an option. He recommended that Victoria remove its current prohibitions and test the feasibility of nuclear energy through scientific and environmental study.[85]

Numerous other pro-nuclear stakeholders also believed that current legislative bans meant that Victoria, or Australia, could not properly consider whether nuclear is a viable option for our energy future. The Committee received several recommendations which urged that bans be overturned so nuclear could be properly explored.[86]

Climate change has been a significant driver of the debate. However, it needs to be emphasised that no opponents of nuclear energy have suggested that low emissions

81 Hon. Peter Vickery QC, *Submission 33*, p. 3.

82 Ibid., p. 10.

83 Ibid., p. 32.

84 Ibid., p. 37.

85 Mr Daniel Walton, *Transcript of evidence*, p. 30.

86 See for example: Barry Murphy, *Submission 27*; Women in Nuclear (WiN) Australia, *Submission 36*, p. 1; Logan Smith, *Submission 43*, p. 3; Barrie Hill, *Submission 47*, p. 10; Minerals Council of Australia, *Submission 78*, p. 3.

technology in the production of energy are not an important mitigation against climate change.

The dispute is not about whether climate change poses a threat, but which technologies should be used to combat it. The contention is not around climate change, but around the necessity for nuclear energy when renewable energy is developing.

Mr Noel Wauchope argued that the nuclear fuel cycle and its operation 'is vulnerable to climate change' because:

> Increasing temperatures can result in reduced nuclear efficiency by directly impacting nuclear equipment or warming the plant's source of cooling water. Nuclear power is uniquely vulnerable to increasing temperatures because of its reliance on cooling water to ensure operational safety within the core and spent fuel storage. As the most water-intensive energy generation technology, nuclear reactors are located near a river or the ocean to accommodate hefty water usage, which averages between 1,101 gallons per megawatt of electricity produced to 44,350 qal/ MWh depending on the cooling technology.
>
> Inland reactors that use rivers as a source of cooling water are the most at risk during heat waves…[87]

Nuclear reactor susceptibility to climate change or extreme weather conditions was a point of contention across both sides of the debate. In his submission, Mr Tristan Prasser believed that nuclear power was 'less susceptible to extreme weather events and climatic variations that other sources of energy, particularly renewable systems dependent on sunshine and/or wind.'[88]

Anti-nuclear stakeholders believed that focusing on the low-carbon output of nuclear distracts from conversations and research into developing renewable energy solutions.

In his submission, Mr White wrote:

> Even if Australia committed to nuclear energy today, it would take considerably more than a decade before the first nuclear power plant came on line. In the meantime, we would have obstructed from the development of reliable, affordable and low greenhouse gas emissions (GHG) electricity system based on coal. So, even though nuclear power plants don't emit much CO2 during the electricity generation phase, and even if their life-cycle CO2 emissions (including construction, fuel production, generation and decommissioning) are arguably comparable with renewable energy sources, the delay in moving to a low GHG emission system makes them a very bad choice from an environmental perspective.[89]

87 Noel Wauchope, *Submission 25*, p. 2.

88 Tristan Prasser, *Submission 80*, p. 8.

89 Philip White, *Submission 17*, p. 9.

Mr Dave Sweeney, Nuclear Free Campaigner, Australian Conservation Foundation, told the Committee that he is concerned that nuclear power could be a 'policy distraction' from embracing renewable technology to drive down fossil fuel emissions.[90]

The Proforma A submission, which was signed by 140 individuals, also contended that focusing on nuclear as an alternative energy source deters from embracing renewable energy solutions to reduce carbon emissions and respond to climate change quickly.[91]

Signatories to the Joint Civil Society Statement[92] believed that Australia should focus on developing renewable energy technologies to reduce carbon emissions instead of exploring options to establish a domestic nuclear industry.[93] The Statement argued that even if nuclear was a viable option for Australia, the lengthy construction phase for reactors would mean it would be a decade before it could contribute to reducing emissions which would allow for 'escalating blackouts and [Australia] would be many thousands of kilo tonnes over its emissions reduction's targets.'[94]

At a public hearing, Mr Gauld, National Policy Officer, ETU (Victoria branch), acknowledged to the Committee that nuclear power does have a lower emissions profile compared to other energy sources; however, emission reductions are an immediate and pressing concern so focus should be on developing renewable technologies:

> Again the emissions profile, the capacity for Australia to deploy new energy sources right now—the immediate economic opportunity is renewables. It can do the job. We are not arguing that nuclear power does not have jobs when it gets built; it does. We are not arguing that it does not have a lower emissions profile than other generation sources; it does have lower. But the economic facts are that we have renewables here now which are low and zero emissions which we are already deploying.[95]

Again, it is not the Committee's intention to adjudicate in such a debate but simply to highlight the questions that are being asked and would need to be asked in the development of plans for the energy mix into the future.

In addition to mitigation against climate change, other issues have been put forward as environmental advantages of nuclear power. One of these is the issue of land use, where the claim is made that nuclear power represents a significantly smaller footprint than many other sources of power, especially some renewables.

In its submission to the Inquiry, the ANSTO suggested that land requirements are a critical consideration when determining the environmental impacts of a source of energy, including nuclear power. This is particularly an issue with encroachment into agricultural land that has the potential for impacting food production into the future.

---

90 Mr Dave Sweeney, Nuclear Free Campaigner, Australian Conservation Foundation, public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 18.

91 *Submission Proforma A*, p. 1.

92 Submission 55

93 Joint Civil Society Statement, *Submission 55*, p. 55.

94 Ibid., p. 9.

95 Mr Trevor Gauld, *Transcript of evidence*, p. 8.

ANSTO told the Committee that it is estimated that the land requirements for the operation of a nuclear power plant correspond to only 0.6 m^2 per GWh(e). However, SMRs promise substantially to reduce this footprint. In contrast, the footprint required for hydropower and large solar power plants is 49 m^2 and 1275 m^2 per GWh(e), respectively. Another study has shown that wind farms require 300 to 500 times more land than a nuclear power plant. [96]

This lower land use was echoed in a submission from GE Hitachi Nuclear, which produces nuclear power plants and is working on the development of a small modular reactor. In its submission GE Hitachi claimed that:

> Nuclear is energy dense with high capacity factors and efficient use of land and materials. Depending on siting location, capacity factors for solar are 15–30% and for wind are 30–50%; however, the capacity factors for nuclear are not weather or time of day dependent and are on the order of 80–90%. Compared to nuclear, solar uses 60 times more land per installed megawatt than nuclear and wind uses 300 times more than nuclear.[97]

Again, the Committee is not making judgements based on the evidence received about the relative merits of nuclear power over renewables from the perspective of land use. Not enough evidence has been received nor sought on the issue.

However, it needs to be one of the factors considered should a prohibition be lifted to enable nuclear power to be included in the energy mix in Australia, and in particular in Victoria. Land use for both the nuclear power generation plant and waste storage would need to be a very significant factor due to the potential to impact the environment, positively or negatively.

8.3.3 Contrary views on nuclear impact on the environment

As stated earlier, it is not the contention of those opposing nuclear power that nuclear power is not a low emissions technology, and nor has it been seriously argued in submissions or in evidence that its low emissions would not be of value in the mitigation of climate change.

Several submissions and witnesses have suggested that nuclear energy would be an option if it was necessary in order to lower emissions. These submissions have argued that it is simply not necessary as renewable energy will, over the medium to long-term, provide low emissions energy without the risks associated with nuclear power. One of the concerns raised about consideration of nuclear energy is that it represents a distraction from the development of renewables.

96 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 46.

97 GE Hitachi Nuclear Energy, *Submission 77*, p. 3.

As an example, a submission from Mr White suggested that the delay in the development of renewables that would accompany the adoption of nuclear energy, given the time it takes to license and construct nuclear power plants, would be very detrimental to Australia's interests. He said in his submission:

> Even if Australia committed to nuclear energy today, 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, and even if their life-cycle CO2 emissions (including construction, fuel production, generation and decommissioning) are arguably comparable with renewable energy sources,30 the delay in moving to a low GHG emission system makes them a very bad choice from an environmental perspective.[98]

A submission from the FOE Australia reiterated this point, quoting Mark Cooper, a senior research fellow for economic analysis at the Institute for Energy and the Environment at Vermont Law School:

> Finally, giving nuclear power a central role in climate change policy would not only drain away resources from the more promising alternatives, it would undermine the effort to create the physical and institutional infrastructure needed to support the emerging electricity systems based on renewables, distributed generation and intensive system and demand management.[99]

8

The Australian Conservation Foundation, in its joint submission with FOE Australia and Environment Victoria, further emphasised this point, stating:

> … the introduction of nuclear power would delay and undermine the development of effective, economic energy and climate policies based on renewable energy sources and energy efficiency.[100]

Another issue that was raised by those opposing nuclear energy in Australia related to its need for substantial amount of water in a country that is very short on that resource.

A submission from Mr Frank Simpson identified the key concerns about the need for water in nuclear energy production. The submission suggested that in the event of a serious accident, such as an overheated reactor, a nuclear power plant is required to have an emergency supply of water that can continue to cool the plant for at least 30 days. The submission said that these water sources, called ultimate heat sinks (UHS) are used to cool the reactor which will continue to produce heat long after it is turned off.

98 Philip White, *Submission 17*, p. 9.

99 Friends of the Earth Australia, *Submission 22*, p. 24 (with sources).

100 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, p. 7.

During an accident, UHS may need to supply 10,000 to 30,000 gallons of water per minute for emergency cooling. This can have the effect of both using a huge amount of water and also having a significant impact on fish and wildlife, if it is not in a dedicated, separate water supply. The submission told the Committee that a 2005 study in southern California suggested that while cooling issues can be a problem for all power plants, they are of particular concern in nuclear power plants.[101]

In his submission, Mr Simpson suggested that nuclear power plant as a whole withdraw and consume more water per unit of electricity produced than coal plants using similar cooling technologies because nuclear power plants operate at a lower temperature and lower turbine efficiency, and do not lose heat via smokestacks. The submission also stated that nuclear power plants use water in a way that no other plant does: to keep the reactor core and used fuel rods call. Mr Simpson said:

> … to avoid potentially catastrophic failure, these systems need to be kept running at all times, even when the plant is closed for refuelling.[102]

This vulnerability and reliance on water was raised by other submitters, including Mr Noel Wauchope who described the nuclear industry as the most water intensive energy generation technology, and that they needed to be located near a river or ocean to accommodate hefty water usage. Mr Wauchope suggested that:

> Nuclear power is uniquely vulnerable to increasing temperatures because of its reliance on cooling water to ensure operational safety within the core and spent fuel storage. As the most water-intensive energy generation technology, nuclear reactors are located near a river or the ocean to accommodate hefty water usage.[103]

Mr Wauchope also suggested that climate change is likely to have a negative impact on nuclear power plants because as temperatures rise, and water becomes less available, inland reactors in particular will be at risk during heat waves. The submission suggests that the IPCC has indicated it very likely that such heat waves will occur more frequently in the coming decades.[104]

Mitigating this view on the negative impacts of the water usage of nuclear power plants, the submission of ANSTO, stated that:

> Water consumption in conventional large 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 cooling water used in power reactors around the world is drawn from the sea or rivers, to which the water is returned only a few degrees warmer and with minimal loss due to evaporation.[105]

---

101 Frank Simpson, *Submission 24*, p. 3.

102 Ibid.

103 Noel Wauchope, *Submission 25*, p. 2.

104 Ibid.

105 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 47.

The submission also stated that 'when compared with other electricity generation technologies, power reactor water requirements are, on average, 2 to 4 times lower than that which is required for sought solar thermal and geothermal power plants.'[106]

However, ANSTO did acknowledge that while nuclear power is better than coal or biogas in terms of its operational water consumption, wind power uses almost no water.

Too slow to mitigate climate change

Another issue raised by opponents of nuclear power is the fact that there is a significant lead time to the construction and operation of nuclear power plants. As a result, it is argued that it will take far too long to get nuclear energy generation up and running in Australia to be of assistance in lowering Australia's emissions and having any impact on the mitigation of climate change.

Submitters have claimed a range of timeframes for a nuclear power plants to become operational, ranging from a relatively short timeframe of less than 10 years that has been suggested by vendors of nuclear power plants such as NuScale, to more than 20 years suggested by opponents of the technology.

During a public hearing, and in answer to a question about when its small modular reactor might be ready for generating electricity should it be allowed to do so, Mr Thomas Mundy of NuScale Power told the Committee that the time required to get a power plant up and running from approval would include the licensing activities, which he estimated in other countries takes between 36 to 48 months. It is unclear whether that is an accurate assessment of the process in Australia, as there is no nuclear industry that establishes any sort of benchmark for the licensing, environmental impact statements and other regulatory requirements. It was Mr Mundy's estimate that if they were to get approval 'soon', they should be able to generate electricity by the end of this decade—2029 or 2030.[107]

It is, of course, impossible to accurately forecast how long it would take to develop the technology in Australia as any nuclear power plants would be the first of a kind, which is likely to be slower in building than subsequent power plants. The regulatory framework would need to be developed before any construction would be able to take place, which is likely to take longer than in jurisdictions with a mature industry.

Significantly less optimistic timeframes were suggested by other submitters. MAPW Australia suggested in its submission that:

> If we experience the same degree of delays in construction as witnessed in other more prepared countries (cost blowouts, material and expertise and labour bottlenecks, unexpected developments)– then we should estimate more like 10 years to get from concrete to fission. Even if we assume novice Australian reactor program management can outstrip the French and the Americans, it is hard to see an Australian reactor

106 Ibid.

107 Mr Thomas Mundy, NuScale Power, public hearing, Melbourne, 14 August 2020, *Transcript of evidence*, p. 5.

> producing electricity—and thus abating greenhouse gas emissions—much before 2040.[108]

This time frame, they argue, is 'way too late', given the urgency to mitigate climate change.[109]

The Joint Civil Society Statement on Domestic Nuclear Power, supported this view stating:

> Nuclear power is a slow response to a pressing problem. Nuclear reactors are slow to build and license. Globally, reactors routinely take ten years or more to construct and time over-runs are common. Construction and commercialisation of nuclear reactors in Australia would be further delayed by the lack of nuclear engineers, a specialised workforce, and a licensing, regulatory and insurance framework.[110]

As suggested previously, the argument has been put that by the time a nuclear facility was developed in Australia, renewable energy development will be to a point that it can provide sufficient energy for Australia's needs.

Mr Holmes a Court in evidence told the Committee that the transition in Victoria's electricity sector:

> … likely will be mostly complete before we could build our very first nuclear reactor. Australia missed the first wave of nuclear power in the 70s and 80s. The second wave of nuclear is barely on the horizon, but it is looking like it might even be a mirage. If we needed nuclear power, this would be a tragedy, but thankfully we are on a path to decarbonising the grid without needing it. [111]

Contradicting this view, Bright New World, a strong advocate for the adoption of nuclear energy, has suggested that the belief that nuclear power plants take too long to build is misleading. In its submission to the Inquiry, Bright New World stated that the most rapid decarbonisation efforts have included nuclear build programs. 'The French nuclear program took 33 years to build 58 reactors. That's 1.75 commissioned reactors per year'. They said that:

> That's the very definition of the controlled sense of urgency we need to tackle a 'climate emergency'.[112]

The submission pointed to other examples of builds of nuclear power plants that were quicker than has been claimed by opponents of nuclear energy. Whether such speeds would be possible in Australia, without a track record of nuclear energy and therefore more streamlined licensing and regulatory arrangements, is an open question.

---

108 Medical Association for Prevention of War (Australia), *Submission 34*, p. 18.

109 Ibid.

110 Joint Civil Society Statement, *Submission 55*, p. 2.

111 Mr Simon Holmes a Court, *Transcript of evidence*, p. 14.

112 Bright New World, *Submission 74*, p. 53.

As with all elements of this Inquiry, evidence presented to the Committee have been claims and counterclaims, from a significant range of organisations and based on a significant range of expertise.

The Committee is not in a position to make judgements about the veracity of all of the claims about costs, timeframes or even environmental impacts. The reality is that while there is a prohibition on nuclear activities, many of these contentious issues will remain unresolved. The only way to determine the costs, timeframes, and environmental impacts is to go through a process of determining viability and the development of the business case, which would by necessity include environmental impact studies. As stated in a previous chapter, while the prohibition is in place such a business case is very unlikely to be developed.

8

9 Public opinion and social licence to operate

9.1 Community engagement

The issue of nuclear energy has proven to be particularly divisive amongst the general public, therefore any future development of nuclear-related activities in Victoria would need to be preceded by extensive community engagement, public debate and education. Community engagement should focus on capturing the broader views of the Victorian public but also needs to make a concerted effort to engage with local communities that might be directly impacted by proposed activities (i.e. host or neighbouring local government areas to nuclear or mining facilities). There was broad consensus amongst the Inquiry's stakeholders that public engagement is a very important element when developing nuclear activities because it builds a basis of knowledge enabling constituents and potential host communities to make more informed choices about whether they approve of expanding nuclear activities in Victoria.[1]

In its submission, Australian Nuclear Science and Technology Organisation (ANSTO) emphasised the importance of public support for the nuclear industry:

> … were the prohibitions to be lifted, it would be essential for any new nuclear activities in Victoria to obtain the broad support of the community. Methods for determining and assessing public sentiment exist and routinely are used by domestic and international policy-makers on a range of policy issues.
>
> The support of any potential host community/ies that stand/s to be most affected by the siting of a nuclear facility also would need to be obtained. Accordingly, any potential future proposal to establish nuclear power in the State or elsewhere in Australia would require comprehensive plans for community engagement and education—delivered at the local, regional, and national levels. It is only through such engagement that the community could gain the sufficient familiarity with, and understanding of, nuclear technology to be in a position to make an informed judgement as to whether Victoria could—and should—consider the inclusion of nuclear power in its energy mix.[2]

While there was broad consensus amongst stakeholders that public consultation is necessary when considering nuclear activities or introducing nucelar power to the energy mix, stakeholders were divided on whether this should occur prior to or after legislative prohibitions are repealed. Pro-nuclear stakeholders believed that proper public input or education could not occur until the prohibitions were repealed as this

1 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 18.

2 Ibid., p. 53.

would allow governments or industry groups to prepare a more fulsome business case in a local context rather than relying on case studies from international jurisdictions. Ms Jasmin Diab, Vice President, Women in Nuclear (WiN) Australia, at a public hearing, told the Committee that overturning Victorian legislative bans on mining and exploration 'will allow for an educated community engagement and public debate and the consideration of nuclear power as part of the energy mix for reducing carbon emissions and firming electricity supply'.[3]

However, several stakeholders believed that there should be public input into the debate on removing legislative prohibitions. Mr Tristan Prasser, in his submission, contended that community engagement 'should start with discussions around lifting the current state prohibition on nuclear power and uranium to allow further feasibility and development assessments to progress.'[4] However, Mr Prasser went on to say that if prohibitions remained in place during a public discussion on nuclear energy it would 'inhibit further community engagement and building of national consensus on this issue.'[5] This was echoed by Mr Dayne Eckermann, General Manager, Bright New World who argued that it would very difficult to conduct feasibility studies in Australia if prohibitions remained in place because the costs and time associated with community consultation could not be justified with them in place.[6]

Public education was widely considered by stakeholders to be an important part of community consultation because it would better ensure that people are able to make an informed decision about repealing prohibitions or introducing nuclear activities. Any proposals would require a detailed plan for public education and input at State, regional and local levels that seeks to provide citizens and communities gain sufficient understanding of nuclear technology and if it should be included as part of a future energy mix.[7]

In its submission, WiN Australia recommended that:

> Education campaigns should be used to address the gaps amongst the general public in both understanding of nuclear energy and understanding of how deep decarbonisation could be achieved.[8]

At a public hearing, in response to a question about what is required to get a social licence for nuclear Mr Barrie Hill responded that education was critical:

> One word: education. What we find around the world is most countries with existing nuclear power plants have got a much better educated community who have a much better understanding.[9]

3 Ms Jasmin Diab, Vice-President, Women in Nuclear (WiN) Australia, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 10.

4 Tristan Prasser, *Submission 80*, p. 10.

5 Ibid.

6 Mr Dayne Eckermann, General Manager, Bright New World, public hearing, Melbourne, 14 August 2020, *Transcript of evidence*, pp. 28–9.

7 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 53.

8 Women in Nuclear (WiN) Australia, *Submission 36*, p. 23.

9 Mr Barrie Hill, public hearing, Melbourne, 28 August 2020, *Transcript of evidence*, p. 31.

The former Ministerial Council for Minerals and Petroleum Resources published the *Principles for Engagement with Communities and Stakeholders* which outlined five general principles necessary for effective public engagement at a site-specific level. However, it acknowledged that community engagement should be tailored by project as factors like location, size and type are important considerations for potential host communities and the general public. The five principles for engagement with communities and stakeholders are:

1. **Communication:** open and effective two-way communication, clear, accurate and relevant information, and timeliness.
2. **Transparency:** clearly identifying an engagement strategy and the objective and outcomes of the project; this should include proper reporting and documentation.
3. **Collaboration:** working cooperatively with the community and key stakeholders to ensure mutually beneficial outcomes.
4. **Inclusiveness:** involve communities and stakeholders early and consistently throughout the process.
5. **Integrity:** conducting engagement in a manner that's fosters trust and mutual respect to build credibility and confidence.[10]

The Committee believes that the above principles are important guiding considerations for any public consultation strategy accompanying investigation into nuclear activities in Victoria. Prior public consultation and input would be imperative if a government were to contemplate lifting legislative prohibitions on nuclear activities as a way to allow for research and development into the viability of a nuclear industry in Victoria or anywhere else. Like this Inquiry, consultation should endeavour to involve the broader Victorian community through providing public forums where constituents can share their views on proposed legislative changes or development of nuclear activities. But it would also need to make a concerted effort to involve potential host communities where infrastructure could be located and seek community consent from these areas.

9

9.1.1 Traditional Owners and First Nations People

Several stakeholders expressed concern that the introduction of nuclear fuel cycle activities, such as mining or exploration, can disproportionately impact aboriginal communities. The Proforma A submission stated that the 'nuclear industry has a history of adverse impacts on Aboriginal communities, lands and waters' and that the 'problems would be magnified if Australia ever advanced domestic nuclear power.'[11]

ANSTO contended that if prohibitions on uranium exploration and mining activities in Victoria were lifted it would be essential that the rights, including Native Title claims and determinations, of Aboriginal people be respected and activities should be to the

10 Ministerial Council on Mineral and Petroleum Resources, *Principles for Engagement with Communities and Stakeholders*, Canberra, 2005, pp. 13–8.

11 *Submission Proforma A*, p. 2.

benefit of host communities and surrounding regions.[12] In its submission ANSTO noted that the 'majority of uranium deposits in Australia and around the world are located on the traditional lands of tribal and first peoples.'[13] Therefore, ANSTO argued that the 'consequence of not meeting community expectations in this regard could be the withdrawal of public support and community consent for those activities to occur.'[14]

The South Australia Nuclear Fuel Cycle Royal Commission (SANFCRC) discussed the importance of engaging with Aboriginal communities throughout the lifecycle of a proposed nuclear facility project. This was considered particularly important because of the profound and enduring impacts previous nuclear activities, such as nuclear weapons testing during the 1950s at Maralinga (South Australia), have had on Aboriginal communities. The Commission's report stated that any specific proposals on land where there are Aboriginal rights and interests there is a strong impetus to:

> … demonstrate to Aboriginal communities' satisfaction how the development would be different to the atomic testing and how lessons had been learned from the past. A fundamental lesson, which should be applied from now, is that any new nuclear activity should not proceed unless and until the health and environmental risks are fully understood by the affected community… Depending on the location and nature of the activity, this may need to address whether any particular risks arise for Aboriginal traditional and contemporary lifestyles.[15]

The Royal Commission discussed the need to establish appropriate frameworks for engaging with Aboriginal communities as part of the broader strategy of community engagement for proposed nuclear fuel cycle activities. The report stated that strategies for engaging Aboriginal communities could include:

> … native title representative organisations, prescribed bodies corporate, Indigenous land use agreements and native title management committees. These structures have processes through which information is presented to and discussed and debated in Aboriginal communities.[16]

In the Committee's view if further community consultation is required in Victoria related to exploration or mining of nuclear materials, there should be a concerted and deliberate effort to include Aboriginal communities, particularly those on lands where proposed facilities or projects could be located. The Committee acknowledges the disproportionate impact of nuclear-related activities Aboriginal communities have faced in the past, and the potential heightened effects for these communities if nuclear activities were to be allowed in Victoria or elsewhere. Therefore, governments and industry representatives should purposefully engage with these communities both in the discussion of lifting prohibitions and about specific project proposals. This should

12 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 19.

13 Ibid., p. 18.

14 Ibid., p. 19.

15 Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, Government of South Australia, South Australia, 2016, p. 126.

16 Ibid.

occur within a larger strategy of community consultation and public input, and seek to engage with Aboriginal communities through targeted means that acknowledges the complex issues and concerns uniquely faced by their members.

9.2 Social licence to operate

Social licence to operate, often simply called social licence, refers to the level of approval or acceptance granted to an organisation's activities by its employees, stakeholders and the general public; especially host communities directly impacted by said activities. The concept of social licence emerged in the late 1960s from the mining industry, developing from the idea of corporate social responsibility as community scrutiny of environmental and social performance increased and influenced the actions of industries. For the mining industry, social licence specifically referred to ongoing acceptance of mining operations by host communities, stakeholders and the wider public.[17]

An issues paper prepared by the New South Wales Parliamentary Research Service on 'Uranium Mining and Nuclear Energy in New South Wales' explained the difference between social licence and social impact assessments, writing:

> A social licence to operate should be distinguished from the more formal social impact assessments, which involve a comparison of expert opinions. A social licence must be earned from the community, while a legal licence is issued by a governing authority; regulatory approval does not necessarily equate to social approval.[18]

The Committee discussed the issue of social licence with many stakeholders throughout the Inquiry in the context of lifting nuclear prohibitions generally and the introduction of nuclear-related activities, particularly mining and exploration which is prohibited under the scope of the Victorian legislation. The question of social licence to operate for nuclear is an important consideration for both sides of the debate. There was general consensus amongst stakeholders that before nuclear activities are introduced in Victoria, or elsewhere, there should be considerable community engagement which seeks to answer the question of whether social licence exists for the nuclear industry, in both a general sense but also for specific activities.

The following section explores the views of various stakeholders on the importance of social licence and social consent for the nuclear industry. The evidence examined addresses the myriad of considerations and questions which need to go into assessing whether there is a social licence for nuclear in Victoria or what is missing that might prevent it from being achieved; this emphasises the importance of community engagement and debate for the energy industry, particularly as it seeks to transition towards new technologies. This section will look at social licence as a general concept, but also consider the issues of community consent, and intergenerational equity which

17 New South Wales Parliamentary Research Service, *Uranium Mining and Nuclear Energy in New South Wales*, issues paper, September 2019, p. 120.

18 Ibid.

are closely related to and influence social licence to operate. The Committee asserts that all of these factors need to be considered in the discussion of nuclear energy through community engagement and public debate, in particular with potential host and neighbouring communities.

Many anti-nuclear stakeholders contended that the nuclear industry does not have a social licence to operate with majority of community sentiment remaining against the introduction of nuclear activities in Australia. The following excerpts taken from both submissions and evidence given at public hearings highlight this contention:

- 'The industry does pose unique challenges and risks, and it also faces, I would say, extensive non-regulatory hurdles. It does not enjoy social licence or community acceptance.'[19]
- 'VTHC does not consider nuclear power to have the social licence to operate in Victoria. Instead, the political energy, investment and time required to adopt nuclear in Victoria could be better spent delivering a significantly faster and safer transition for workers and their communities to a renewable energy future.'[20]
- 'Legislation banning nuclear power should also be retained because there is no social license to introduce nuclear power to Australia… Opinion polls find that Australians are overwhelmingly opposed to a nuclear power reactor being built in their local vicinity (10–28% support, 55–73% opposition)…'[21]

Mr Trevor Gauld, National Policy Officer, Electrical Trades Union argued that renewable energy does have a social licence to operate so investment and development should focus on developing renewables rather than trying to ascertain if nuclear energy has social licence:

9

> I guess the biggest point for us now is that the renewable industry has got community acceptance, it has got social licence, it is being deployed now and it is employing now. It does not, other than the Star of the South, have regulatory hurdles. Why? Why would we not just choose to better invest and plan the thing that is already here that is cheaper?[22]

The issue of social licence was also discussed by many pro-nuclear stakeholders who acknowledged it was important part of moving towards introducing nuclear-related activities in Victoria. They emphasised that an important part of assessing whether there is a social licence for the industry or to move in that direction requires open and transparent information about what is being proposed. There should be honest education about the types of projects being proposed, where they could be located and what the impacts of the project could, including any potential human or environmental risks.

---

19 Mr Dave Sweeney, Nuclear Free Campaigner, Australian Conservation Foundation, public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 13.

20 Victorian Trades Hall Council, *Submission 61*, p. 2.

21 Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*, pp. 6–7.

22 Mr Trevor Gauld, National Policy Officer, Electrical Trades Union, public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 8.

In its submission, the Construction, Forestry, Maritime, Mining and Energy Union (CFMMEU) (Mining and Energy Victoria) asserted that a 'just transition' of the coal industry would play an important role in obtaining social licence for the nuclear industry:

> … a 'Just Transition' to nuclear power could provide the essential social licence for this proven technology to overcome lingering public concerns around its safe operation in local communities where they might be located if locally they were to replace existing coal generators.
>
> …
>
> A fair and just transition for coal industry workers and their community is unlikely to be facilitated through any full transition to renewable energy… The direct replacement of coal fired power stations with nuclear power could ensure a fair and just transition for existing coal workers, their families and communities. This could be a very valuable asset needed to overcome any local public resistance to the introduction of nuclear power because of the "not in my back yard" mentality.[23]

This was reiterated by the Union's Secretary, Mr Geoff Dyke, at a public hearing, who stated:

> We have well-educated and skilled workers, stable government, good industry regulation and—probably more importantly—communities who need viable transitions. And that is a critical part of the social licence for establishing [the nuclear industry].[24]

9

Mr Mark Richards, Mining and Energy Division, CFMMEU, contended that local factors influence the debate on social licence and should be factored into broader discussions. Mr Richards, in his evidence, discussed that the issues created from the declining coal industry, namely unemployment and safeguarding grid stability, need to be considered alongside the question of social licence in the debate around nuclear energy. It was suggested that these types of local factors can shape community views on nuclear energy, and that contextualising the nuclear debate alongside local factors is important. In evidence, Mr Richards stated:

> Where it fits into the social licence for our area is that we have high unemployment, as we mentioned, and we have coal that is being shut down and phased out… [Nuclear] is the same jobs; it is the same technologies. We have the same workers transitioning to an equal spec job, to be honest, and we do have hundreds unemployed. We lost over 700 people at Hazelwood directly—3000 if you look at the numbers there. With Yallourn power station at a very similar age and quality of plant, that may be closing—they are predicting, I think, 2032, but there is the belief that it will happen before that. So we are concerned about, you know, the grid collapsing as well as jobs; that is where it fits into our social licence.[25]

---

23 Construction, Forestry, Maritime, Mining and Energy Union, *Submission 20*, pp. 3, 13.

24 Mr Geoff Dyke, Secretary, Victorian Branch, Construction, Forestry, Maritime, Mining and Energy Union, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, pp. 1–2.

25 Mr Mark Richards, Mining & Energy Division, Construction, Forestry, Maritime, Mining and Energy Union, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 3.

This was echoed by Mr Robert Parker, Vice President, Australian Nuclear Association who also discussed that social licence is an important issue but this should be done within a context which acknowledges the impacts of winding down the coal industry. Mr Parker also used the example of the Latrobe Valley, at a public hearing he argued that:

> Yes, social licence is an issue, but one of the greatest resources of the Latrobe Valley I became aware of when we spoke to union groups within the Latrobe Valley and also with the Latrobe City Council —I became incredibly aware —was the huge human resource in the Latrobe Valley, the trade skills. I became aware of what we are seeing in some towns such as Morwell: increasing destabilisation as a result of the winding back of the coal plant and that there is increased economic pressure on those communities. We could revitalise those communities. We could certainly lift up the technical skills…[26]

In the Committee's view, obtaining the social licence to operate is an important factor for any nuclear activity or facility; particularly because there has been ongoing, and often times substantial opposition to the introduction of nuclear energy or nuclear‑related activities in Victoria and Australia. While the Committee notes the question of whether Victorian bans should be lifted puts more focus on exploration and mining, rather than energy production, nonetheless social licence remains important.

The Committee perceives that there are two social licence questions to be answered: the general social licence of a nuclear industry and the specific social licence of a nuclear activity or facility. The former can be answered partially by seeking community input into whether the current prohibitions should be lifted. However, the Committee believes that a more fulsome public debate on nuclear generally and associated activities specifically is hindered by the current prohibitions, even if the discussion only focuses on exploration and mining activities. As has been discussed several times throughout this report, the current legislative bans make it unlikely that any detailed business case or feasibility study would be conducted, the outcome of which would be important evidence to consider in a public debate on nuclear activities.

9.2.1 Community consent

For any nuclear‑related activity it is important to obtain community consent from areas likely to be more directly impacted. Project proponents should identify the membership of a community where consent ought to be obtained and engage in thorough, transparent and detailed discussion with those community members seeking to obtain their approval to host or be neighbour to nuclear facilities or activities. If a proposal is more widespread or considerable, broader community consent is required.[27]

26 Mr Robert Parker, Vice President, Australian Nuclear Association, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, p. 18.

27 New South Wales Parliamentary Research Service, *Uranium Mining and Nuclear Energy in New South Wales*, p. 119.

Several lessons can be learned from the international nuclear industry's approach to community engagement and consent during the 1970s and 1990s which emphasise the importance of obtaining consent for a nuclear project. It was found that:

> Developments failed when plans to site new nuclear facilities considered only technical characteristics or communities were not consulted, or governments pushed ahead without consent. Since the mid-1990s, most governments and proponents of nuclear developments adopted a new approach that involved communities in decisions relating to nuclear sites.[28]

Some stakeholders pointed to the recommendations of the Standing Committee on the Environment and Energy's (Cth) *Inquiry into the prerequisites for nuclear energy in Australia* as evidence of the importance of community consent for nuclear energy or activities. That Committee recommended that any lifting or partial lifting of nuclear prohibitions needed to be 'subject to the results of a technology assessment and a commitment to community consent as a condition of approval.'[29]

In its submission, ANSTO suggested that a consequence of not meeting community expectations or understanding of the risks and benefits of a nuclear-activity could result in the withdrawal of community consent for those activities to occur.[30] The submission argued that because any nuclear activity has been the 'subject of considerable community debate and, in some cases, concern,' project proponents are required to facilitate or assess the support and consent of the general public and potential host communities.[31]

Mr Benjamin Cronshaw predicted that 'there would be problems getting community consent and bipartisan support for uranium mining in Victoria'.[32] But he believed it would be useful to assess whether any related activities were economically and technologically viable and could be 'acceptable to the community.'[33]

Several pro-nuclear stakeholders who discussed the issue of social licence and community consent with the Committee recommended that the siting process of a nuclear facility should involve some degree of volunteerism by the host community. This processed was used for the siting of the proposed National Radioactive Waste Management Facility (NRWMF) where the project proposal was made public and communities nominated their interest in hosting the facility; the Commonwealth Government was then required to choose an appropriate site from the pool of locations that had been nominated. The process for identifying a site for the NRWMF involved two stages of nominations. A nomination by an Aboriginal Land Council of Aboriginal

28 Ibid.

29 Parliament of Australia, House of Representatives Standing Committee on the Environment and Energy, *Not without your approval: a way forward for nuclear technology in Australia*, December 2019, p. 53.

30 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 18.

31 Ibid.

32 Mr Benjamin Cronshaw, *Submission 41*, p. 5.

33 Ibid.

land within the area of the Council preceded a general nomination of potential sites by persons who held an interest in the site.[34]

At a public hearing, Mr Dayne Eckermann, General Manager, Bright New World, asserted that the process for gaining consent for nuclear facilities needs to involve transparency around the risks and benefits of the technology, he stated:

> With regard to social licence, that process as well as another process we have going on here in South Australia at the same time for the nuclear waste facility for low-level and intermediate waste –these two events –demonstrated that you can be quite open and honest about the benefits and risks of nuclear power or nuclear technologies and work with the community. You do not basically plonk in a project, announce it and then defend it from criticism and that sort of stuff. You go, 'Look, we're thinking of building a nuclear power plant and we need these favourable characteristics', which is what they did with the nuclear waste facility, 'Is there anyone out there that is interested in doing this and exploring it?'. There are gateways so you can say, 'No, we don't want this anymore', and then the project proponent will have to turn around and go, 'Okay, fair enough'.[35]

Mr Eckermann concluded that:

> That kind of standard community engagement that was set up in that process is a way in which a community can look at these kinds of technologies and enter in softly, understand what is being proposed and then make a decision on whether it is something that they would be happy to have.[36]

The SANFCRC made a finding on the successful processes for engaging a community with the aim of getting consent for a nuclear facility. The Royal Commission found that the community consent processes should include the following key characteristics:

- **Transparency:** the decision-making framework and licensing and approval requirements should be transparency; and project proponents should demonstrate a willingness to change the framework to meet new or unforeseen developments.
- **Longer community engagement:** be prepared to engage in a longer community engagement process than is usual for other typical developments and avoid arbitrary deadlines.
- **Early and deep engagement:** with local communities to ensure they have proper knowledge and understanding of the proposal by using partnership models for community engagement.
- **Learning processes:** provide opportunities for local communities to engage in learning processes about what hosting the facility would entail without actually committing to hosting facility.

---

34 *National Radioactive Waste Management Act 2012* (Cth) ss 5(1), 7(2).

35 Mr Dayne Eckermann, *Transcript of evidence*, p. 25.

36 Ibid.

- **Resourcing:** for a community organisation to deliberate on the proposal and engage independent advice to review information.
- **Independent regulator:** that is trusted and experienced and that are accessible to the community and willing to provide information on the regulatory and decision making process, proposal and varying views.
- **Availability of scientific evidence:** preferably from multiple bodies.
- **Provision of benefits:** for the community for the service it is providing to wider society through hosting the nuclear facility.
- **Continuity of individuals:** involved in the development and delivery of the project.[37]

The Committee agrees in principle with the community consent factors outlined by the Royal Commission. Large portions of the public are concerned about the risks associated with nuclear energy or nuclear related activities, therefore, it is important that any proposed activities seek to gain broader public acceptance and the consent of potential host communities. Furthermore, any project proposal needs to specifically engage with potential host communities, and neighbouring communities, using the above characteristics to develop a comprehensive community engagement plan with the goal of getting consent to site a nuclear facility.

The remit of this Inquiry is to explore the potential benefits to Victoria in removing prohibitions under the *Nuclear Activities (Prohibitions) Act 1983* (Vic), which pertains to uranium mining and exploration and the construction of nuclear facilities, not the use of nuclear as an energy source. Therefore, community engagement proceeding from this Inquiry would be focused on these issues, unless there was a repeal or consideration to repeal federal prohibitions. Nonetheless, until prohibitions are lifted it is likely to be difficult to engage in deep community engagement in Victoria with potential host communities because this would require a detailed project plan for citizens to consider. As discussed throughout this report, a detailed project plan is unlikely to be made until the viability of a nuclear activity is proven through a feasibility study, including environmental impact studies, and a business case proving its economic viability. This is unlikely to occur whilst prohibitions in Victoria remain in place, as this type of business case study would be time consuming and costly.

9.2.2 Intergenerational equity

Intergenerational equity is a legal principle which affirms that the present generation has a responsibility to ensure the health and protection of the environment are maintained or improved for the benefit of future generations. This principle is highlighted in legislation, including: s 1D of the *Environment Protection Act 1970* (Vic) and s 3A(c) of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

37 Honourable Kevin Scarce, *Nuclear Fuel Cycle Royal Commission Report*, pp. 122–5.

Section 1D of the Environment Protection Act reads that:

> The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.[38]

Intergenerational equity is based on three factors of conservation:

- **Conservation of options:** requires each generation to conserve natural and resource diversity to ensure future generations have options for solving their own problems and meeting their needs.
- **Conservation of quality:** requires each generation to maintain the quality of natural and cultural environments so that they are not passed onto future generations in a worse condition than they were received.
- **Conservation of access:** requires each generation to gives it members equitable access to the legacy of past generations and conserve this access for future generations.[39]

The issue of intergenerational equity was discussed largely indirectly with the Committee through stakeholder concerns about the legacy a nuclear activity could be leaving for future generations. Many stakeholders believed that the management of nuclear waste just shifts the problem of disposal to future generations or could have environmental impacts that undermine the conservation of options and quality principles. For a more detailed discussion on waste management issues raised by stakeholders refer to Chapter 8

Mr Bart Wissink's submission outlined the key criteria the World Nuclear Association considers to determine if nuclear fuel management is sustainable. This included the criteria that it 'protects human health and the environment has no greater impact on the health of future generations than is allowed today' and that 'it answers to a present need but does not impose burdens on future generations.'[40]

One submitter, on a modified Proforma A submission, requested that 'All politicians in Victoria should think very carefully about the legacy they will leave to future generations and show their total support for nuclear prohibition…'.[41]

Several anti-nuclear stakeholders contended that the introduction of nuclear energy or related activities would create untenable issues for future generations, such as the waste management problem, environmental pollution and others. The following excerpts are indicative of the concerns raised by these stakeholders:

---

38 *Environment Protection Act 1970* (Vic) s 1D.

39 New South Wales Parliamentary Research Service, *Uranium Mining and Nuclear Energy in New South Wales*, pp. 117–8; Edith Brown Weiss, 'Intergenerational equity: a legal framework for global environmental change', in, *Environmental change and international law: New challenges and dimensions*, United Nations University Press, Tokyo, 1992, pp. 10, 12.

40 Mr Bart Wissink, *Submission 29*, p. 470.

41 Ms Margaret Devine, *Submission 7*, p. 1.

- 'If the policy of leaving bulk radioactive materials in situ continues, it would be deeply unfair to present inhabitants, title holders and future generations to open up more sites to mining of radioactive materials... There will be no net gain to future generations if one pollutant (for which there are renewable alternatives) is substituted by another that has more insidious impacts requiring control and management on timescales far into the future.'[42]
- 'Society can sometimes be bought with incentives for the present generation, but the costs of getting it wrong will be borne by future generations.'[43]
- 'Chernobyl and Fukushima are no-go zones and will continue to be for generations. Exclusion zones of many thousands of square kilometres have created economic dead zones which will remain long into the future.'[44]
- 'We feel that present-day generations have no right at all to impose on futures ones the enormous cost of human resources to care for the wastes and obsolete installations they leave behind them, to say nothing of the continuous risks this involves.'[45]
- '[Waste] is a serious issue that has definitely not been solved as most radioactive materials have a half life between 10,000 and 1,000,000 years. In other words, we not only have to ensure that these final resting places for such dangerous materials keep us and our children safe, but also thousands of generations down the line.'[46]

In contrast, some pro-nuclear stakeholders argued that the introduction of nuclear energy would ensure intergenerational equity because its low-emission technology would assist with decarbonisation and Australia's climate change goals.

9

Dr John Patterson, in his submission, expressed concern that the 'current situation with regard to the menace of Climate Change for our future generations in Australia and overseas.'[47] He contended that nuclear energy could be an 'indispensable part of reducing our carbon dioxide emissions' in alignment with Australia's decarbonisation goals.[48]

Dr Mark Ho, President, Australian Nuclear Association, explained:

> ... nuclear power is a key component of many countries' plans for a clean energy future with low, carbon emissions. With around 440 reactors operating in the world today, nuclear power is a proven form of clean and reliable electricity generation.[49]

---

42 Rosamund Krivanek, *Submission 65*, p. 5.

43 Philip White, *Submission 17*, p. 4.

44 Mr Trevor Gauld, *Transcript of evidence*, p. 2.

45 Uniting Church in Australia (Synod of Victoria and Tasmania), *Submission 70*, p. 11.

46 Frank Simpson, *Submission 24*, p. 5.

47 Dr John Patterson, *Submission 28*, p. 1.

48 Ibid.

49 Dr Mark Ho, President, Australian Nuclear Association, public hearing, Melbourne, 25 June 2020, *Transcript of evidence*, pp. 16–7.

10 Nuclear activities in Victoria

10.1 Nuclear-related opportunities in Victoria

As discussed throughout this report, Victorian legislation prohibits uranium and thorium mining and exploration with federal legislation prohibiting the use of nuclear materials for energy production or establishing nuclear reactors. The Committee was tasked with examining potential opportunities for Victoria to participate in the nuclear fuel cycle and the benefits of removing current prohibitions enacted by the *Nuclear Activities (Prohibitions) Act 1983* (Vic). The following section looks at nuclear-related opportunities in Victoria for medicine and thorium exploration and mining.

The Committee contends that assessing potential benefits or opportunities in a Victorian, or even Australian, context is difficult because of the existing prohibitions. As noted in other sections of this report, the viability of any nuclear activity is difficult to measure because current state and federal prohibitions (set out in Chapter 2) limit the ability for research to be conducted. Instead, governments and industry need to rely on examples from other parts of the world or speculative studies when assessing any potential opportunities. This approach has several limitations, namely that local factors play a significant role in determining viability and strengths of nuclear activities or energy production; therefore, examples from other countries have limited applicability. Current prohibitions are a deterrent to research and assessment of nuclear in a local context, making it difficult to develop accurate business cases or viability studies which could be used to properly assess if a nuclear activity or industry should be established in Victoria. By establishing more accurate feasibility studies in a Victorian context, governments, the industry and the general public are better educated about what nuclear could mean for the community and can make a more informed choice about whether Victoria should expand its participation.

10.1.1 Nuclear medicine

Nuclear medicine, also known as molecular imaging, is a specialised area of radiology that uses very small amounts of unsealed radioactive materials (radiopharmaceuticals) 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 (function). Nuclear medicine therapy may be used to control, and in some cases cure, a range of conditions such as thyroid cancer, overactive thyroid, and bone pain caused by cancer metastasis.[1] This branch of radiology is often used to help diagnose and treat abnormalities very early in the progression of a disease, such as thyroid cancer.[2]

1 Australasian Association of Nuclear Medicine Specialists, *What is Nuclear Medicine?*, n.d., <https://aanms.org.au/what-is-nuclear-medicine> accessed 08 April 2020.

2 John Hopkins Medicine, *Nuclear Medicine*, n.d., <https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/nuclear-medicine,> accessed 08 April 2020.

The main difference between nuclear imaging and other imaging systems is that, in nuclear imaging, the source of the emitted radiation (the radioisotope) is within the body. Nuclear imaging shows the position and concentration of the radioisotope. Both bone and soft tissue can be imaged successfully with this system.[3]

How does nuclear medicine work?

Soft tissue such as intestines, muscles, and blood vessels are difficult to map using a standard X-ray unless a contrast agent is used because x-rays pass through them. Nuclear imaging uses a tiny amount of radioactive substance as a contrast agent for a scan. The radioactive substance (called a radionuclide, radiopharmaceutical or radioactive tracer), is given orally, injected or inhaled and absorbed by body tissue, causing that tissue to give off radiation, which is detected by a radiation detector (usually a gamma camera) enabling digital signals to be produced and stored on computer.[4]

The extent to which a radiopharmaceutical is absorbed, or 'taken up', by a particular organ or tissue can indicate the level of function of the organ or tissue being studied.[5] By measuring the behaviour of the radionuclide in the body during a nuclear scan, a healthcare provider can assess and diagnose various conditions, including:[6]

- tumours and cancers
- aneurysms
- irregular/inadequate blood flow to tissues
- infections
- haematomas
- organ enlargement
- cysts.

Several different types of radionuclides are available, including the elements technetium, thallium, gallium, iodine, and xenon. The type of radionuclide used depends on the type of study and the body part being studied.[7]

Common nuclear medicine techniques include:[8]

- Positron Emission Tomography (PET)
- Single Photon Emission Computed Tomography (SPECT)

---

3 Australian Nuclear Science and Technology Organisation, *What are radioisotopes?*, n.d., <https://www.ansto.gov.au/education/nuclear-facts/what-are-radioisotopes> accessed 9 April 2020.

4 John Hopkins Medicine, *Nuclear Medicine*.

5 Australasian Association of Nuclear Medicine Specialists, *What is Nuclear Medicine?*

6 John Hopkins Medicine, *Nuclear Medicine*.

7 Ibid.

8 Australasian Association of Nuclear Medicine Specialists, *What is Nuclear Medicine?*

- cardiovascular imaging
- bone scanning.

In Australia, nuclear medicine is provided by recognised specialist medical practitioners who have undertaken an advanced speciality three-year training program post-Fellowship of either the Royal Australasian College of Physicians or the Royal Australian and New Zealand College of Radiologists. There are approximately 450 credentialled specialists in nuclear medicine in Australia who deliver nuclear medicine services at approximately 200 sites across Australia. The Australasian Association of Nuclear Medicine Specialists is the main organisation in Australia representing the speciality of nuclear medicine, taking a major role in the promotion and advancement of the clinical practice of nuclear medicine and having responsibility for accreditation of both practices and training sites.[9]

In Victoria, the *Radiation Act 2005* (Vic) establishes a system of licensing for users of radiation equipment and managers of radiation practices. Radiation licenses are issued by the Department of Health and Human Services. Nuclear medicine specialists, technicians and radiologists require a 'use license' to operate radiation sources/units in Victoria. Compliance with the *Code of Practice for Radiation Protection in the Medical Applications of Ionizing Radiation* is a condition of such licences. A use license allows an individual to use specific types of radiation sources for a specific purpose. Failure to hold the required use license is an offence under the *Radiation Act 2005*.[10]

The Australian Synchrotron is located in Clayton, Victoria and is operated by the Australian Nuclear Science and Technology Organisation (ANSTO). According to ANSTO's submission the Australian Synchrotron:

> … facilitates research with applications across numerous industries and sectors, including medicine, manufacturing, nanotechnology, and minerals exploration. Using accelerator technology to produce a powerful source of light many times brighter than the sun, the facility allows for the examination of the atomic and molecular detail of materials'.[11]

10

The Australian Synchrotron's applications include:

- drug discovery
- health product and medical device development
- additive and chemical manufacturing
- energy extraction and conversion
- energy storage and transportation
- environmental monitoring

9 Ibid.

10 Department of Health and Human Services, *Medical*, n.d., <https://www2.health.vic.gov.au/public-health/radiation/licensing/use-licences-employees/sector-specific-information/medical> accessed 9 April 2020.

11 Australian Nuclear Science and Technology Organisation, *Submission 62*, p. 34.

- minerals processing
- resource exploration
- waste management and remediation
- biofortification and solid state analysis
- commercial process evaluation
- composite materials.[12]

ANSTO described the Australian Synchrotron as an 'anchor tenant' for medical research, technology and innovation which has been used to 'anchor a number of medical sector collaborations with Victorian institutions in recent years.'[13] For example, the Synchrotron played a role in the discovery of Venetoclax, which is a medication treatment for Chronic Lymphocytic Leukaemia (CLL).[14]

Are legislative prohibitions hindering the nuclear medicine sector?

Some stakeholders believed that legislative prohibitions are hindering research and development for the nuclear medicine sector, particularly in Victoria. The following excerpts are taken from submissions which are indicative of assertions made by some stakeholders:

- 'Future projections for radiopharmaceuticals place Australia in a prime position currently to take advantage of [the industry's] growth, if the moratorium on nuclear technologies is lifted.'[15]
- 'Yet Victoria, which views medical and pharmaceuticals as a priority industry, is effectively stopping itself from fully participating in the sector.'[16]

In its submission, Telix Pharmaceuticals believed that 'future nuclear energy needs could be symbiotically planned with a number of allied industries in mind, such as medicine… fully integrated alongside nuclear power generation'.[17]

The Minerals Council of Australia suggested in its submission that the 'Victorian government has identified a number of priority industries and sectors which will underpin economic growth and jobs',[18] one of which was medical/ pharmaceuticals. Its submission contended that the *Nuclear Activities (Prohibitions) Act 1983* 'is impeding Victoria as it attempts to foster emerging industries, particularly those identified as priority sectors'.[19]

---

12 Ibid.

13 Ibid.

14 Ibid. CLL is the most common type of leukaemia in the country, with around 350 people dying from the disease and 1300 new diagnoses each year.

15 Marcos Fernandes, *Submission 64*, p. 6.

16 Minerals Council of Australia, *Submission 78*, p. 4.

17 Telix Pharmaceuticals Limited, *Submission 58*, p. 2.

18 Minerals Council of Australia, *Submission 78*, p. 4.

19 Ibid.

The Committee notes that the *Nuclear Activities (Prohibitions) Act 1983* (Vic) does not explicitly deal with the use of nuclear materials for medicinal purposes, but it does prohibit the construction of nuclear reactors. This prevents Victoria from establishing a nuclear reactor for medical and industrial purposes which could be used to produce and supply radioisotopes for medical and industrial applications. In the Committee's view this is the extent that current Victorian prohibitions impact the nuclear medicine or pharmaceutical sector. If Victoria was interested in becoming a supplier of radioisotopes for medical or industrial purposes the legislative prohibitions would need to be repealed. However, as mentioned throughout this report Victoria does receive supply of radioisotopes both from materials imported into Australia and from the OPAL reactor at Lucas Heights (NSW).[20]

Some stakeholders believed that Victoria could host nuclear facilities in addition to the Australian Synchrotron for medical and industrial purposes. A common suggestion was the establishment of a second nuclear research reactor, like the OPAL reactor, to prevent medicinal supply shortages which have occurred in the past when there have been outages in the New South Wales reactor. In his submission, Mr Logan Smith argued that the legislative ban on nuclear reactors prevents Victoria from more meaningfully participating in the nuclear medicine sector and that removing prohibitions would give Victoria opportunity to 'examine the practicality and viability of a second facility to produce medical and industrial isotopes to help secure continued supply, should one facility enter a shut-down period.'[21] Similarly, Dr Sarah Lawley's submission advocated that 'Victoria could also host advanced facilities' in addition to the Australian synchrotron.[22]

At a public hearing, Dr Carl-Magnus Larsson, CEO and Deputy CEO, Australian Radiation Protection and Nuclear Safety Agency, in response to a question about if a second research reactor is needed in Australia to support the Lucas Heights in meeting demand responded:

> I think the government's consideration at the time when it was decided to fund the new facility at Lucas Heights was that there should be production in Australia. Theoretically Australia could rely on the importation of these substances, but that would mean being dependent on a relatively small number of producers around the world. In some cases also these producers operate ageing facilities and ageing reactors, so there is uncertainty around the possibility to sustain a steady supply of nuclear medicine. We are talking here about molybdenum-99 and technetium-99.
>
> The ANM [Australian Nuclear Medicine] facility, or the new facility, at Lucas Heights is obviously a facility that is intended to make sure that we can sustain the supply to the Australian market. There are considerations that would have to go into a decision that expand the production capacity. That has to do with the economy, and this outside the

20 Mr Noel Cleaves, Manager, Environment Health Regulation and Compliance, Department of Health and Human Services, public hearing, Melbourne, 12 March 2020, *Transcript of evidence*, p. 16.

21 Mr Logan Smith, *Submission 43*, p. 3.

22 Dr Sarah Lawley, *Submission 49*, p. 2.

> remit that we have. Our remit is the health and safety of the workers and the public. That is our focus, so am not really able to answer your question because that, again, would be a policy decision.[23]

Some anti-nuclear stakeholders refuted claims that current bans have impacted the nuclear medicine sector and that Victoria could significantly expand its participation in the sector if it removed its prohibitions.[24] At a public hearing, Dr Margaret Beavis, Medical Association for Prevention of War (Australia) critiqued the assertion that current prohibitions are hindering research into nuclear medicine, she stated that the suggestion 'not having a reactor is holding back medical research' is 'plainly nonsense'.[25] This was echoed in Ms Rosamund Krivanek's submission which contended that 'nuclear medicine and scientific research are established activities that do not rely on a hugely expanded nuclear industry.'[26]

Mr Trevor Gauld, National Policy Officer, Electrical Trades Union believed that there is 'no demand for expansion' of facilities, such as a research reactor, for nuclear medicine, at a public hearing he stated:

> They currently satisfy Australia's needs. They are already established. In fact, we could reduce our demand on those facilities if we moved away from developing some of those medicines using nuclear and in fact invested in some of the ways that those medicines can be created synthetically, which would remove some of the nuclear risk that currently is associated with that medicine.[27]

Mr Dave Sweeney, Nuclear Free Campaigner, Australian Conservation Foundation argued that nuclear-related medical activities are not precluded because of existing prohibitions because 'it is not about nuclear medicine or industrial applications.' He refuted any assertion that the prohibitions have an 'unintended consequence' on the nuclear medicine sector.[28]

FINDING 10: The nuclear medicine industry is not hindered significantly by the current prohibitions against uranium or thorium exploration and mining. Current legislative prohibitions only prohibit mining and the construction or operation of certain nuclear facilities, such as nuclear reactors. This does exclude Victoria from hosting a nuclear research reactor or other nuclear facilities which could be used to increase supply of radioisotopes for medical or industrial purposes. The Committee notes that if Victoria did seek to establish a research reactor, Victorian and Commonwealth prohibitions would need to be repealed to allow this to happen. Therefore, a repeal of just Victorian legislation would not be sufficient to expand our involvement in nuclear medicine beyond what is currently permissible.

---

23 Dr Carl-Magnus Larsson, CEO and Deputy CEO, Australian Radiation Protection and Safety Agency, public hearing, Melbourne, 12 March 2020, *Transcript of evidence*, p. 27.

24 See for example, Mr Trevor Gauld, National Policy Officer, Electrical Trades Union, public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 2.

25 Dr Margaret Beavis, Medical Association for Prevention of War (Australia), public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 22.

26 Ms Rosamund Krivanek, *Submission 65*, p. 9.

27 Mr Trevor Gauld, *Transcript of evidence*, p. 3.

28 Mr Dave Sweeney, Nuclear Free Campaigner, Australian Conservation Foundation, public hearing, Melbourne, 26 June 2020, *Transcript of evidence*, p. 14.

FINDING 11: The current market for this material is receiving enough supply from international import and the OPAL reactor at Lucas Heights. The Committee does not believe that fully repealing the *Nuclear Activities (Prohibitions) Act 1983* would have a material influence on the nuclear medicine sector, as it is unlikely Victoria's involvement would increase beyond its current capacity.

10.1.2 Thorium exploration and mining

In other parts of this report (see Chapter 3), the Committee has presented the evidence it received which discussed the viability and opportunities for Victoria if prohibitions against thorium exploration and mining were lifted and the potential for including it as part of a future energy mix. The Committee found that stakeholders were divided on whether there was any real future viability in thorium exploration, mining or energy production.

Several pro-nuclear stakeholders believed that the use of thorium as an energy source had economic, environmental and safety benefits for Victoria, particularly because Victoria hosts several thorium deposits.[29] In contrast, anti-nuclear stakeholders were of the view that thorium is not economically or technically viable therefore had nil to minimal opportunities which were not sufficient enough to justify lifting current legislative prohibitions against mining and exploration.[30]

Please refer to section Chapter 6 for a more fulsome discussion on the views of stakeholders on using thorium as an energy source in Victoria.

In the Committee's view, definitive statements or assessment on the viability or opportunities in thorium exploration or mining are difficult to make and would not be useful because of the absence of proper data or a detailed business case. Current assessments rely on comparative data from other jurisdictions which can only be applied to a Victorian, or Australian, context in a limited capacity. It has been noted throughout this report to properly consider expanding nuclear-related activities, a proper business case would need to be developed which is based within an Australian market using local factors; rather than modelling or comparative analysis based on other jurisdictions or hypothesised examples. The Committee considers there is a need for more reliable feasibility research into thorium to properly ascertain if it is a viable option for Victoria to pursue exploration and mining in this area.

On this basis, the Committee believes it is not in a position to comment on the technical or economic viability of thorium exploration, mining or energy use because there is insufficient evidence to support any conclusion. It is the Committee's view that a more detailed business case is needed which looks at the issue of technical and economic viability from the Victorian context. However, like other business case studies discussed

29 For example see: The Thorium Network, *Submission 79*.; Hon. Peter Vickery QC, *Submission 33*.

30 For example see: Friends of the Earth Australia, Australian Conservation Foundation and Environment Victoria, *Submission 39*.; Rosamund Krivanek, *Submission 65*.; Tracey Anton, *Submission 66*.

in this report it would be expensive and need to be extensive in scope, considering costs related to materials, construction, and supply chain, locations, resources, financing, waste management, licensing and environmental impacts. It is highly unlikely that such a study will be undertaken whilst prohibitions remain place, not just in Victoria but also Australia.

Therefore, the Committee acknowledges that the prohibitions, both Victorian and Commonwealth, do impede the in-depth research that would be needed to properly ascertain if thorium-based activities would be viable. The issue of viability is unlikely to be resolved unless the prohibitions are lifted so that a detailed business case can be established.

FINDING 12: The Committee is not convinced that thorium exploration and mining is economically or technologically viable for Victoria.

Adopted by the Legislative Council Environment and Planning Committee

Parliament of Victoria, East Melbourne
2 November 2020

Appendix 1
About the Inquiry

A1.1 Submissions

1	Don Hampshire
2	Robert Heron
3	Terje Petersen
4	Janet Nixon
5	Karen Furniss
6	Graeme Tychsen
7	Barbara Devine
8	Vivian Smith
9	Lachlan Dow
10	RVS Industries
11	Alan Hewett and Joan Jones
12	Audrey Gutte
13	Anne Wharton
14	Professor John Quiggin
15	Amy Butcher
16	Nick Pastalatzis
17	Philip White
18	Leah McDermott
19	Simon Brink
20	CFMMEU ME Victorian branch
21	Azark Project
22	Friends of the Earth Australia
23	Professor Derek Abbott
24	Frank Simpson
25	Noel Wauchope
26	Bill Buchanan
27	Barry Murphy
28	Dr John Patterson
29	Bart Wissink
30	Robyn Sharp
31	Colin Smith
32	Ian Hore-Lacy
33	Hon. Peter Vickery QC
34	Medical Association for Prevention of War
35	Alan Hamill
36	Women in Nuclear (WIN) Australia
37	GNE Advisory
38	Tony Irwin
39	Friends of the Earth, Australian Conservation Foundation, Environment Victoria
40	SMR Nuclear Technology
41	Benjamin Cronshaw
42	NuScale Power
43	Logan Smith
44	Nuclear for Climate Australia, Australian Nuclear Association
45	Nuclear Economics Consulting Group
46	Anthony Watson
47	Barrie Hill
48	Confidential
49	Dr Sarah Lawley
50	Australian Nuclear Association
51	John Poppins
52	M V Ramana
53	Rosalind Byass
54	Kim Grierson
55	Australian Conservation Foundation
56	Electrical Trades Union Victoria Branch
57	Allison Roma Guerin

58	Telix Pharmaceuticals Limited
59	Damian Jones
60	Phil Bourne
61	Victorian Trades Council
62	ANSTO
63	Engineers Australia
64	Marcos Fernandes
65	Rosamund Krivanek
66	Tracey Anton
67	Australian Institute of Physics, Victoria
68	Adam Corrie
69	Sharon Wright
70	Uniting Church in Australia, Synod of Victoria and Tasmania
71	Australian Workers Union
72	Barbara Fraser
73	Bree Bateman
74	Bright New World
75	Nuclear Now Alliance
76	Terrestrial Energy Inc.
77	GE Hitachi Nuclear Energy
78	Minerals Council of Australia
79	The Thorium Network
80	Tristan Prasser
Pro Forma submissions	
1	Jessica Lawson
2	Marie-Louise Drew
3	Alana Hunt
4	Glenda McIntyre
5	Katie Lavers
6	Phyllis Di Palma
7	Mark Ritchie
8	Rebecca Sharpe
9	Tut Jonathon
10	Jean Le Quesne
11	Timothy Mullen
12	John Cunningham
13	Marion Shepherd
14	Marion Giles
15	Martine Holberton
16	Mia Haseldine
17	Scott Cumberland
18	Darian Zam
19	Alexander Ressel
20	Roger Loughbrough
21	Tim Brown
22	Diwani Oak
23	Jonathon Peter
24	Darren McGowan
25	Sasha Kelly-Thatcher
26	J Marsh
27	Mia Trujillo
28	Gary Brooker
29	A R Polack
30	Rhonda De Stefano
31	Julia Mateljan
32	Eileen Whitehead
33	Jean Christie
34	Angela Merriam
35	Pam Di Lorenzo
36	Liz Raven
37	Dawn Joyce
38	Wayne Jones
39	Jackie Curtis
40	Monica O'Leary
41	Ron McLean
42	Rohan Wilton
43	Dion Leeuwenburg
44	Joy Danielson
45	Alison Copley
46	Rosie Baker
47	Karen Collopy
48	William Routt
49	Shane Sutcliffe
50	Eugene Chattelle
51	Liz Wilson

52	Kyle Jessen
53	Karen Rees
54	Jenni Baxter
55	Julie Day
56	Jan Blomfield
57	James Nordlund
58	Geraldine Valentine
59	Isabella Doherty
60	Susan Allen
61	Brian Tomlinson
62	Chris Slater
63	Kathleen Basman
64	Lesley Killen
65	Wendy Cox
66	Sebastian Lyons
67	Rachel Dubois
68	Michelle Pretty
69	Ken Wilson
70	Melanie Chilianis
71	Christine Hugo
72	Raymond Rudd
73	Claudia Gallois
74	Gail Chilianis
75	Isobel Palmer
76	Richard Stanford
77	Anna Dowbnia
78	Merrill Jusuf
79	Kaye Cook
80	Norma Forrest
81	Frances Bell
82	Rhonda Green
83	Mark Jones
84	Jenny Forster
85	Leah Misiurka
86	Mary Cotter
87	Keri James
88	Michelle Charalambous

89	Gisela Faull
90	Iolanda Francis
91	Linda Castello
92	Kundu Liven
93	Diana Corbyn
94	Beata Provis
95	Jessica Sabatinit
96	Glenn Mallaby
97	Warwick Hill
98	Anna Husband
99	Cam Walker
100	Keely Worth
101	Jess Scarlett
102	Max Sargent
103	Rosemary Mattingley
104	Dale Curtis
105	Paul Desmond
106	Glenys Davis
107	Marion Gray
108	Nina Stick
109	Rowena Skinner
110	Kristine Phillip
111	Judy O'Donnell
112	Blanche Verlie
113	Sean Corrigan
114	John Molloy
115	Jan Mitchell
116	Fleur Rubens
117	Kerry Echberg
118	Patricia Fraser
119	Jeltje Fanoy
120	Michelle Destefano
121	Jill Thio
122	Stuart Spark
123	Cathryn Audley
124	Deborah Bourke
125	Helen and Martin Boyer

A1

126	Fraser Rowe
127	Pete Malone
128	Em Gayfer
129	Jeffrey Barlow
130	Barbara Pelczynska
131	Charles Ablitt
132	Susan Patton
133	Denis Martin
134	Barbara Crljen
135	Cate Stirling
136	Gabrielle Doolan
137	Vicky Hyduke
138	Maxwell Fitzsimmons
139	Terry Mason
140	Nora Moore

A1.2 Public Hearings

Thursday 12 March 2020

Room G6, 55 St Andrews Place, East Melbourne

Name	Title	Organisation
John Kalish	Assistant Secretary (*via video link*)	Australian Safeguards and Non-Proliferation Office (ASNO)
Melissa Skilbeck	Deputy Secretary, Regulation Health Protection and Emergency Management	Department of Health and Human Services
Dr Angie Bone	Deputy Chief Health Officer, Environment	
Noel Cleaves	Manager Environmental Health Regulation and Compliance	
Dr Carl-Magnus Larsson	CEO and Deputy CEO (*via video link*)	Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)

Thursday, 25 June 2020

Room G1.G2, 55 St Andrews Place, East Melbourne

Name	Title	Organisation
Geoff Dyke	Secretary Victorian Branch	Construction, Forestry Maritime Mining and Energy Union
Mark Richards	CFMMEU Mining & Energy Division	
Dr Jo Lackenby	President (*via video link*)	Women in Nuclear Australia
Jasmin Diab	Vice President (*via video link*)	
Dr Mark Ho	President (*via video link*)	Australian Nuclear Association
Robert Parker	Vice President (*via video link*)	
Dr John Harries	Secretary and Public Officer (*via video link*)	
Daniel Walton	National Secretary (*via video link*)	Australian Workers' Union

Name	Title	Organisation
James Sorahan	Executive Director MCA Victoria	Minerals Council of Australia
Patrick Gibbons	Director, Principal Advisor Energy	
Jeremiah Josey	Founder & Chief Executive Officer (*via video link*)	The Thorium Network
Dr Dragos Petrescu	Chief Operating Officer (*via video link*)	
Dian Kemp	Nuclear Chemical Engineer (*via video link*)	

Friday, 26 June 2020

Room G1.G2, 55 St Andrews Place, East Melbourne

Name	Title	Organisation
Michael Watson	Political Officer	Electrical Trades Union (Victoria branch)
Trevor Gauld	National Policy Officer	
Jim Green	National Nuclear Campaigner, Friends of the Earth Australia	Friends of the Earth Australia and Australian Conservation Foundation
Dave Sweeney	Nuclear-Free Campaigner, Australian Conservation Foundation	
Dr Tilman Ruff AO	–	Medical Association for Prevention of War (Australia)
Dr Margaret Beavis MBBS FRACGP MPH	–	
Mark Zirnsak	Senior Social Justice Advocate	Uniting Church in Australia (Synod of Victoria and Tasmania)

Friday, 14 August 2020

Via video link

Name	Title	Organisation
Thomas Mundy	Chief Commercial Officer	NuScale Power
Cheryl Collins	Director of Sales	
Michael Shellenberger	–	Environmental Progress
Dr Ben Heard	Founder	Bright New World
Dayne Eckermann	General Manager	
Professor John Quiggin	VC Senior Research Fellow, School of Economics, University of Queensland	–
Ian Hore-Lacy	Senior Advisor	World Nuclear Association
King Lee	Director, Harmony Programme	

A1

Friday, 28 August 2020

Via video link

Name	Title	Organisation
Dr Helen Caldicott	–	–
Simon Brink	–	–
Bart Wissink	–	–
Barrie Hill	–	–
Professor Andrew Peele	Group Executive, Research Translation and Director, Australian Synchrotron	Australian Nuclear Science and Technology Organisation (ANSTO)
Professor Lyndon Edwards	National Director, Australian Generation IV International Research	
Dr Robert Gee	General Manager, Minerals and Radiation Services	
Steven McIntosh	Senior Manager, Government and International Affairs	

Friday, 11 September 2020

Via video link

Name	Title	Organisation
Professor Stephen Wilson	Energy Economist	–
Simon Holmes a Court	–	Energy Transition Hub
Dr Dylan McConnell	Climate and Energy College, University of Melbourne	–

Extract of proceedings

Legislative Council Standing Order 23.27(5) requires the Committee to include in its report all divisions on a question relating to the adoption of the draft report. All Members have a deliberative vote. In the event of an equality of votes, the Chair also has a casting vote.

The Committee divided on the following questions during consideration of this report. Questions agreed to without division are not recorded in these extracts.

Committee meeting—21 October 2020

Chapter 3

First paragraph under *Uranium mining*: Mr Limbrick moved, that the words 'However, the Committee notes that as exploration is prohibited by the Act it is unclear whether unidentified resources may exist.' be inserted.

The Committee Divided.

The question was put.

Ayes	Noes
Mr Meddick	Ms Terpstra
Dr Ratnam	Ms Taylor
Dr Bach	
Mr Limbrick	
Mr Bourman	
Ms Bath	
Mr Hayes	
Mr Melhem	

The question was agreed.

Chapter 4

Paragraph 11 after *The Energy Mix*: Ms Taylor moved, that the words 'However technological advances in renewable energy are very likely to greatly improve its performance in the very near term.'

Ms Bath moved, that the amendment be moved to Paragraph 4.22

The Committee Divided.

The question was put.

Ayes	Noes
Dr Bach	Mr Meddick
Ms Bath	Ms Terpstra
Mr Limbrick	Dr Ratnam
	Ms Taylor
	Mr Hayes
	Mr Melhem

The question was negatived.

Original question put.

The Committee Divided.

Ayes	Noes
Mr Meddick	Dr Bach
Ms Terpstra	Ms Bath
Dr Ratnam	Mr Limbrick
Ms Taylor	
Mr Hayes	
Mr Melhem	

The question was agreed.

Paragraph 11 after *The Energy Mix*: Mr Limbrick moved, that the words 'such as natural gas peaking plants', be inserted after the phrase 'fast start generation'.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Bach	Mr Meddick
Ms Bath	Ms Terpstra
Mr Limbrick	Dr Ratnam
Mr Melhem	Ms Taylor
	Mr Hayes

The question was negatived.

Paragraph 7 after *Victorian Context*: Ms Taylor moved, that the paragraph be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Mr Meddick	Dr Bach
Ms Terpstra	Ms Bath
Dr Ratnam	Mr Limbrick
Ms Taylor	Mr Melhem
Mr Hayes	

The question was agreed.

Paragraph 2 after *Projection of electricity prices*: Ms Taylor moved, that a paragraph, as amended, be inserted that reads:

In Victoria, the Government has introduced its Energy Fairness Plan, which builds on the Independent Review into the Electricity and Gas Retail Markets in Victoria and incorporates the delivery of fairer energy regulation and is a significant regulatory change. The plan seeks to protect Victorians with the introduction of stronger protections for consumers and tougher penalties for retailers who do the wrong thing. Further, in 2019 the Government implemented the 'Victorian Default Offer' to provide a simple-to-understand, reliable offer for consumers.

The Committee Divided.

The question was put.

Ayes	Noes
Mr Meddick	Dr Bach
Ms Terpstra	Mr Limbrick
Dr Ratnam	Ms Bath
Ms Taylor	Mr Hayes
Mr Melhem	

The question was agreed.

Paragraph 3 after *State of the Energy Market 2020*: Ms Taylor moved, that the paragraph be amended to read:

AEMO intervened in the market to manage security issues. The AER reported that the market operator has directed generators to operate even if it is not economic for them to do so. It has also de-energised transmission lines in Victoria and has instructed load shedding twice in 2019. Load shedding is when power companies reduce electricity consumption by switching off the power supply to groups of customers because the entire system is at risk.

The Committee Divided.

The question was put.

Ayes	Noes
Ms Taylor	Mr Limbrick
Dr Ratnam	Ms Bath
Ms Terpstra	Dr Bach
Mr Hayes	Mr Bourman
Mr Melhem	
Mr Meddick	

The question was agreed.

Paragraph before the Finding: Ms Taylor moved, that the paragraph be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Mr Meddick	Ms Terpstra
Dr Ratnam	Dr Bach
Ms Taylor	Mr Bourman
Mr Hayes	Mr Limbrick
	Ms Bath
	Mr Melhem

The question was negatived.

Chapter 5

Paragraph 2 after *How are costs compared across different electricity technologies?*: Ms Taylor moved, that the paragraph be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Mr Meddick	Dr Bach
Ms Terpstra	Mr Bourman
Dr Ratnam	Mr Limbrick
Ms Taylor	Ms Bath
Mr Hayes	Mr Melhem

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Paragraph 2 after *How are costs compared across different electricity technologies?*: Ms Taylor moved, that the paragraph be amended to read:

The LCOE method of costing energy generation is commonly used in the development of energy policy. It is noted that some in the energy sector consider this method to be limited. These limitations are noted in section xx below' and that the words 'it is considered substantially flawed by many in the energy sector' be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Mr Meddick	Dr Bach
Ms Terpstra	Mr Bourman
Dr Ratnam	Mr Limbrick
Ms Taylor	Ms Bath
Mr Hayes	
Mr Melhem	

The question was agreed.

Committee meeting—2 November 2020

Paragraph before *Australia*: Ms Taylor moved, that the paragraph be amended by adding the words:

Because Australia has no nuclear energy industry currently, the costs from countries where there is a mature industry are likely to be misleading. At a public hearing Dr McConnell told the Committee:

To that end, there are basically two main points I would like to make: firstly, that the emerging dynamics and requirements of the power system present a bit of a challenge to technologies with a cost structure like that of nuclear; and secondly, without strong government intervention, nuclear power will face a lot of challenges in a liberalised power system like the one we have here. Both of these combine to create basically significant barriers for the development of nuclear power in Australia.

The Committee Divided.

The question was put.

Ayes	Noes
Mr Meddick	Dr Bach
Ms Terpstra	Mr Bourman
Dr Ratnam	Mr Limbrick
Ms Taylor	Ms Bath
Mr Hayes	
Mr Melhem	

The question was agreed.

Paragraphs 3–7 after the first chart on *Capital Costs*: Ms Taylor moved, that the paragraphs be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Hayes
Ms Taylor	Dr Bach
Mr Meddick	Mr Limbrick
Ms Terpstra	Mr Bourman
	Mr Melhem

The question was negatived.

Paragraph before second chart on *Capital Costs*: Ms Taylor moved, that new paragraph be inserted that reads:

Further complicating the issue of costs, the Committee has also been told that cost blowouts are common in the nuclear industry so any estimated figures may need to be treated with caution. In its submission to the inquiry, Friends of the Earth identified a number of blowouts in the cost of nuclear power plants around the world, citing recent examples of significant cost increases:

- The estimated cost of the high-temperature gas-cooled SMR (HTGR) under construction in China has nearly doubled;
- The cost of Russia's floating SMR quadrupled;
- The estimated cost of Argentina's SMR has increased 22-fold above early, speculative estimates and the cost increased by 66% from 2014, when construction began, to 2017;
- The cost estimate for the Vogtle project in US state of Georgia (two AP1000 reactors) has doubled to more than US$13.5 billion per reactor and will increase further.9 In 2006, Westinghouse said it could build an AP1000 reactor for as little as US1.4 billion22—10 times lower than the current estimate for Vogtle;
- The estimated cost of about €12.4 billion23-24 for the only reactor under construction in France is 3.8 times greater than the original €3.3 billion estimate;
- The estimated cost of about €11 billion25 for the only reactor under construction in Finland is 3.7 times greater than the original €3 billion estimate; and
- The estimated combined cost of the two EPR reactors under construction in the UK, including finance costs, is £26.7 billion (the EU's 2014 estimate of £24.5 billion plus a £2.2 billion increase announced in July 2017). In the mid-2000s, the estimated construction cost for one EPR reactor in the UK was £2 billion28, almost seven times lower than the current estimate.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Limbrick
Ms Taylor	Ms Bath
Mr Meddick	Dr Bach
Ms Terpstra	Mr Bourman
Mr Hayes	
Mr Melhem	

The question was agreed.

Finding 2: Ms Taylor moved, that text be inserted into Finding 2 that reads: 'However, there is substantial evidence on the customary cost blowouts and delays of the nuclear industry to instruct the Committee'.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Taylor	Ms Bath
Mr Meddick	Dr Bach
Ms Terpstra	Mr Hayes
	Mr Limbrick
	Mr Bourman

The question was negatived.

Finding 3: Mr Meddick moved, that the text as amended, be inserted, that reads: 'and it is recognised that, currently, nuclear is at the high end of the as the second-highest cost-range across all technologies.'

The Committee Divided.

The question was put.

Ayes	Noes
Mr Melhem	Ms Bath
Dr Ratnam	Dr Bach
Ms Taylor	Mr Limbrick
Mr Meddick	Mr Bourman
Ms Terpstra	
Mr Hayes	

The question was agreed.

Finding 4: Mr Meddick moved, that Finding 4 be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Taylor	Dr Bach
Mr Meddick	Ms Bath
Mr Hayes	Ms Terpstra
	Mr Limbrick
	Mr Bourman

The question was negatived.

Finding 5: Ms Terpstra moved, that a new Finding be inserted that reads: 'Without subsidisation a nuclear power industry will remain economically unviable in Australia for now.'

The Committee Divided.

The question was put.

Ayes	Noes
Mr Hayes	Mr Bourman
Ms Terpstra	Mr Limbrick
Mr Meddick	Dr Bach
Ms Taylor	Ms Bath
Dr Ratnam	
Mr Melhem	

The question was agreed.

Chapter 6

Paragraph before *Reprocessing of nuclear fuel*: Ms Taylor moved, that text be inserted that reads:

In fact the provision of front end nuclear for Australia is not economically feasible as fuel processing activities would occur overseas as explained by Mr Hore-Lacy from the World Nuclear Association at a public hearing:

We would import the finished fuel, yes, because I think, and by most people's reckoning, it would not be economic to build those facilities for fuel fabrication and enrichment and conversion in Australia because there is surplus capacity overseas at very competitive prices, but it would quite likely be Australian uranium that we might use.

The Committee Divided.

The question was put.

Ayes	Noes
Mr Hayes	Mr Bourman
Ms Terpstra	Dr Bach
Mr Meddick	Ms Bath
Ms Taylor	Mr Limbrick
Dr Ratnam	
Mr Melhem	

The question was agreed.

Paragraph 4 after *Waste from nuclear power generation*: Ms Taylor moved, that text be omitted that reads:

'Because nuclear fuel is so energy dense, very little is required to produce a significant amount of electricity. As a result, a correspondingly small volume of waste is produced. The average waste from a reactor supplying one person's electricity needs for a year would be about the size of a house brick, of which approximately 5 grams is HLW. The generation of electricity from a typical 1,000 megawatt nuclear power station, produces three cubic metres of HLW per year if the used fuel is repurposed. In fact, the Committee heard evidence that the entirety of nuclear waste produced since nuclear reactors came into being could fit onto a soccer field, piled 10 metres high.'

and that it be replaced by text that reads:

'Current global levels of high-level waste generated by nuclear power stations annually is approximately 34,000m^3, or the equivalent to 3,400 concrete trucks worth of high-level waste each year. The construction of more nuclear power stations will only increase this output. More specifically in relation to waste volumes from SMRs, the SANFC Royal Commission noted:

SMRs have lower thermal efficiency than large reactors, which generally translates to higher fuel consumption and spent fuel volumes over the life of a reactor.'

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Finding 6: Ms Taylor moved, that text be inserted into the Finding that reads:

and the rapid advancement of renewable technology, which is cheaper and quicker to implement than other energy sources.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Taylor	Ms Bath
Mr Meddick	Dr Bach
Mr Hayes	Ms Terpstra
	Mr Limbrick
	Mr Bourman

The question was negatived.

After Finding 6: Mr Meddick moved, that a new Finding be inserted that reads:

To entertain a shift in State policy is not only incongruous with Federal policy, but to reverse the State policy setting would have the effect of creating a high-level, lasting toxic waste problem for future generations in a climate of waste reduction policy.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Paragraph 2 after *Cost of SMRs*: Ms Taylor moved, that the words be deleted that read:

Rather, the Committee believes that a business case conducted within the Victorian context is needed to fully understand the costs associated with developing this technology, however, that is unlikely to occur if prohibitions remain in place.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Paragraph before *SMR Design*: Ms Taylor moved, that text be omitted that reads:

A detailed business case and feasibility study would be needed to properly assess the commercial or economic viability of technologies such as SMRs, but as the Committee has mentioned already this is unlikely to be undertaken with current prohibitions

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Before Finding 7: Mr Meddick moved, that new text be inserted into the Chapter that reads:

- The argument in favour of Small Modular Reactors is unfounded as it is based on expensive, unproven and disputed technology.
- Thorium is not a viable fuel source on either economic or environmental grounds.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Chapter 7

Paragraph before *Health and Safety*: Ms Taylor moved, that text be omitted that reads:

The Committee is not to date assured that the framework is satisfactory, particularly when one notes the significant deficiencies in the meeting of regulatory parameters in some notable examples such as the problematic history and ongoing status of Olympic Dam. However, the Committee is also confident that Australia is served well by a robust and effective framework that is capable of being adapted and refined to effectively cater for any future expansion in the domestic nuclear environment.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Second last paragraph: Mr Meddick moved, that text be inserted that reads:

The Committee acknowledges this claim was strongly disputed by other witnesses.

The Committee Divided.

The question was put

Ayes	Noes
Mr Melhem	Mr Limbrick
Ms Terpstra	Ms Bath
Dr Ratnam	Dr Bach
Mr Meddick	Mr Bourman
Ms Taylor	
Mr Hayes	

The question was agreed.

Chapter 8

Finding 9: Mr Meddick moved, that a new Finding be inserted that reads:

The Committee finds that those who propose a policy shift have not presented any argument, data or proof in support of their position that cannot be nullified by those arguing against. Any advantages are speculative in nature, and do not outweigh the identified and proven risks.

The Committee Divided.

The question was put.

Ayes	Noes
Ms Taylor	Mr Bourman
Dr Ratnam	Mr Limbrick
Mr Hayes	Ms Bath
Mr Meddick	Mr Melhem
Ms Terpstra	

The question was agreed.

Paragraph 4 after *Low or no emission technology*: Ms Taylor moved, that words be inserted that read:

However, the technology is not ready for deployment and climate change is occurring now. By the time nuclear power generation could get off the ground in Australia, renewables will have resolved the issues arising from emissions.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Paragraph 12 after *Low or no emission technology*: Ms Taylor moved, That words be inserted that read:

However, Canada has a long-established nuclear industry that has been in place for many years. It would not be possible to establish a nuclear industry in Australia, running with sufficient expediency or cost-effectiveness, in order to combat climate change now.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Second paragraph before *Nuclear risks a much lesser evil than climate change*: Ms Taylor moved, that the paragraph be omitted.

The Committee Divided.

The question was put

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Heading *Nuclear risks a much lesser evil than climate change*: Ms Taylor moved, that the Heading be replaced by a Heading that reads: *Climate change and energy generation*.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Heading *Nuclear risks a much lesser evil than climate change* : Mr Hayes moved, that the heading be replaced by a heading that reads: *Nuclear risks and the impact of climate change*.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Paragraph 16 after *Nuclear risks a much lesser evil than climate change:* Ms Taylor moved, that words be inserted after 'received several recommendations' that read: 'from pro-nuclear stakeholders.'

The Committee Divided.

The question was put.

Ayes	Noes
Mr Meddick	Mr Melhem
Ms Taylor	Dr Bach
Mr Hayes	Ms Bath
Ms Terpstra	Mr Limbrick
	Mr Bourman

The question was negatived.

Final paragraph in chapter: Ms Taylor moved, that the paragraph be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Mr Meddick	Mr Melhem
Ms Taylor	Dr Bach
Mr Hayes	Ms Bath
Ms Terpstra	Mr Limbrick
	Mr Bourman

The question was negatived.

Chapter 9

Paragraph before *Traditional Owners and First Nations People*: Ms Taylor moved, that the paragraph be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Ms Terpstra	Mr Melhem
Ms Taylor	Dr Bach
Dr Ratnam	Mr Limbrick
	Mr Bourman
	Mr Hayes
	Ms Bath
	Mr Meddick

The question was negatived.

Paragraph before *Traditional Owners and First Nations People*: Ms Taylor moved, that a new paragraph be inserted that reads:

At a public hearing, Simon Holmes a Court told the Committee:

> As I am sure the committee knows, there are two regulatory barriers for nuclear power in Victoria: section 8(1)(d) of Victoria's Nuclear Activities (Prohibitions) Act and section 140A of the commonwealth EPBC Act. Imagine for a moment that all social opposition to nuclear melts away and that a new era of bipartisanship emerges, strongly supporting nuclear power across local, state and federal governments. Imagine these governments removed the prohibitions and they worked efficiently to enact the thousands of pages of regulations required to enable a safe nuclear sector. Imagine then that the governments decided to provide financial guarantees and concessional loans of an unprecedented magnitude and agreed to take on the long-term waste storage obligations and indemnify nuclear projects against accidents. Now imagine that that political support remained intact across three levels of government and across five federal election cycles. With the social, political and legal barriers removed and with strong government support and regulations in place, now the difficult part begins.
>
> Before a current generation nuclear power plant could be built we would need the following: an owner willing to turn a blind eye to the nuclear sector's track record of massive time and budget blowouts. We would need a retailer willing to sign a 30- to 40-year power purchase agreement for energy at two to three times the current cost and wait 15 years for the privilege of the first kilowatt hour. We would need a capable builder, but who do we turn to? Westinghouse is bankrupt. AREVA became insolvent and is now part of EDF. South Korea's Kepco has been mired in scandal. Perhaps we would go with Russia or China. We would need a community, preferably one on the

coast, happy to host a reactor, and we would need confidence that the renewable energy sector would slow down and their costs would increase. Ladies and gentlemen, I agree with Dr Ziggy Switkowski, who told last year's federal inquiry that the window for gigawatt-scale nuclear has closed in Australia.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Paragraph 7 after *Social licence to operate*: Ms Taylor moved, that the paragraph be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Mr Meddick	Dr Bach
Ms Taylor	Mr Hayes
Dr Ratnam	Mr Bourman
Ms Terpstra	Mr Limbrick
	Ms Bath
	Mr Melhem

The question was negatived.

Paragraph before *Community consent*: Ms Taylor moved, that the paragraph be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Second paragraph before *Intergenerational equity*: Mr Meddick moved, that words be inserted after the words 'potential host communities' that read:

Any consideration of a repeal of the moratorium should seek whole of community—i.e. State-wide—consultation, asking a simple question: Do you support or not support repealing the moratorium that prevents mining, processing, power and high-level toxic waste generation of radioactive material?

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Paragraph before *Intergenerational equity*: Ms Taylor moved, that the paragraph be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Chapter 10

Paragraph 2 after *Nuclear-related opportunities in Victoria*: Ms Taylor moved, that the paragraph be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Paragraph 13 after *How does nuclear medicine work?*: Ms Taylor moved, that the paragraph be omitted.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Finding 12: Ms Taylor moved, that the words 'and that with prohibitions on nuclear activity, it is unlikely that a detailed business case will be undertaken to provide further evidence.' Be deleted from the Finding.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Ms Bath
Ms Terpstra	Mr Limbrick
Ms Taylor	Mr Bourman
Mr Meddick	
Mr Hayes	
Dr Bach	
Mr Melhem	

The question was agreed.

New Recommendation after Finding: Mr Meddick moved that a Recommendation be inserted that reads:

Based upon evidence presented, historical record and widely accepted safety and detrimental health factors, the Committee recommends that lifting the moratorium does not occur.

The Committee Divided.

The question was put.

Ayes	Noes
Dr Ratnam	Mr Melhem
Ms Terpstra	Dr Bach
Ms Taylor	Ms Bath
Mr Meddick	Mr Limbrick
Mr Hayes	Mr Bourman

There being an equality of votes, the Chair gave his casting vote to the Noes.

The question was negatived.

Minority reports

MINORITY REPORT

Jeff Bourman, MLC

From the evidence presented, it is clear that unless a business case is raised, the commercial viability of nuclear power will never be quantified. A business case is very unlikely to be done given the current restrictions. Therefore, it would be reasonable to relax the restrictions only to the extent necessary for the business case to be prepared.

Recommendation 1
That an investigation into exactly what restrictions would need to be relaxed to ensure that a business case can be raised, be conducted as soon as possible and a report be prepared and presented to the Parliament of Victoria for consideration.

MINORITY REPORT

Legislative Council Standing Committee on Environment and Planning
INQUIRY INTO NUCLEAR PROHIBITION

As Victoria continues its energy transition several key principles should guide us. These are reliability and accessibility, affordability, and sustainability. By embracing these principles our aim should be to increase the supply of energy, while also lowering emissions. As such, they are critical for the benefit of both households and industry.

The Committee heard that no one form of energy will be sufficient to meet our state's needs. Consequently, all energy options should be considered by the Victorian Government. That should include the potential for nuclear energy in any future energy mix – we must be energy agnostic, never guided by ideology.

There are serious challenges in decarbonising electricity production and excluding nuclear technology means that we cannot explore the advantages it yields, such as small land use, low carbon intensity, high level of safety, and extremely long infrastructure lifespan. Whilst a social license would need to be obtained for usage of nuclear technologies, it is also unknown whether a social license exists for some of the infrastructure required for large scale variable renewable technologies. There is already resistance to new transmission infrastructure required for variable renewable energy technologies, which may be amplified further if large scale pumped hydroelectric dams are also required. This may be a step too far for some communities. Although imported variable renewable generation infrastructure is relatively inexpensive, it also has a relatively short lifespan, locking in perpetual replacement costs and dependency on foreign production.

However, the desirability of nuclear energy in Victoria cannot be meaningfully considered while the legislative ban on nuclear energy remains in place. The substantive report makes it plain that a business case cannot be mounted while the ban remains. A business case would be necessary to enable an assessment of Victoria's nuclear energy potential.

Several experts presenting testimony to the inquiry made comments on the difficulty of conducting a full business case while the legislative prohibition is in place.

Dayne Eckermann, the General Manager at Bright New World, stated:

> *"The question that I normally ask when we bump into vendors and talk to them is: if Australia removed the prohibitions, would you come here? And every vendor has said yes. They look at Australia. We are a mature country. We have a very well experienced engineering and scientific workforce here. We are well regarded in nuclear science and technologies globally—ANSTO is one of our shining lights."*

"But it all falls down when they go, 'But we can't because it is prohibited, and I can't justify to my management or my board to spend the time to come to Australia, spend the money, do all the work, do that community consultation process', because no management or board will approve that, because it is prohibited."[1]

Professor Stephen Wilson also stated in testimony to the inquiry that the act of removing the nuclear prohibition alone could improve energy costs and competition in the market:

"What is it that creates that competitive dynamic that keeps people honest, that ensures companies are sharpening their pencils and giving the best deal to the customers? One of the things is the day-to-day live competition, but another thing is the threat of entry in the future. So if you say, 'Nuclear's bad, we're not allowed to look for gas, we've got to close the coal plants', you are just shooting the competition dead, and that is not going to lead to good outcomes for customers, for consumers, for society, for the manufacturing sector. That is why I say that on day one of the repeal, even though it is not obvious and it might not be easy to put a precise dollar value on it, you will have created value—substantial value."[2]

In exploring energy options, the Victorian Government should seek to act in concert with the Federal Government wherever possible. The Federal Parliament report of the inquiry into the prerequisites for nuclear energy in Australia, which was tabled in December 2019, recommended that the Australian Government should "consider the prospect of nuclear energy technology as part of its future energy mix". The Federal report also places emphasis on the need for "cooperation with relevant state and territory governments", which is a necessary requirement for exploring our energy options. We support recommendation 2(b), which recommends commissioning the Productivity Commission to undertake an assessment of the economic viability of nuclear generation in Australia.

In March 2019, the Parliament of New South Wales' Standing Committee on State Development also recommended lifting the prohibition on uranium exploration in that jurisdiction. Victoria should move in concert with the Federal Government and its most competitive state neighbour, New South Wales. To do otherwise would be to ensure Victoria is left behind. This would see Victorians failed, not only directly in terms of energy, but also economically and regarding emission reduction.

The National Energy Market Operator (AEMO) has created a roadmap for energy transition through the regularly updated Integrated System Plan to provide a depth of understanding to guide both private and Government investment into energy generation and system

---

[1] Mr Dayne Eckermann, General Manager, Bright New World, public hearing, 14 August 2020, *transcript of evidence*, pp 28-29.
[2] Professor Stephen Wilson, public hearing, 11 September 2020, *transcript of evidence*, p 6.

infrastructure. This plan has not considered nuclear as an option to model how that would impact the national energy grid.

Michael Shellenberger from Environmental Progress highlighted some of the problems with excluding nuclear options from the ISP in testimony to the Committee:

> *"Two weeks ago the Australian Energy Market Operator published its 2020 Integrated System Plan. It is admirable that groups are trying to work through their future difficulties, but by excluding nuclear up-front, the study goes against the recommendations about the importance of and the low-carbon nature of nuclear energy. Even more worrying, by excluding nuclear but increasing interconnections the integrated system plan is pointing our way to an unstable grid, ever more reliant on the few remaining fossil fuel facilities. Because the plan is most vague about the worst of the variability and storage problems—that have never been solved, by the way, anywhere in the world—while eliminating the successful majority nuclear solutions that have been demonstrated time and again, the plan is taking major risks with the Australian people's health and welfare."*[3]

Exploring Victoria's nuclear energy potential would also enable us to holistically leverage the technology in other industries. There may be opportunities for the application of nuclear technology in agriculture, food, water and health, for example. Similarly, there are many exciting applications of nuclear technology in space exploration, and the prohibition severely limits Victoria's contribution in this area.

Finally, in any future consideration of nuclear energy technology the will of the Victorian people must be respected. An informative and extensive consultation process with any impacted local communities, especially Indigenous groups, would need to be a pre-requisite for any nuclear application to proceed.

[3] Mr Michael Shellenberger, Environmental Progress, public hearing, 14 August 2020, *transcript of evidence,* p 12.

Recommendation 1:

Repeal the Nuclear Activities (Prohibitions) Act 1983.

Recommendation 2:

Continue to work with federal and state counterparts to follow developments in nuclear technologies.

Recommendation 3:

Government should make representations to COAG Energy Council for AEMO to consider the addition of nuclear modelling into the Integrated System Plan.

Signatories:

David Limbrick MP

Beverley Macarthur MP

Matthew Bach MP

Legislative Council Environment and Planning Committee inquiry into Nuclear Prohibition:

Minority Report – Nina Taylor MLC

Victoria is currently contributing to a low carbon energy mix through Victorian Government policies encouraging renewable energy, a more diffuse grid including localised energy production and storage, and the removal of brown coal fired energy sources. Enabling the exploration and production of uranium and thorium has little to no potential in Victoria given the lack of infrastructure, the length of time combined with the cost of building a non-competitive industry from scratch, no identified decommissioning strategy, and the enormous burden of producing radioactive waste without any identified storage options. Throughout this inquiry we have heard from a range of parties, however none of those parties who proposed that we take a path towards a nuclear industry in Victoria have been able to adequately address these points, submitting that somehow the enormous cost, lack of social licence, and an declining ability to be a viable energy source will be overcome through the passage of time. We saw a number of the familiar tired tropes come out around renewable technology around intermittency, lack of energy storage and very little discussion of centralised energy systems (that nuclear requires by design) versus diffuse and interconnected systems of energy.

Throughout this inquiry we largely avoided the issue of cost, with other members and I seeking detailed economic modelling which was not forthcoming, however cost is part and parcel of potential. It would beggar belief that in assessing the potential benefits to Victoria in removing prohibitions enacted by the *Nuclear Activities (Prohibitions) Act* 1983, the disastrous costs of such a step would be ignored. Yet through this inquiry we did not but scratch the surface of the costs associated with such a move and whilst I believe that our findings will not give rise to a vindication for lifting the nuclear prohibition ban, ignoring the enormity of these costs artificially enhances the status of the nuclear industry in contravention to the current energy costs transition trends and methods.

This minority report will cover each of the terms of reference in turn.

(1) investigate the potential for Victoria to contribute to global low carbon dioxide energy production through enabling exploration and production of uranium and thorium;

The potential of a uranium mining and nuclear energy industry was categorised by many industry proponents as the definitive way to a lower carbon emission profile. This is a manipulative and futile argument. Climate change is occurring now, and we have little time to de-carbonise. In the time it would take for the nuclear industry to advance sufficiently in Victoria, we may have missed this window of opportunity. Best estimates from the nuclear industry put forward from other jurisdictions have a nuclear industry being created in a decade. (Mr Thomas Mundy, Chief Commercial Officer, NuScale Power, Inquiry into Nuclear Prohibition, Legislative Council Environment and Planning Committee, Transcript of Evidence, 14 August 2020, p 7). This is in addition to the established research showing that it is a higher cost, highly centralised form of energy, with enormous expenses associated with the waste it produces and the decommissioning of the sites it uses. It reflects a strategic marketing angle of nuclear proponents to enforce an ill-matched nexus between uranium mining and nuclear energy production and a solution to the catastrophic consequences of climate change. This false imperative needs to be called out.

Throughout this inquiry the issue of potential – and lack of potential, came to a head time and time again. Most industry proponents appearing before the inquiry seemed to be dismissive of their capacity to construct a business case, and I found it particularly strange that they had no in-depth modelling, or cost analysis, even detailed risk/benefit analysis based on Australian conditions to be able to provide to the inquiry.

However, relevant data on this topic is readily available. The South Australian Nuclear Fuel Cycle Royal Commission (SANFCRC) had an almost exact same framework inquiry run by a specialist state body set up for that purpose – who through modelling from the global engineering firm Parsons Brinkerhoff, found that nuclear power did not make sense in Australian conditions due to cost (http://nuclearrc.sa.gov.au/tentative-findings/, p.12)

The modelling put forward that electricity from a range of nuclear technologies could deliver power in the range of $180–$246/MWh. This range is significantly higher than the SANFCRC's high projected prices for South Australian electricity under a range of future assumptions. (http://nuclearrc.sa.gov.au/app/uploads/2016/05/WSP-Parsons-Brinckerhoff-Report.pdf)

This modelling is not long completed – it is four years ago that this exercise was undertaken. Even though there will be small differences in the assumptions that underpin the modelling if applied to a Victorian setting, it must be pointed out that the cost assumptions have shifted further in favour of renewables given the strong drop in price of renewable energy and renewable energy producing technology, especially in solar. This is while in the same intervening period the global conditions for the uranium mining and nuclear energy sector deteriorated. (https://www.smh.com.au/politics/federal/risk-of-catastrophic-failure-if-australia-adopts-nuclear-energy-20190829-p52m2h.html#:~:text=There%20is%20a%20risk%20of,Mile%20Island%20in%20the%20US.)

Our transition to a low carbon energy future is already well underway. This low carbon/no carbon transition in energy policy and practice is an emerging discipline and looks at the challenges, opportunities and mechanisms for transitioning our energy systems from being dominated by fossil fuels (especially brown coal in Victoria, and coal in the broader Australian context) to predominantly renewables.

As was put to the inquiry by Simon Holmes a Court (noted energy industry analyst) (Inquiry into nuclear prohibition, Legislative Council Environment and Planning Committee, 11 September 2020, pp 6-7) in his submission:

'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 portfolio of variable renewables with dispatchable energy sources.'

This is borne out by the Australian Energy Market Operator's (AEMO) 2020 Integrated System Plan (ISP) which shows this on a whole-of-grid scale (https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp).

'The ISP outlines several paths forward for the National Electricity Market (NEM), all of which project a significant increase in the proportion of energy provided by renewables. The primary difference between the scenarios is the speed of transition — under the Central scenario two of Victoria's three coal power stations close in the 2040s, under the Step-change scenario all would close a decade earlier.'

In other words, by the time Australia could build its first nuclear power station, our whole grid can, and likely will, be almost completely decarbonised.'

(2) identify economic, environmental and social benefits for Victoria, including those related to medicine, scientific research, exploration and mining;

There will be no environmental benefit, just an enormous environmental risk being created. Contentious public debate and wrangling within both state and federal jurisdictions over nuclear waste has been going on for over three decades. In medicine and scientific research there is already access to adequate low-grade nuclear material to conduct necessary work.

In exploration, mining and construction, the creation of a new industry would bring economic and social benefits for the state in the form of employment in return for the long-term expense of creating the industry. However, this would entail enormous state subsidies (Dr Dylan McConnell, Inquiry into nuclear prohibition, Legislative Council Environment and Planning Committee, Transcript of Evidence, 11 September 2020, p 21) as the inquiry noted from the modelling and costs presented, we would lock the Victorians into higher energy costs, environmental risks and hitherto unresolved nuclear waste, water use and decommissioning issues while almost certainly facing justified community and business backlash. (https://www.pri.org/stories/2017-07-31/finlands-solution-nuclear-waste-storage-may-set-example-world#:~:text=The%20Onkalo%20Nuclear%20Waste%20Repository%20is%20planned%20for%20an%20island,will%20need%20to%20be%20done.&text=The%20site%20at%20Onkalo%20will%20store%20radioactive%20waste%20for%20100%2C000%20years.)

Peter Farley, a fellow of the Institution of Engineers Australia for almost 30 years has commented publicly on some of the practical aspects impacting the nuclear industry's ability to acquire a social licence:

"*As for nuclear the 2,200 MW Plant Vogtle is costing US$25 billion plus financing costs, insurance and long-term waste storage. ... For the full cost of US$30 billion, we could build 7,000 MW of wind, 7,000 MW of tracking solar, 10,000 MW of rooftop solar, 5,000MW of pumped hydro and 5,000 MW of batteries. ... That is why nuclear is irrelevant in Australia. It has nothing to do with greenies, it's just about cost and reliability.*"

(https://reneweconomy.com.au/how-did-wind-and-solar-perform-in-the-recent-heat-wave-40479/)

There is already the ability to create jobs where Victoria holds a natural advantage, where the cost to create sustainable jobs would not be so ludicrously high. As outlined earlier, we have a choice to have the best carbon mitigation energy strategies, not just an expensive mining and energy boondoggle.

There is simply no case for wasting time and resources on a technology that is literally the slowest to build, most expensive, most dangerous, and least flexible form of new power generation. The Andrews Labor Victorian State Government has recognised this and has moved to pursue amendments to the *National Electricity (Victoria) Act* 2005 to override the current "complex and outdated" national regulatory regime that has led to grid bottlenecks and delays' (https://www.pv-magazine-australia.com/2020/02/19/victoria-decides-to-go-it-alone-on-transmission-to-unlock-more-large-scale-renewables-and-batteries/).

There are great economic, environmental and social benefits for Victoria in coherent and consistent national and state energy policy that aims at creating a lower carbon emission energy framework. This has been critically lacking for the Commonwealth under the last several conservative governments, where there has been a slavish attention paid to the vested interests who own stranded assets within the fossil fuel industry. This has been combined with an inaction on a number of policy settings that impact Australia's work toward mitigating climate change and has led to the Andrews State Labor Government going it alone in many areas of energy and climate change policy.

As a result of such strident reforms, our Victorian government has been able to facilitate the entry of the largest battery in the Southern Hemisphere, to be built in Geelong. The net effect will be to improve network reliability, create and support local jobs, and support our renewable transition in Victoria.

'*Delivered by global renewable energy company Neoen, the battery will help store renewable energy when the weather makes it plentiful and discharge it into the grid when it is needed most*'

(https://www.invest.vic.gov.au/news-and-events/news/2021/big-battery-to-help-power-victorias-renewable-energy-sector).

In addition, electricity grid upgrades between the Snowy, North-West Victoria and Melbourne would offset energy deficits from coal power station closures in Victoria. (https://www.energymatters.com.au/renewable-news/electricity-grid-upgrade-storage/)

National Leadership would assist in expediting such critical upgrades to advance the renewable transition to meet projected energy requirements. In building toward a low carbon energy future, the lack of uranium mining and nuclear industry has not held us back, the Commonwealth Government policy morass and inaction most certainly has.

One of our foremost unions representing workers in the energy sector – the Electrical Trades Union (ETU) expressed this succinctly in their transcript of evidence to the inquiry:

"The ETU has taken a measured and considered risk-based approach over a long period of time on this issue and engaged with both the proponents and opponents as well as with experts from the scientific and medical communities, amongst others. The reality is Australia is in a very lucky place. We simply do not need nuclear power. There is no inherent intractable policy problem in Australia for which the only possible answer is nuclear. When it comes to energy generation there are safer, cheaper, faster, cleaner options that can deliver the outcomes we need and deliver them now".

*(*ETU, Inquiry into nuclear prohibition, Legislative Council Environment and Planning Committee, Transcript of Evidence, 26 June 2020, p 4).

(3) identify opportunities for Victoria to participate in the nuclear fuel cycle; and

At the risk of stating the obvious, if cost, time, high energy prices and intractable political and social wrangling over nuclear waste and contamination are not evaluated then there is opportunity for Victoria to participate in the nuclear fuel cycle. The inquiry heard from many experts in the energy field of the relatively high cost of nuclear energy and building a nuclear industry, the many years it will take to build such an industry, and the many examples of unresolved nuclear waste and decommissioning costs and environmental health and safety issues (https://www.tai.org.au/content/nuclear-power-uninsurable-and-uneconomic-australia).

Victoria would have to participate knowing:

- It would have to be done at the expense of the state, given there are virtually no private companies willing to build and participate (as seen by the examples of Westinghouse, AREVA and Kepco); (Dr Dylan McConnell, Inquiry into nuclear prohibition, Legislative Council Environment and Planning Committee, Transcript of Evidence, 11 September 2020, p 21).

- The background of the nuclear sector's track record of massive time and budget blowouts (as evidenced by the Russian light-water floating Smaller Modular Reactor [SMR] and Argentina's light-water SMR); (https://reneweconomy.com.au/small-modular-reactor-rhetoric-hits-a-hurdle-62196/?__cf_chl_jschl_tk__=888f5120d3dd408affa013205a3b96f47fdb076d-1603429337-0-ATwoQ9bk9QZzmAQ-9kkuvz4KYuwBzUGsxLox2Tx9aSlac5hbSW5jm3QE6T8m4R5UqEkWwBbngkf5oN2_NlnqnIZQiCDeglIq5FM2YEANkvRKG6mUaonI7oFR6baAXX9pf1d3FMxR-5p-oRIprenO-EvcJZCIfZXwnTUYtg4CVJ1gJdwU5elxLNfCM8x--ixDUteXaoC3o4T4PRcgXCwLxZ6E7r5hQznAdq5mD9WYh1Tq4Qlv7J0Y_3kSAVxwFpgion9HMA7O2kkEmOIsFEI7HtsPWyUadL0kSi_2YHqLpwzomTord9bj-kgvifJbJquo3z55gFZcM8NjBzp-lFfkM2A)
- The industry would need a retailer willing to sign a 30 year power purchase agreement for energy at two to three times the current cost and wait at least 10-15 years for the privilege of the first kilowatt hour; (Simon Holmes a Court, Inquiry into nuclear prohibition, Legislative Council Environment and Planning Committee, 11 September 2020, p 18).
- A community would need to host the reactor, this would need to be near water (probably located on the coast given the need for water cooling);
- The only way the nuclear industry would be competitive in price is if the renewable energy sector growth reverses with their costs and also reverses their current downward trend in cost by increasing costs significantly; (*https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp*)
- There would need to be an agreement around high level nuclear waste with the most likely scenario that the state would have to agree to take on the long-term waste storage obligations, against a backdrop of no agreement on low level radioactive waste at a state and federal level for over a decade. Note the recent

example of the proposed Kimba radioactive waste dump. (https://www.abc.net.au/news/2020-04-16/risk-kimba-nuclear-dump-may-breach-human-rights-committee-says/12154474#:~:text=A%20report%20by%20the%20Joint,to%20culture%20and%20self%2Ddetermination.)

- There would need to be a full-scale rewrite of environmental, energy and planning law to accommodate such a change at both a federal and state level, with Governments having to provide financial guarantees and concessional loans of an unprecedented magnitude and indemnify nuclear projects against accidents (https://www.tai.org.au/sites/default/files/P782%20Over%20Reactor%20%5BWEB%5D.pdf#overlay-context=content/nuclear-power-uninsurable-and-uneconomic-australia, p.5.

It was put well by (Simon Holmes a Court, Inquiry into nuclear prohibition, Legislative Council Environment and planning Committee, Transcript of Evidence, 11 September 2020, p 14) who outlined in their evidence:

'I would say the team at AEMO has just completed what is probably the most rigorous report on energy transition ever undertaken, certainly in Australia and quite likely the world, on energy transition in a grid. There are more than 100 person years of work in the last edition of that report, and the consultation on that has been incredibly broad. The methodology is well documented, and the process has been incredibly transparent; many, many people have kicked the tyres of that review. Their process is to work out the least cost path forward under a number of different scenarios, and only one of those scenarios is tightly emissions constrained. That is called the step-change scenario. The central scenario is business as usual, and there are a couple of other scenarios, but in none of those scenarios does coal get picked. Coal is an allowable technology, and it is in the matrix, so in the least cost path forward coal does not get picked. Now, in modelling I have done and all the modelling I have looked at nuclear comes in as more expensive than coal, so no matter what scenario we take, if we follow the least cost path forward, nuclear does not get chosen. There are also schedule issues, as I mentioned in my introduction. It is unlikely that even if we started now, we would be able to have any nuclear operating in Australia before 2040, so it does not feature in our energy plans for economic and schedule reasons.'

(https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-is)

(4) identify any barriers to participation, including limitations caused by federal or local laws and regulations

Victoria's nuclear prohibition through the *Nuclear Activities (Prohibitions) Act* 1983 and the mirror provisions in section 140A of the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* are regulatory hurdles that would need to be removed. There would then be a need for incredibly complex environmental, energy and work safety regulation with regard to nuclear power generation. This work would be across state and Federal jurisdictions and would take several years.

There is no social or economic licence for these industries. There is deep community opposition toward any countenance of a uranium mining industry or a nuclear energy industry in Victoria, and this has been shown by the popularity of maintaining strong anti-uranium and anti-nuclear policies and commitments. No credible political party has put this proposition forward as a front and centre policy commitment for good reason – they would have to publicly enunciate the solutions to all the financial, social and environmental costs. They would have to deal with potential site and waste issues that come with such a proposal. They would be destroyed politically for such folly and this would be made easy by the deep wellspring of community opposition to the dangers of such an industry, and the understanding if the community of the risks of nuclear activities.

Catastrophic failures in the nuclear industry still continue to pollute our environment in extraordinary volume. The sheer amount of radioactive material being dumped into the ocean from Fukushima in Japan, the inter-generational government debt incurred in attempting to remediate what can be remediated, and the ongoing battle to stabilise the site amidst a realisation that the surrounding area will be closed off to all human activity for hundreds of years. (https://theconversation.com/japan-plans-to-dump-a-million-tonnes-of-radioactive-water-into-the-pacific-but-australia-has-nuclear-waste-problems-too-148337) This, combined with the shameful episodes of covert nuclear testing both in Australia and within our region have informed our populace over generations around the dangers of nuclear activity. (https://www.abc.net.au/news/2020-03-24/maralinga-nuclear-tests-ground-zero-lesser-known-history/11882608) Given we have had unprecedented bushfires, floods and damaging weather events in the last decade with a projected increase in these events due to climate change it would be hard to eliminate reasonable risk from the operation of any major nuclear facility anywhere in Australia.

The costs associated with the creation of a uranium mining industry and nuclear energy industry in Victoria would likely fall to the state given the lack of a consistent energy policy in Canberra This is made even harder given the trenchant community opposition. It would take a brave or foolish government to seek an economic mandate for such subsidies and would most likely fit the description of taking 'the nuclear option'.

The time it takes to create such an industry makes it unworkable as a climate change mitigation strategy in energy policy. Put quite simply, if we are to wait for a nuclear industry to be built from the ground up, we will have missed the timeframe necessary on reducing carbon emissions. The ETU put it well in their submission:

'If, and it is a massive if, the Victorian regulatory changes occurred, the federal regulatory changes occurred, all of the community consultation and approval occurred, environmental approvals occurred, the skills that we need were sourced, contracts were signed, insurance was somehow secured and a nuclear power station was built and somehow all of that miraculously occurred within the next four and a half years despite nuclear power stations never being built that fast before in countries that already have the policy, regulatory and community settings needed and the average time being closer to 10 years and usually 15 years, if somehow all of that happened between now and 2025, the renewable deployments already occurring in the grid, the grid expansions, the upgrades already in place between now and 2025, plus whatever developments occur in that time—and I note the pace of the development of hydrogen fuel cells is rapid—then the nuclear plant that was built would literally have no market to bid into unless the government subsidised every single megawatt of its power it ever produced by something in the order of 60 to 80 per cent to even get it close to the same price as either the renewable generators or the remaining coal generators still in operation.'

*(*ETU, Inquiry into nuclear prohibition, Legislative Council Environment and Planning Committee, Transcript of evidence, 26 June 2020 *p 30).*

There is already a glut of uranium globally in conjunction with a lack of demand, so there is no imperative to drive the mining of uranium in Victoria.
(https://www.cnbc.com/id/100901959)

Water usage in the nuclear fuel cycle is of historical issue - with mining of uranium in Australia (and globally) such as Olympic Dam, using large amounts of water – an average of 37 megalitres of groundwater per day (https://s3-ap-southeast-2.amazonaws.com/assets.yoursay.sa.gov.au/production/2017/11/09/03/09/17/3923630b-087f-424b-a039-ac6c12d33211/NFCRC_Final_Report_Web.pdf p.12)

Renewables currently beat the nuclear energy industry on price (as per AEMO analysis) and are advancing at a much faster rate, with storage mechanisms and capacity technology expanding at a similar rate also.

There is currently a strong global and local focus on reducing the accumulation of waste (such as Victorian Government landfill policy and the Environmental Protection Agency work on reducing hazardous materials), and such a move would not only undermine this as to make it seem farcical. Adding highly radioactive nuclear waste and nuclear operating sites that may never be able to be remediated (effectively becoming no-go zones to be guarded forever by state and local authorities) adds a burden to Victoria that should not be tolerated when the waste profile of renewables is stark in comparison. Even without this comparison the waste profile of the nuclear industry is one that has never stood up to community scrutiny and should rule the industry out immediately.

To suggest that the ban needs to be lifted to advance the nuclear industry in Victoria, is to exclude the multitudes of issues within the nuclear industry proper, namely occupational and health concerns historically with incidents in mining locally and abroad, cost blowouts, significant and profound project delays globally, catastrophic incidents, a void of long-term solutions for toxic high-level nuclear waste and more.

There is potential in the uranium mining and nuclear energy industry in Victoria – potential environmental disaster, potential economic disgrace, potential social outrage and a potential waste legacy for thousands of years. This is not a potential we need; it is a danger we must avoid.