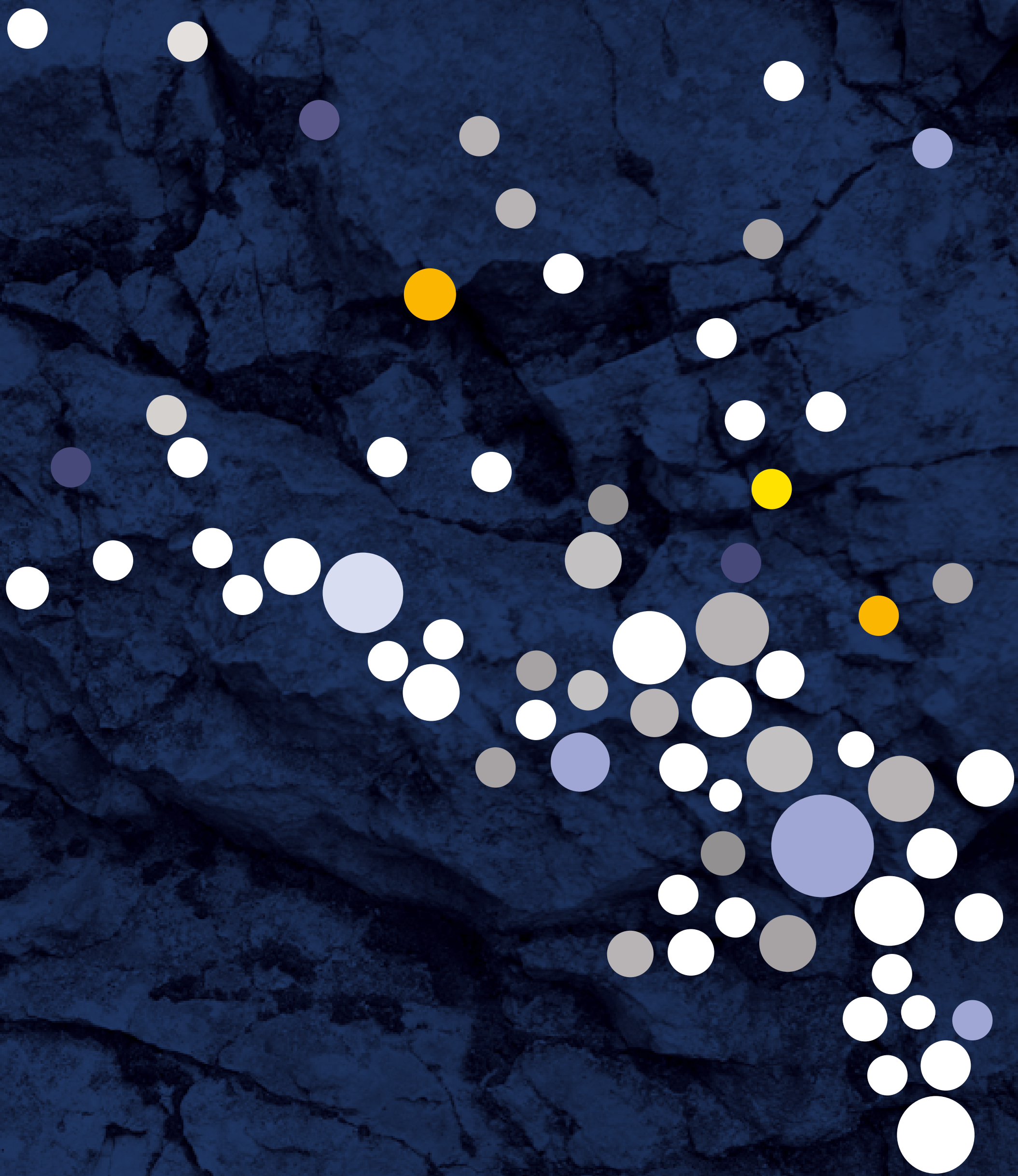
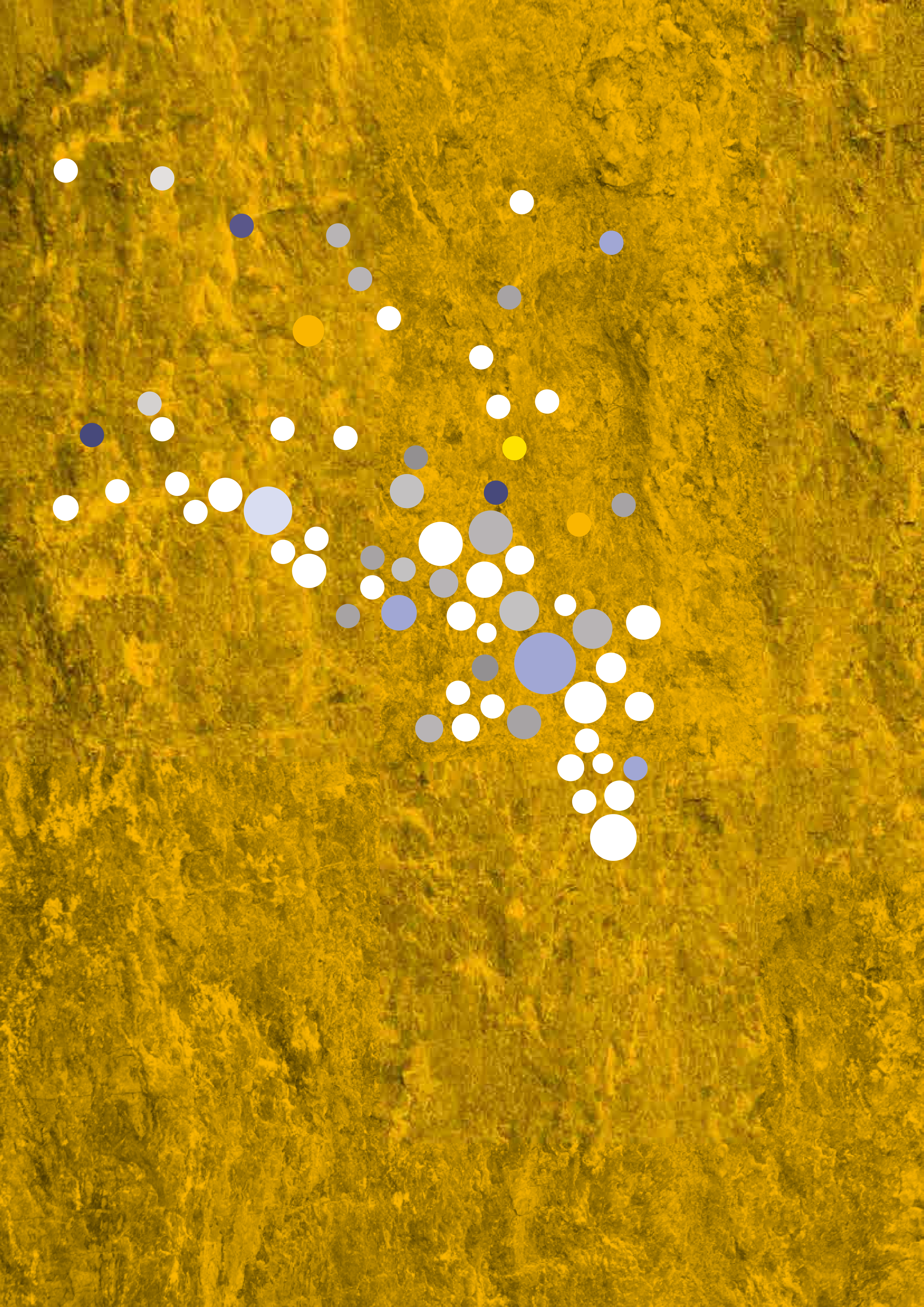


NUCLEAR FUEL CYCLE ROYAL COMMISSION

TENTATIVE FINDINGS



NUCLEAR FUEL CYCLE ROYAL COMMISSION
TENTATIVE FINDINGS

February 2016
Adelaide, South Australia

NUCLEAR
FUEL CYCLE
ROYAL
COMMISSION

CONTENTS

OVERVIEW

The Tentative Findings of the Nuclear Fuel Cycle Royal Commission are an interim step in the Commission's process before the completion of its report in May 2016. They reflect the Commission's current thinking on the issues it considers to be important and the most cogent evidence relevant to them. They do not contain recommendations.

They are shared with the community as part of the Commission's commitment to conducting an open process with access to the written submissions, oral evidence and material it considers to be significant.

Comment is sought on the Tentative Findings to better inform and refine the Commission's thinking before it finalises its findings and makes recommendations. For details on how to comment go to www.nuclearrc.sa.gov.au or see page 41. The closing time for responses to the Tentative Findings is 5pm 18 March 2016.

ABOUT THE COMMISSION

The Commission was established by the South Australian Government on 19 March 2015 to undertake an independent and comprehensive investigation into the potential for increasing South Australia's participation in the nuclear fuel cycle, specifically in four areas of activity:

- expanded exploration, extraction and milling of minerals containing radioactive materials
- the further processing of minerals and the processing and manufacture of materials containing radioactive and nuclear substances
- the use of nuclear fuels for electricity generation
- the establishment of facilities for the storage and disposal of radioactive and nuclear waste.

The Commission's task is to identify, from credible and reliable sources, relevant facts as to this potential, and the associated risks and opportunities for the South Australian community, economy and environment. Its role is to provide considered advice to government to inform decision-making, not to conduct a poll on whether such activities should occur.

The Commission has approached this task by gathering information through written submissions, evidence of witnesses at its public sessions, and its own research, both in Australia and overseas. To further inform its thinking, the Commission engaged organisations with the expertise and experience to undertake detailed assessments of the commercial viability and economic impacts of potential nuclear activities. The Tentative Findings draw together the major elements of that information.

In the Tentative Findings, the Commission has not addressed every issue raised in the written submissions and oral evidence, nor has it identified the submissions it has expressly accepted or rejected.

KEY TENTATIVE FINDINGS

South Australia can safely increase its participation in nuclear activities and, by doing so, significantly improve the economic welfare of the South Australian community.

Community consent would be essential to the successful development of any nuclear fuel cycle activities.

The management of the social, environmental, safety and financial risks of participation in these activities is not beyond South Australians.

Long-term political decision-making, with bipartisan support at both state and federal government levels, would be a prerequisite to achieving progress.

Any development would require sophisticated planning and consent-based decision-making, acknowledging the particular interests and experiences of regional, remote and Aboriginal communities.

EXPLORATION, EXTRACTION AND MILLING

An expansion of uranium mining has the potential to be economically beneficial. However, it is not the most significant opportunity.

FURTHER PROCESSING AND MANUFACTURE

In an already oversupplied and uncertain market, there would be no opportunity for the commercial development of further uranium processing capabilities in South Australia in the next decade. However, fuel leasing, which links uranium processing with its eventual return for disposal, is more likely to be commercially attractive, creating additional employment and technology-transfer opportunities.

ELECTRICITY GENERATION

Taking account of future demand and anticipated costs of nuclear power under the existing electricity market structure, it would not be commercially viable to generate electricity from a nuclear power plant in South Australia in the foreseeable future.

However, Australia's electricity system will require low-carbon generation sources to meet future global emissions reduction targets. Nuclear power may be necessary, along with other low-carbon generation technologies. It would be wise to plan now to ensure that nuclear power would be available should it be required.

MANAGEMENT, STORAGE AND DISPOSAL OF WASTE

The storage and disposal of used nuclear fuel in South Australia is likely to deliver substantial economic benefits to the South Australian community. An integrated storage and disposal facility would be commercially viable and the storage facility could be operational in the late 2020s.

To deliver long-term benefits to future generations of South Australians, a special arrangement such as a state wealth fund should be established to accumulate and equitably share the profits from the storage and disposal of waste.

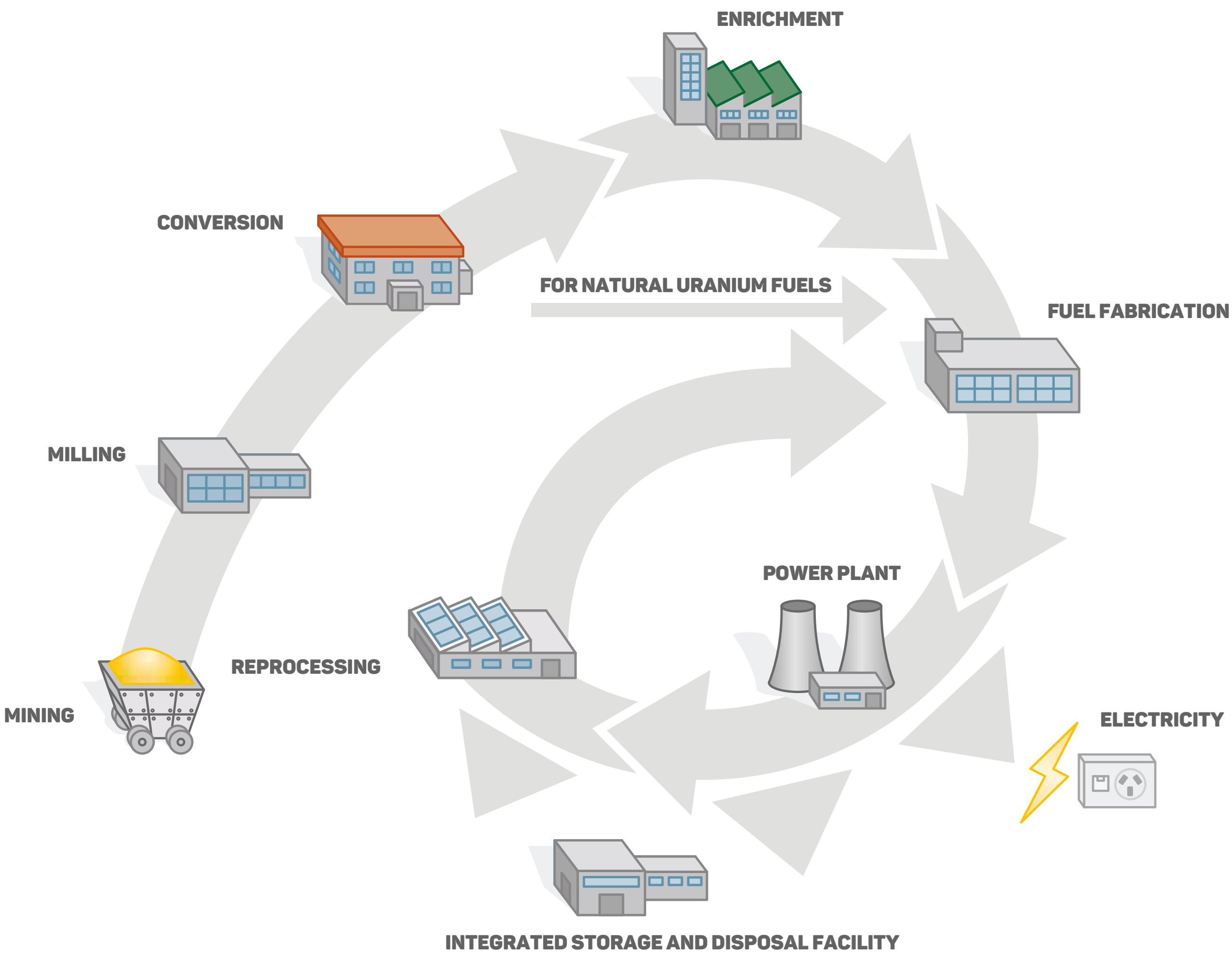


Figure 1: The nuclear fuel cycle.
Adapted image courtesy of the Department of the Prime Minister and Cabinet, Australian Government.

THE ENERGY FUTURE

1. The energy sector in Australia and elsewhere is undergoing transformation as a result of new technologies, changes to traditional supply and demand characteristics, and a desire to reduce carbon emissions. This transformation presents opportunities, and needs to be guided by stable medium-to long-term government policies that encourage appropriate and timely investment. Such policies must be based on evidence, not opinion or emotion.[1]
2. The extent of the opportunities for future South Australian participation in the global markets for uranium ore and other nuclear fuel cycle services is highly dependent on the policies and decisions of all nations as to:
   a. global policy measures adopted to address climate change, and the speed of the implementation of actions to transition to low-carbon energy generation
   b. the suitability of nuclear power as an energy generation option for local conditions
   c. the extent and pace of the installation of any new nuclear power plants.[2]
3. The Paris Agreement negotiated at the 2015 United Nations Climate Change Conference[3]:
   a. calls for signatories to adopt policies that aim to limit any rise of the global average temperature to 'well below 2 °C' above pre-industrial levels and 'to pursue efforts to limit the temperature increase to 1.5 °C' above pre-industrial levels
   b. permits countries to identify their own measures for reducing greenhouse gas emissions
   c. does not identify a mechanism for determining individual countries' share of reductions.
4. The global abatement commitments made before the Paris conference in 2015 will not achieve the 'well below 2 °C' target. Significant additional action will be required. The slower the abatement action taken now to effect this transformation, the greater the action that will need to be taken later, and the greater its costs and impact on the global and local economy.[4]
5. In addition to other measures such as energy efficiency and demand management, it will be necessary to significantly transform Australia's energy sector to meet the widely accepted global target of zero energy sector emissions by 2050. That will be necessary to support pathways to decarbonise other economic sectors such as transport.[5]
6. The Australian Government does not plan to formally review its current and any further carbon abatement commitments before 2017.[6]
7. Nuclear power is presently, and will remain in the foreseeable future, a low-carbon energy generation technology. A recent peer-reviewed meta-analysis of lifecycle modelling undertaken by the National Renewable Energy Laboratory in the United States, which was used by the Intergovernmental Panel on Climate Change (IPCC), concludes that nuclear power has greenhouse gas emissions equivalent to other low-emission technologies such as wind, solar photovoltaics (PV) and concentrated solar thermal. Each of these technologies has greatly lower emissions than gas, and significantly lower again than coal. Other significant studies and reports undertaken on a full lifecycle basis also show that nuclear, wind and solar are low-carbon technologies. [7]
8. In Australia, the ability for nuclear power to contribute to emissions reductions before 2030 is affected significantly by the long lead time to make new capacity operational. Should only modest progress be achieved in emissions reductions before 2030, as appears likely based on current achievements, more rapid action would need to be taken to reach a net zero emissions target from energy generation by 2050.[8]
9. The politics concerning global efforts to reduce emissions are fluid. It would be wise to plan now for a contingency in which external pressure is applied to Australia to more rapidly decarbonise. Action taken now to settle policy for the delivery and operation of nuclear power would enable it to potentially contribute to a reduction in carbon emissions. While it is not clear whether nuclear power would be the best choice for Australia beyond 2030, it is important that it not be precluded as an option.[9]

EXPLORATION, EXTRACTION AND MILLING

The activity under consideration is expansion of the current level of exploration, extraction and milling of minerals containing radioactive materials in South Australia.

WHAT ARE THE RISKS?

10. Exploration activities for all minerals are most commonly undertaken by remote geophysical methods and pose low environmental risks. Where drilling occurs, if properly applied, the current administrative and regulatory processes are sufficient to manage the environmental and other risks. There are always risks of non-compliance with licence requirements, and this has occurred in the past.[10]

11. Mining and milling activities for all minerals pose risks to human health and the environment, which need to be managed. If expanded, uranium mining and milling activities in South Australia would create similar risks to those arising from current uranium mining activities. In the case of expanded underground operations by today's method (see Figure 2), the risks and their current mitigation measures are[11]:

- **a.** the production of mine wastes, most significantly tailings, which are deposited in engineered containment dams—they are licensed under state law and required to contain features to avoid structural collapse and limit seepage potential, and to provide for monitoring to control seepage, and capping at closure
- **b.** the handling of ores containing radioactive minerals, both extracted uranium and its waste products—human exposure is controlled through ventilation, automated processes, protective equipment, engineered barriers and employee monitoring
- **c.** the generation of dust—monitored and controlled by the use of filtration systems and wetting dry surfaces
- **d.** the access of wildlife to acidified tailings—managed by the use of audio and light deterrents, and fencing
- **e.** the extraction and use of water to support mineral processing—modelled before commencing activities and monitored over time to ensure extraction is sustainable.

Some of the environmental effects identified in current and former mines elsewhere in Australia are more challenging than in the arid conditions of South Australia. In parts of South Australia, such as Radium Hill, the uranium ore contains few sulphides. Sulphides create conditions that allow uranium to migrate through the environment.

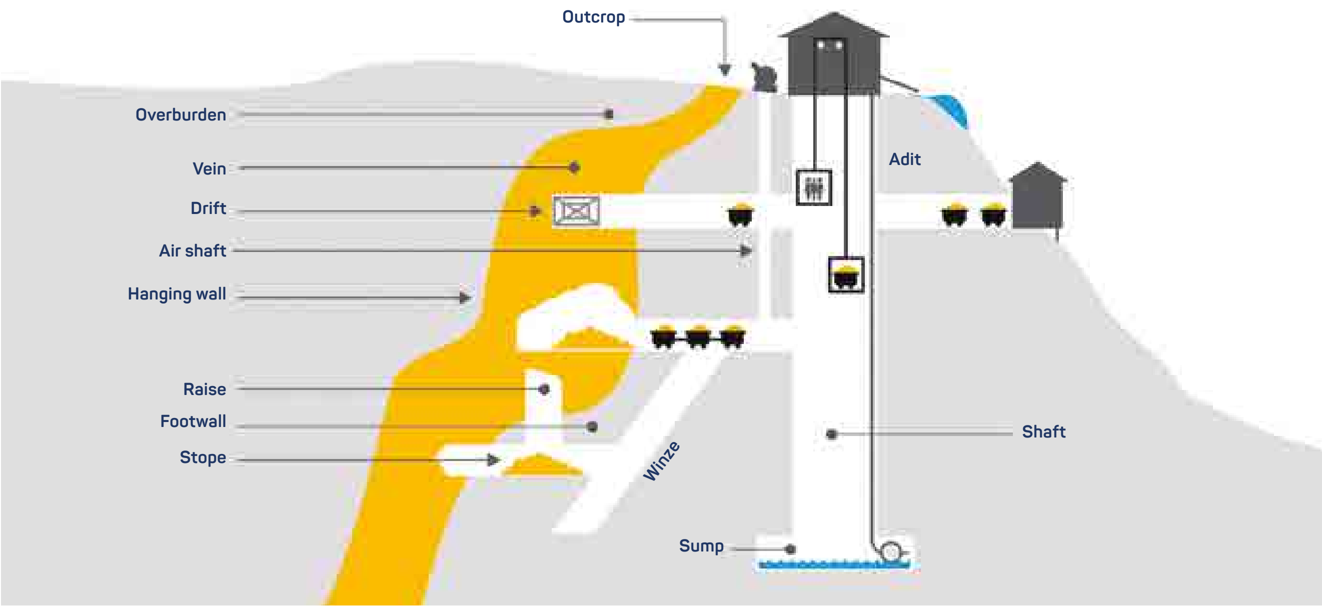


Figure 2: **The underground uranium mining method, which is used at the Olympic Dam mine.**
Image courtesy of Department of State Development, Government of South Australia.

12. In the case of in-situ leach (ISL) mining (see Figure 3) in South Australia, activities are presently conducted in aquifers, which, because of their natural salinity and radon content, have no human or stock use. The risks of ISL mining and their primary means of management are:[12]

a. the potential for contamination of non-target aquifers through acid solution migration—modelled before extraction starts and monitored at the points of injection and extraction, and at nearby monitoring wells

b. the production of solid and liquid wastes—the solid waste is stored in purpose-built containment facilities and the liquid waste disposed of in the target aquifers, where it naturally attenuates over the long term

c. the handling of radioactive materials, both extracted uranium and its waste products—human exposure is limited, and is monitored and controlled using protective equipment, engineered barriers and automated processes.

13. The lessons that have emerged from the state-owned uranium mine at Radium Hill, which closed in 1961, and the associated treatment works at Port Pirie have been incorporated into current regulatory frameworks, which require[13]:

a. the environmental consequences of mining activities to be addressed in the establishment and operation of mines and associated facilities

b. the planned decommissioning and rehabilitation of mine sites to minimise ongoing risks to the environment

c. the separation of facilities from sensitive environments, such as adjoining estuaries and population centres

d. an independent environmental regulator to monitor and enforce compliance with those requirements in accordance with internationally accepted standards.

14. The risk of post decommissioning impacts from exploration and mining is addressed by a regulator holding a financial security or bond in the amount of the estimated cost of remediation. The value of the bond is usually adjusted over the mine's operational life. An exception to this practice is the state's largest mining project, Olympic Dam. Although there is provision for closure costs in the company's internal accounts, the mine has been permitted by special legislation to operate without a separate financial security being held by government.[14]

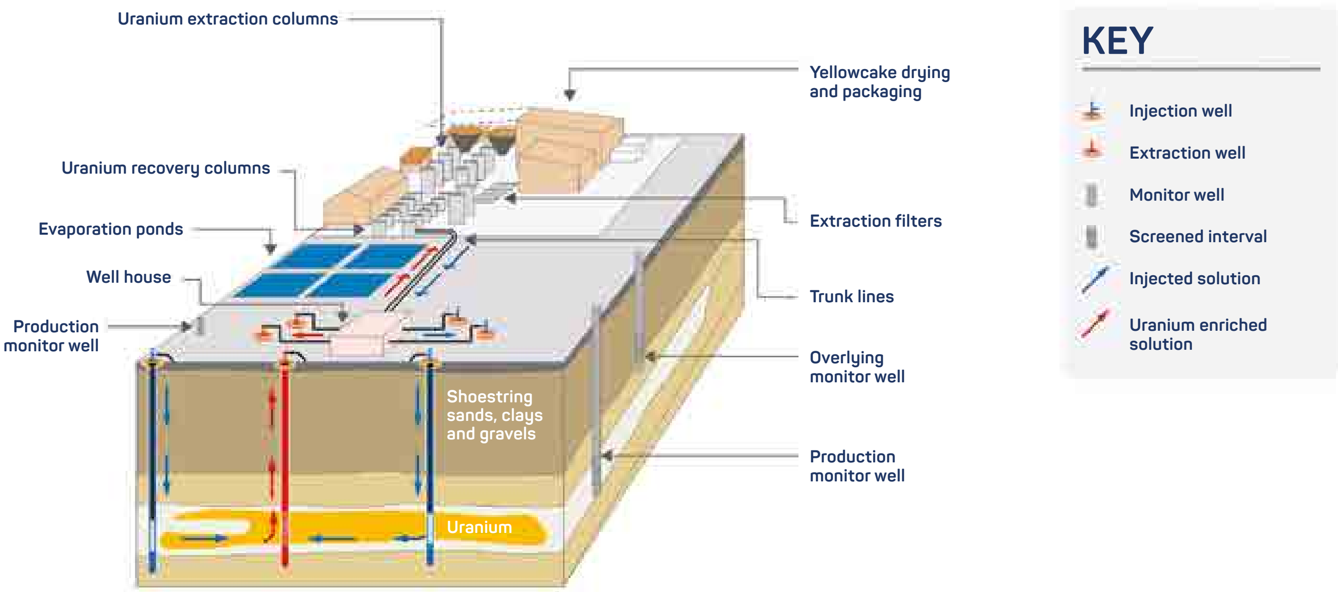


Figure 3: **The in-situ leach uranium mining method, which is used at the Beverley and Four Mile mines.**
Image courtesy of Heathgate Resources.

ARE THE ACTIVITIES FEASIBLE?

15. Given the detailed knowledge of uranium deposits in South Australia, the similarity of geological characteristics in the north of the state, and what is known about the development of mineral systems, there are good reasons for concluding that new commercial uranium deposits can be found in the state.[15]

16. The barriers to the successful exploration for those uranium deposits—barriers that are shared with other minerals—include[16]:

- **a.** the extent and thickness of cover over the state's mineral-bearing rock
- **b.** the cost of drilling activities
- **c.** the low probability of success in drilling in greenfield locations
- **d.** the absence of data from drilling in significant parts of the state
- **e.** the lack of widespread application of new sensing technology
- **f.** the lack of an integrated pre-competitive dataset containing information from related drilling and sensing activities
- **g.** to a lesser extent, the mineral's current market price.

17. The South Australian Government's Plan for Accelerating Exploration (PACE) has led to increased investment in mining exploration. However, exploration expenditure is cyclical. When the mineral exploration industry has invested in projects during less favourable economic conditions (with the support of government), it has been better placed to take advantage of subsequent recoveries in the markets for those commodities.[17]

IN WHAT CIRCUMSTANCES ARE THE ACTIVITIES VIABLE?

18. The significant barriers to the viability of new uranium mine developments in South Australia are[18]:

- **a.** the current low price of uranium and uncertainty about the timing of any price increases
- **b.** the costs of identifying new deposits
- **c.** the requirements for regulatory approval of new uranium mining activities from state mining and environmental regulators and the federal environmental regulator. Although the approvals processes at the state and federal government levels have a common purpose, they are separate, have different timeframes, require different information, and can result in differing conditions being imposed on the same activity. This has increased the anticipated costs of, and timeframes for, regulatory approval for a new uranium mine.

19. Increases in the uranium price in the short term are unlikely given existing inventories. While the low price has restrained greenfield exploration, recent commercial decisions in Australia do not give a clear indication of the future prospects of the uranium industry. While Toro Energy is preparing to start operation of a new mine in Western Australia, ERA has decided not to expand its output at its operations in the Northern Territory, and the Honeymoon Mine is in care and maintenance. BHP Billiton's decision not to expand Olympic Dam is principally related to copper, the mine's main output.[19]

20. South Australian uranium production in 2014/15 was valued at about $346.5 million, with associated royalties of $15.9 million. South Australia could in the short term return to full capacity production levels of about 5000 tonnes. Increasing output beyond those levels would require further investment in new production capacity. Additional in-situ leach mining, although able to be established more quickly than underground mining, would have only a modest impact. It is unclear at this time whether new methods of ore treatment at Olympic Dam would result in additional output.[20]

21. Even if production could be increased to meet very optimistic demand forecasts under strong climate action policies (such as those forecast by the International Energy Agency), the value of production in South Australia by 2030 and associated royalties, while significant in themselves, are small in terms of the state's total revenues. Considering the value of uranium once it is processed into a fuel, South Australia could derive greater value from its extraction if it were able to process uranium into a fuel source, as explained in Tentative Findings 96-102.[21]

22. Energy generation technologies that use thorium as a fuel component are not presently commercial, nor 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. Although South Australia possesses numerous thorium deposits, it does not have a competitive advantage in that resource as it does with uranium.[22]

See also Social and community consent, page 21; Land, heritage and respecting rights, page 22; and Risks and challenges, page 23.

FURTHER PROCESSING AND MANUFACTURE

The activity under consideration is the further processing of minerals, and the processing and manufacturing of materials containing radioactive and nuclear substances (but not for, or from, military uses) including conversion, enrichment, fabrication or reprocessing in South Australia.

WHAT ARE THE RISKS?

23. For conversion, enrichment and fuel fabrication facilities, the most significant environmental and safety risks are posed by toxic, corrosive and potentially explosive chemicals, rather than the radioactivity of the materials involved. All hazardous materials used and produced in these processes would have to be carefully managed; however, many of these chemicals are already used and safely managed by Australian industry.[23]

24. In conversion and enrichment facilities, uranium hexafluoride is a toxic, volatile solid, and is harmful if directly inhaled. If it is exposed to water vapour in the air it forms a corrosive chemical. Other corrosive, flammable and explosive chemicals used throughout these processes present further safety and environmental risks. Containment barriers in these facilities are important to manage these risks and prevent any chemical releases into the environment. Should these barriers be damaged or breached, there is a risk of chemical release and damage to the surrounding environment.[24]

25. If inhaled or ingested, airborne low-level radioactive materials also present health risks to workers in further processing facilities. These risks are managed by using protective clothing for workers, monitoring and containment, and ventilation and air filtering.[25]

26. The risk of significant releases of radioactive materials into the environment during normal operation at conversion, enrichment and fuel fabrication facilities is low. Radioactive releases during an accident are possible, but the radiological consequences would be expected to be limited due to the low radiotoxicity of the uranium compounds involved.[26]

27. Conversion, enrichment and fuel fabrication processes (see Figure 4) produce chemical and radioactive wastes. Techniques exist to minimise the hazardous materials in the waste produced during these processes, such as by filtering or 'scrubbing' gaseous discharges, and recovering and reusing chemicals in liquid discharges. In the enrichment process, depleted uranium tails are a byproduct of the manufacturing process. These tails are produced in large volumes and require storage and security.[27]

ARE THE ACTIVITIES FEASIBLE?

28. There is no technical impediment to providing conversion, enrichment or fuel fabrication services in Australia. The technology associated with chemical processing or manufacturing is transferrable. South Australia has the skills base to provide processing services. The development of any services is impeded by a legislative framework that prohibits these activities. A regulatory structure would need to be developed to provide for their licensing.[28]

IN WHAT CIRCUMSTANCES ARE THE ACTIVITIES VIABLE?

29. At present, the market for uranium conversion and enrichment services is oversupplied. The amount of oversupply is in contention, mainly because of the manner in which the industry operates. Although some of the oversupply arises from secondary sources that will eventually diminish, excess capacity in the conversion market is about 28 per cent, and for enrichment the figure is about 25 per cent. There is also a sizeable surplus in global fuel fabrication capacity. This has depressed current prices, most evidently in prices for enrichment, which at December 2015 were at an historical low of US$60 per separative work unit (SWU), whereas the average price between 2005 and 2013 was just above US$140 SWU.[29]

30. To inform consideration of their viability, a high-level financial analysis of processing services was undertaken on a range of technologies, development costs and combinations of services. The analysis shows[30]:

    a. There are some limited circumstances in which a standalone conversion facility in South Australia could be viable. While a wet conversion facility is marginally unviable in many scenarios, it is not ruled out. It would be viable if the price for conversion services was greater than its long-term average of US$16 per kilogram of uranium (current spot prices are about half that). At the long-term average price, it would be viable if the cost of capital was lower than the 10 per cent used in the analysis. A dry conversion facility is potentially viable under a range of scenarios, although it is used commercially in only one facility internationally.

    b. A centrifuge enrichment facility is not, on balance, likely to be viable in South Australia as a standalone activity, or in combination with conversion. In a range of future scenarios, a facility utilising gas centrifuge technology would not be viable even if prices revert to their long-term historical average of US$140 SWU by 2030. Private investment has not led to

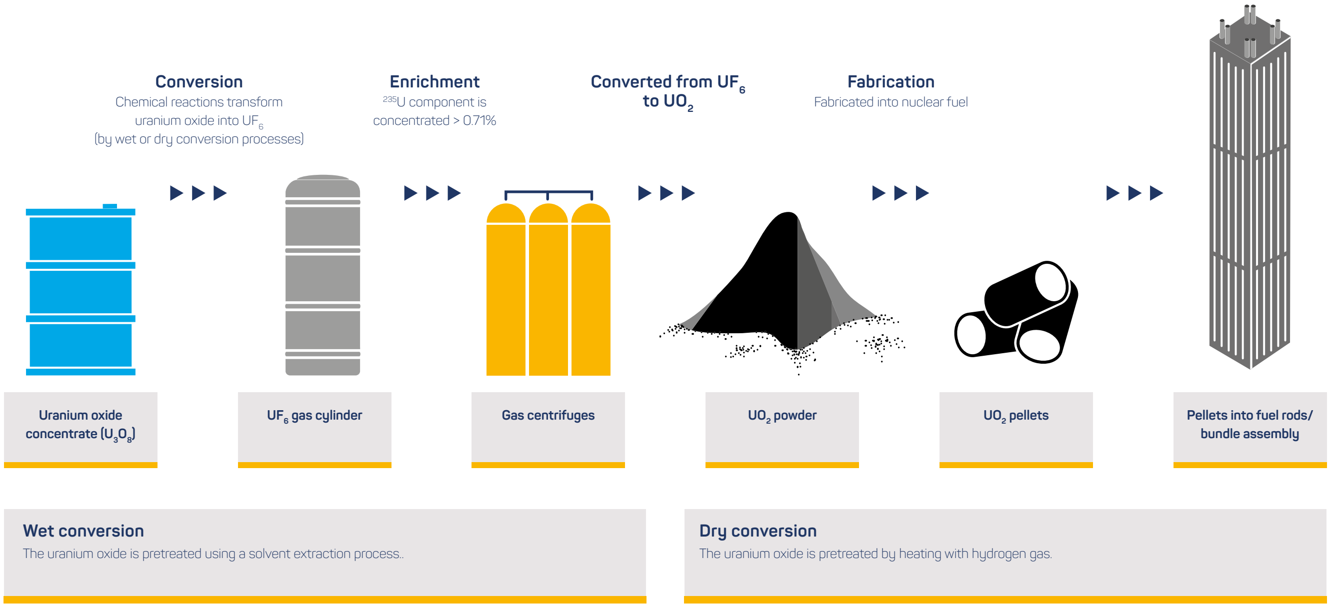


Figure 4: The conversion, enrichment and fuel fabrication processes.

laser enrichment technology being demonstrated at a commercial scale. If laser enrichment technology can lead to substantially lower capital and operating costs, it would have considerable value as a potential economically disruptive technology. However, it would require significant further private investment, with the associated commercial risk, to realise that value.

c. Fuel fabrication facilities could be commercially viable, the more profitable being those concerned exclusively with fabricating fuel for light water reactors. Those manufacturing fuel for pressurised heavy water reactors are less profitable, although still marginally viable.

31. Facilities delivering these services are located in countries that have an associated domestic nuclear energy industry. Further, particularly for enrichment and fuel fabrication, there are substantial barriers to entry. In addition to the vertical integration of some incumbents, the long-term contractual arrangements between customers and service providers deliver significant value to incumbency and experience.[31]

32. Overall, the financial assessment points to, at best, marginal investment outcomes for facilities based on proven technologies, and a limited range of positive investment outcomes for facilities based on proprietary or unproven technology. Combined with significant barriers to entry, the current market oversupply and the uncertainty around future growth of nuclear power generation, there would be no opportunity for the commercial development of further processing capabilities in South Australia, assuming they were in competition with existing suppliers. The position could well be different for an existing supplier seeking to expand its operations. Proximity of uranium mining would not, by itself, present a competitive advantage for conducting processing activities.[32]

33. However, the concept of fuel leasing, which links uranium processing with its eventual return for disposal, discussed at Tentative Findings 96 to 102, may present competitive advantages.

REPROCESSING[33]

34. The radio-chemical processing of used nuclear fuel, or reprocessing, is presently undertaken in countries with domestic nuclear power generation. Reprocessing, which separates fission products to allow the re-use of some fuel components, is a technically sophisticated undertaking with high capital and operational costs. Reprocessing has proven to be a risky technology to introduce, with two overseas facilities experiencing significant operational difficulties. The commercial viability of reprocessing has been undercut by the availability and low cost of uranium.

35. Without nuclear power generation, a used fuel reprocessing facility would not be needed in South Australia, nor would it be commercially viable. On that view it is not necessary to address its specific environmental and health risks.

NUCLEAR MEDICINE[34]

36. Facilities operated by the Australian Nuclear Science and Technology Organisation (ANSTO) in Sydney for manufacturing nuclear medicine are presently being expanded for the production of radioactive medical isotopes, most notably the radionuclide ^{99}Mo, which is used for diagnostic imaging. Considering the cost of the infrastructure and the nature of the market, the duplication of such facilities in South Australia would not be profitable or cost effective.

37. There are opportunities, complementary to ANSTO's activities, to make greater use of and expand the capabilities of the cyclotron and laboratories concerned with the manufacture of radiopharmaceuticals at the South Australian Health and Medical Research Institute (SAHMRI). These opportunities are in the development of new techniques for the manufacture of radionuclides for medicine, providing the skilling of Australian and overseas technicians and conducting research to develop new therapies. Manufacturing radiopharmaceuticals using a cycloctron produces very small quantities of short-lived wastes, which are already managed.

See also Social and community consent, page 21; Land, heritage and respecting rights, page 22; and Risks and challenges, page 23.

ELECTRICITY GENERATION

The activity under consideration is the establishment and operation of facilities to generate electricity from nuclear fuels in South Australia.

WHAT ARE THE RISKS?

38. Nuclear power plants are very complex systems, designed and operated by humans, who can make mistakes. There have been three major accidents in nuclear power plants involving the release of radioactive material into the environment: Three Mile Island in 1979, Chernobyl in 1986 and Fukushima Daiichi in 2011. The broader health impacts are discussed in Tentative Findings 122-124.[35]

39. Each accident has been thoroughly and credibly investigated to determine both causes and lessons to be learned.[36]

40. The accident at Three Mile Island in the United States was started by the erroneous closure of valves on the water supply to the reactor's cooling system. The reactor shut down automatically, but there were failures in the emergency cooling systems, which caused the melting of fuel. As a result, fission products were released to the reactor building and very small amounts of radioactivity were released externally. Water flow was restored to allow cooling. No deaths or injuries resulted. The Chernobyl accident in Ukraine was caused by the deliberate overriding of safety systems in a so-called test, which exposed grossly deficient policies and guidelines for operational safety and the absence of any safety culture. A critical design flaw, not present in new commercial reactor designs, led to an increase rather than a decrease in fission heat production as the core temperature rose. Ultimately there was a chemical explosion that caused the death of two workers and caused the release of a significant amount of radioactive material into the environment.[37]

41. An examination of the Fukushima Daiichi accident in Japan revealed[38]:

    a. critical weaknesses in plant design, and in emergency preparedness, in the event of severe flooding caused by a tsunami

    b. weaknesses in Japan's regulatory framework in terms of both a lack of regulatory independence and multiple decision-makers, which obscured lines of responsibility

    c. the absence of an appropriate safety culture within the reactor operator, the nuclear regulator and the government. This resulted in a number of unchallenged assumptions, including that the plant was so safe that an accident of this magnitude was simply unthinkable, and that there would never be a loss of all electrical power at a plant for more than a short time.

42. The lessons learned from the design, siting and cultural factors that contributed to these accidents have been applied to new developments. These factors pose less of a risk today were nuclear power to be contemplated in South Australia. Yet there can be no guarantee that accidents will not occur again. While the consequences are severe, such accidents are rare given there is 16 000 continuous years of nuclear power plant operation in 33 countries. The risk of nuclear accident should not of itself preclude consideration of nuclear power as a future electricity generation option.[39]

IS THE ACTIVITY FEASIBLE?

43. Nuclear power is a mature, low-carbon electricity generation technology. Although established nuclear power plant designs have operated for many decades, new designs continue to be developed and explored. Nuclear power's deployment is characterised by large upfront capital costs and long periods of construction and operation. It offers high capacity and reliability, but typically lacks the ability to follow the peaks and troughs of a highly variable demand profile.[40]

44. While the technology to develop a nuclear power plant could be readily transferred from experienced commercial vendors, careful consideration would need to be given to the geophysical characteristics necessary for plant operation. Water requirements for a nuclear plant are significant, even when dry cooling techniques are employed. Current designs would necessitate access to seawater for cooling.[41]

45. If nuclear power were to be developed in South Australia, a proven design should be used that has been constructed elsewhere, preferably on multiple occasions, and should incorporate the most advanced active and passive safety features. This is likely to include consideration of small modular reactor (SMR) designs, but exclude for the foreseeable future fast reactors and other innovative designs because[42]:

    a. the generating capacities of SMRs would be attractive to integration in smaller markets, such as in South Australia and in off-grid applications. The commercial deployment of one or more light water SMR designs is likely overseas within the next decade. If successful this would provide credible evidence as to capability and costs

b. fast reactors or reactors with other innovative designs are unlikely to be feasible or viable in South Australia in the foreseeable future. No licensed and commercially proven design is currently operating. Development to that point would require substantial capital investment. Moreover, the electricity generated has not been demonstrated to be cost-competitive with current light water reactor designs.

IN WHAT CIRCUMSTANCES IS THE ACTIVITY VIABLE?

46. The future viability of nuclear power, as for any generation source, can only be analysed as part of the electricity supply system in which it would be integrated.[43]

47. The National Electricity Market (NEM), which supplies electricity to South Australia and states other than Western Australia[44]:

    a. is carbon emissions intensive

    b. predominantly comprises ageing centralised generators that have low operating costs with fully amortised capital costs

    c. does not require generation sources to bear the costs of their carbon emissions

    d. is subject to government interventions directed at lowering carbon emissions, which are not technology neutral nor have been demonstrated to achieve a low carbon system with the lowest overall cost.

48. Low average wholesale prices and relatively flat average demand forecasts for the NEM present challenges to the viability of any new electricity generation infrastructure suited to baseload supply.[45]

49. The following characteristics of the South Australian region of the NEM could affect the viability of any current or potential new baseload generator, such as a nuclear power plant[46]:

    a. The annual demand profile is characterised by peaks which substantially exceed average daily demand, which results in a third of South Australia's generation mix being used less than 200 hours annually.

    b. The daily minimum demand for electricity has been falling as a result of increased penetration of solar photovoltaics (PV). Yet solar PV has had little effect on peak demand requirements.

    c. Total demand is small, with low expected short-and medium-term growth, such that a very large generator would supply a large portion of demand.

    d. There is substantial, and growing, intermittent generating capacity, which relies on interstate coal generation and peaking gas generation to continuously balance supply and demand.

    e. The penetration of wind and solar PV has altered the operational characteristics of existing gas and coal generation from baseload to load following.

    f. South Australia's relative isolation from the wider NEM due to limited transmission interconnection inhibits the import and export of electricity.

    g. Relative to other regions of the NEM, South Australia has one of the highest average wholesale prices and some of the greatest price volatility.

50. Future network infrastructure, generation, services and demand in the NEM will be affected by factors such as federal government policy, changes in technology, and economies of scale in production and consumption. There is considerable uncertainty about how these factors might change. While the expected downward trend in the cost of renewable technologies to 2030 has been factored into assessments in estimating the changing mixture of generation in the NEM, the cost of nuclear is assumed to remain unchanged.[47]

51. Given that uncertainty an assessment of the viability of establishing a nuclear power plant in South Australia requires investigation of existing large and potential new small nuclear plants, the impact of additional renewable capacity, the penetration of electricity storage technologies, and likely wholesale electricity prices. In the case of wholesale electricity prices, this includes addressing the potential impact of policies reflecting both moderate and strong emissions abatement targets across the Australian economy.[48]

52. Based on analyses addressing these issues, it can be concluded that[49]:

    a. on the present estimate of costs and under current market arrangements, nuclear power would not be commercially viable to supply baseload electricity to the South Australian subregion of the NEM from 2030 (being the earliest date for its possible introduction)

    b. it would not be viable

        i. on a range of predicted wholesale electricity prices incorporating a range of possible carbon prices

        ii. for both large and potentially new small plant designs

        iii. under current and potentially substantially expanded interconnection capacity to Victoria and NSW

iv. on a range of predictions of demand in 2030, including with significant uptake of electric vehicles

c. nuclear would be marginal in the event of a lower cost of capital that was typical for the financing of public projects and under strong climate action policies.

53. Off-grid nuclear power also is unlikely to be viable in South Australia in the foreseeable future because of low demand, even assuming optimistic growth of mining activities, and the likely location of that demand.[50]

54. There is considerable optimism about the potential of renewable technologies to meet South Australia's electricity needs. This is in part justified by rapid declines in the cost of electricity generated from these sources. If further substantial reductions in cost are realised, renewable generation and storage will be able to meet a significant proportion of demand, with the size of their share depending on their costs. However, even on anticipated substantial reductions in costs, renewables alone (wind, solar PV and storage) will not provide the lowest cost mix of generation. Modelling which takes account of reductions and the effect of potential strong climate action policies suggests that the low cost mix involves a substantial fraction of demand being met by gas generation.[51]

55. While nuclear generation is not currently viable, it is possible that this assessment may change. Its commercial viability as part of the NEM in South Australia under current market rules would be improved if:

a. a national requirement for near-zero CO^2 emissions from the electricity sector made it impossible to rely on gas generation (open cycle gas turbine and combined cycle gas turbine) to balance intermittency from renewable sources

b. the intermittency of renewables could not be adequately supported by cost-effective storage at scale, or by new demand sources such as power to fuel, which converts surplus power into a transport fuel source

c. transmission system augmentations required to support substantially greater wind generation and commercial solar PV were more expensive than anticipated

d. the costs and risks associated with demonstrating and integrating carbon capture and storage with fossil fuel generation at scale were greater than anticipated

e. current capital and operating costs of nuclear plants were substantially reduced, which would require overcoming complexities and inexperience in project construction. Some reductions in costs have been partially demonstrated for recent plants constructed in China, but not yet in Europe or the United States

f. changes to government policy resulted in[52]:

i. a price on carbon emissions in the economy (including from electricity generation)

ii. finance at costs lower than that available on the commercial market (that is, a form of loan guarantee)

iii. long-term revenue certainty for investors.

56. The challenges to the viability of nuclear power generation under current market conditions in South Australia should not preclude its consideration as part of a future energy generation portfolio for the NEM. There is value in having nuclear as an option that can be readily implemented.[53]

57. A future national electricity supply system must be designed to be low-carbon and reliable at the lowest possible system cost. Resolving this 'trilemma' will be difficult and will likely require government policies to be carefully considered. Australian and overseas experience suggests market intervention can have unintended consequences.[54]

58. There are many combinations of generation technologies for a future low-carbon electricity system: it is not a simple choice between nuclear or renewables. A combination of technologies and approaches is likely to be required. Each technology and approach will offer relative advantages and disadvantages in terms of emissions intensity, reliability and cost.[55]

59. Identifying whether a particular generation portfolio will deliver electricity at the lowest possible cost requires an analysis of the future cost of the system as a whole. It is not sufficient to compare the levelised cost of electricity (LCOE) for different forms of generation in Australia. For example, LCOE does not account for the costs of transmission and distribution, which are substantial elements of the electricity supply system.[56]

60. At present, there is no analysis of a future NEM that examines total system costs based on a range of credible low-carbon energy generation options. Such an analysis would be required before it could be asserted that any option would deliver reliable, low-carbon electricity at the

lowest overall cost—with or without nuclear power. That analysis must be based on the realistic prospects of the commercial and technical viability of relevant generation options, bearing in mind that[57]:

a. tidal and geothermal energy sources remain commercially unproven at scale in Australia. In the case of geothermal, there are unresolved technical challenges in rock fracturing and commercial challenges given the substantial cost of drilling. The extent of the commercial deployment of biomass is significantly affected by the alternative value of the resource, its low energy density, and the cost of its transport

b. carbon capture and storage (CCS) integrated with new fossil fuel plants remains commercially unproven at scale internationally and in Australia, and would require significant public investment to achieve

c. battery technologies for on-grid storage are scaleable but have not been commercially deployed in Australia as they are not yet cost competitive with other established means of supply. The economics of their deployment may be improved by falling costs and rising retail prices for electricity. Pumped hydro, another form of storage, may be viable in South Australia but presents significant siting and environmental challenges in new locations.

61. A critical issue awaiting determination in a total systems cost analysis of a future NEM is whether nuclear could lower the total costs of electricity generation and supply. That could arise if a system, including nuclear, is able to reduce the combined costs of the[58]:

a. overcapacity that must be incorporated into generation because of the intermittent nature of some renewables

b. additional transmission and distribution infrastructure required to connect and support remote and distributed generation sources.

See also Social and community consent, page 21; Land, heritage and respecting rights, page 22; and Risks and challenges, page 23.

MANAGEMENT, STORAGE AND DISPOSAL OF WASTE

The activity under consideration is the management, storage and disposal of nuclear and radioactive waste from the use of nuclear and radioactive materials in power generation, industry, research and medicine (but not from military uses).

62. The activity of storing and disposing of wastes produced domestically from industry, research and medicine presents different risks and opportunities than storing and disposing of international used fuel and intermediate level waste from power generation. They need to be addressed separately.

63. The safe management, storage and disposal of Australian and international waste require both social consent for the activity and advanced technical engineering to contain and isolate the waste. Of the two, social consent warrants in planning and development much greater attention than the technical issues.[59]

AUSTRALIAN LOW LEVEL AND INTERMEDIATE LEVEL WASTE

WHAT ARE THE RISKS?

64. Australia holds a manageable volume of domestically produced low and intermediate level radioactive wastes. These low level wastes comprise contaminated soils, decommissioning waste from research reactors, and equipment and laboratory items from the operation of Australia's research reactors and medical facilities. The intermediate level wastes include vitrified (glass) waste from reprocessed research reactor fuel and some materials from the decommissioning of research reactors. The wastes result from science, medicine and industry, the products of which have served current and past generations of Australians.[60]

65. Low level waste mostly contains radionuclides (an atomic nucleus that emits radiation) with short half-lives. This means it requires containment and isolation from the environment for up to a few hundred years to reach background (natural) levels. Low level waste does not generate heat. Intermediate level waste needs a greater degree of containment and isolation than low level waste due to its higher radioactivity and possible higher proportion of long-lived radioactive materials. It requires shielding during storage and transport. It does not generate significant quantities of heat. Both types of wastes are solids at the point of disposal.[61]

IS THE ACTIVITY FEASIBLE?

66. The federal government controls and manages most Australian low level and intermediate level waste. The balance of national waste is managed by state and territory governments and, while not insignificant in volume, is of smaller proportion. At present, Australian low level waste is stored in a significant number of facilities in each state, including universities, hospitals and by industry, pending final disposal. While these storage facilities are licensed for this purpose, they are managed by organisations whose primary function is not the storage and disposal of radioactive waste. There appear to be advantages in terms of managing long-term risks in a purpose-built, centralised facility.[62]

67. Many countries, including Finland, France, Hungary, South Africa, South Korea, Spain and the United Kingdom, have developed and operate purpose-built low level waste repositories. These repositories handle volumes far greater than exist in Australia. New facilities are currently being planned in other countries including Belgium.[63]

68. Repositories have been developed on a range of sites and in a variety of climates—many of which are much less favourable than conditions in South Australia. The designs of those facilities have been adapted to suit those conditions. There is substantial experience in their design, management and operation, and in the case of France, their closure, which has informed applicable international standards. The performance of those facilities in providing long-term isolation and containment is assessed during their operation.[64]

69. The disposal of low level and short-lived intermediate level waste need not rely on the technical characteristics of the site. There is no need for a perfect site; rather, a sufficient one. The emphasis is placed on a facility design that is engineered with sufficient barriers that, in combination, provide for long-term containment and isolation of radionuclides. When disposed of in near-surface facilities, the risks of migration of such radionuclides into the natural environment is managed by[65]:

   a. disposing of the waste in solid and insoluble form

   b. containing the waste in a purpose-built package

   c. adding a further steel or concrete barrier around the waste container

   d. designing and building the facility in a way that retains the waste and prevents moisture ingress from the natural environment.

   Modern waste facilities incorporate such controls.

70. A key element of their successful development has been an acceptance that a society that creates wastes has an obligation to manage it. Successful development in recent times has involved an acceptance that a community that hosts a facility to manage and dispose low and intermediate level waste should be recompensed for the service it provides to society as a whole.[66]

IN WHAT CIRCUMSTANCES IS THE ACTIVITY VIABLE?

71. The federal government is currently managing a process to identify a site for the centralised, long-term disposal of its low level and intermediate level waste. The Commission is not considering the proposed storage and disposal of that waste while that process is underway.[67]

72. In the event that the process currently underway is unsuccessful, there is no reason that a community in South Australia, on the principles outlined in these findings in relation to social and community consent, ought not consider and be informed about the hosting of such a facility.

INTERNATIONAL USED FUEL (HIGH LEVEL WASTE) AND INTERMEDIATE LEVEL WASTE

WHAT ARE THE RISKS?

73. Following its discharge from a reactor, used fuel comprises ceramic uranium material which remains sealed in its metal cladding. It generates heat and is highly radioactive and hazardous. The principal concern is the potential for radionuclides to migrate from the used fuel into the natural environment, where they could be inhaled or ingested by humans and other organisms. That hazard diminishes over time. Within 500 years, the most radioactive elements have decayed. However, because of its radioactivity, used fuel requires isolation from the environment for many hundreds of thousands of years.[68]

74. There is international consensus that geological disposal is the best technical solution for the disposal of used fuel. Two countries, Finland and Sweden, have successfully developed long-term domestic solutions. That success has been both in gaining social consent for a facility and in developing an engineering and technical solution that has been licensed to safely provide for disposal over a long period. The more advanced of the two projects will start receiving used fuel early in the next decade.[69]

75. In these facilities, the risk of the radionuclides migrating into the environment is managed by the geology in which the facility is situated as well as its engineered barriers (see Figure 5).

76. Each facility is sited in geological conditions that naturally limit the potential pathways for migration. While it is not possible to know the geological and climatic conditions in the distant future, reasonable predictions of such future behaviour have been made from careful study of the particular geological formations over much longer periods in the past. Safety analysis has included an assessment of the barrier performance in a range of scenarios of possible future events over one million years. Geological analogues or observed natural conditions in similar ore bodies or materials provide additional confidence.[70]

77. Engineered barriers are designed to work in combination to greatly delay the exposure of the fuel to groundwater and ensure that if the radionuclides migrate into the natural environment, the level of radioactivity would be below that produced by natural sources. Engineered barriers include[71]:

- **a.** waste being in solid form—either retained in the original spent fuel ceramic or incorporated into a solid matrix. This could be a glass structure (known as vitrified waste), a ceramic or a synthetic rock (such as Synroc)
- **b.** solid waste being contained inside a purpose-built package to protect it from mechanical loads
- **c.** the package being deposited inside an additional container to prolong containment
- **d.** the use of a buffer to impede moisture ingress and thereby reduce corrosion
- **e.** the use of backfill and plugs to provide structural support to the tunnel and impede groundwater flow
- **f.** the facility being designed and constructed in a way that acts as a geological barrier.

IS THE ACTIVITY FEASIBLE?

78. For the management of used fuel and intermediate level wastes, South Australia has a unique combination of attributes which offer a safe, long-term capability for the disposal of used fuel. They include[72]:

- **a.** the underlying Archaean geological structure, the Gawler Craton, at an appropriate depth for disposal
- **b.** low levels of seismic activity overall and, in some parts, very low levels relative to elsewhere in the world
- **c.** an arid environment in many parts of the state
- **d.** a mature and stable political, social and economic structure
- **e.** pre-existing sophisticated frameworks for securing long-term agreement with rights holders and the broader community.

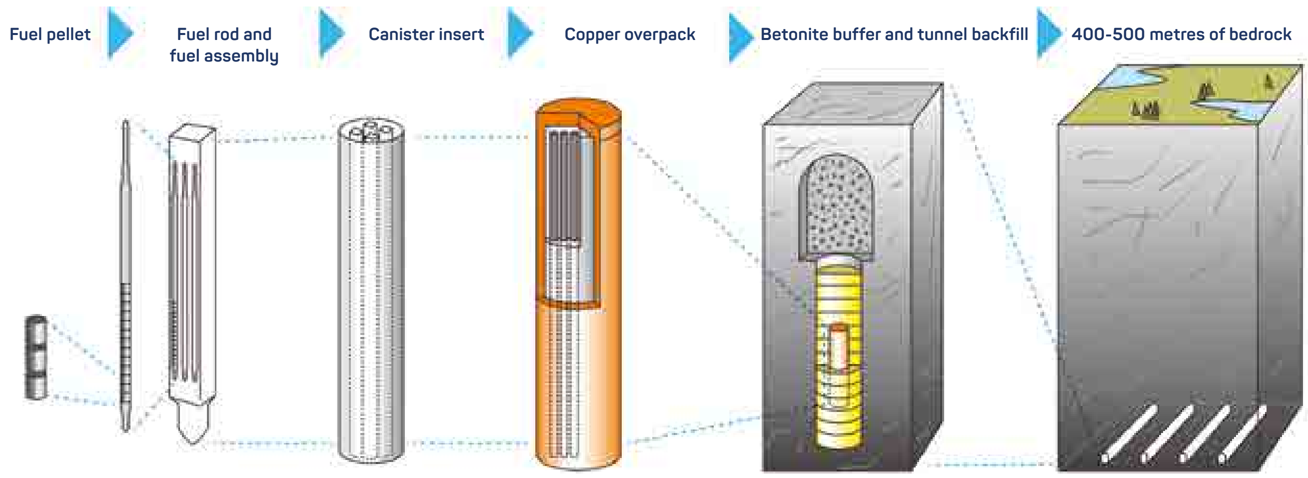


Figure 5: The KBS-3 type multi-barrier system for the containment and isolation of spent nuclear fuel in a deep geological repository.
Image courtesy of Posiva Oy.

79. The storage and disposal of international used fuel and intermediate level waste in a South Australian location are likely to be technically feasible. However, detailed investigations to demonstrate suitability would be required once prospective sites were identified. Siting a facility—which is not part of the Commission's Terms of Reference—would require sophisticated planning and consent-based decision-making outlined in Tentative Findings 103 to 111.[73]

80. The timeframe for the development of a geological disposal facility for used fuel on the Finnish and Swedish models is long. These successful projects have taken more than 30 years to develop—although the facilities were not required before that time and the disposal methods and technology were being investigated concurrent with implementation. Any future proposal could draw on these experiences to reduce licensing and construction timeframes.[74]

IN WHAT CIRCUMSTANCES IS THE ACTIVITY VIABLE?

81. Globally, there are significant quantities of used fuel from nuclear reactors in temporary storage awaiting permanent disposal, including in the Asia-Pacific region, for example, in Taiwan, Japan and Korea. In 2015, there were global inventories of 390 000 tonnes heavy metal (tHM) of used fuel and reprocessed waste, and about 9.9 million cubic metres (m^3) of intermediate level waste in storage. The quantities will grow as these countries continue to rely on nuclear power as a source of generating low-carbon energy. By 2090, the amount of used fuel is projected to be more than 1 million tHM.[75]

82. International conventions require that countries generating used fuel must address its management domestically; however, the development of international or regional solutions for disposal are permitted. While there are international models that address the transfer of hazardous waste between countries, there are no operating models for the commercial transfer of used fuel for disposal. Any proposal to store and dispose of used fuel in South Australia would require agreements between customer countries and both the federal and state governments.[76]

83. Used fuel is an issue of global concern and, like other countries that participate in its supply chain, Australia has a direct interest in[77]:

a. preventing nuclear weapons proliferation

b. maintaining the security of nuclear materials

c. assisting other countries to lower carbon emissions.

Australia would derive a reputational and financial benefit by assisting other countries in providing a disposal solution for used fuel.

84. Given the quantities held by countries that are yet to find a solution for the disposal of used fuel, it is reasonable to conclude that there would be an accessible market of sufficient size to make it viable to establish and operate a South Australian repository.

85. There is no existing market to ascertain the price a customer may be willing to pay for the permanent disposal of used fuel. Willingness to pay may be inferred from several sources, including[78]:

- **a.** the financial costs that a utility might otherwise incur in storing and disposing of used fuel
- **b.** the substantial funds held and provisions made for the future management, storage and disposal of used fuel by countries with nuclear plants
- **c.** the cost of alternative strategies involving reprocessing
- **d.** reductions in project risk and the resultant cost of capital by having reliable, fixed-cost waste disposal
- **e.** distress payments to avoid plant shutdowns.

86. In conducting an analysis of viability, a conservative baseline price for permanent disposal is $1.75 million per tHM for used fuel and $40 000 per m^3 for intermediate level waste. Those figures take account of the lowest willingness-to-pay figure, establishment, operational and post-closure costs. They are not a recommended price, and a higher figure could be negotiated in a range of circumstances.[79]

87. A complete storage and disposal concept would comprise the following integrated facilities[80]:

- **a.** an above-ground interim storage facility which temporarily houses purpose-built packages or 'casks' made of metal or concrete that contain used fuel and intermediate level waste. The area required is 2.5–4 square kilometres
- **b.** a separately located, secure, underground repository facility comprising a series of tunnels into which specially designed canisters containing used fuel and intermediate level waste are deposited for permanent disposal (see Figure 6). Such a facility would have a small surface footprint relative to its underground area. The underground area would depend to a very significant degree on the facility's design and the characteristics of the used fuel and intermediate level waste.

88. Financial assessments suggest such integrated facilities with the capacity to store and dispose of 138 000 tHM of used fuel and 390 000 m^3 of intermediate level waste operating over about 100 years would be highly profitable in a range of scenarios. Those volumes represent about 13 per cent of the projected global fuel inventory, based on a very conservative waste assumption that restricts the number of operational reactors to the current number planned to be in operation in 2030, with no additions. Based on financial assessments, such a proposal is viable even assuming[81]:

- **a.** substantial contingencies for large cost overruns
- **b.** smaller market share
- **c.** the receipt of a significantly lower price for providing a disposal option for used fuel and intermediate level waste.

89. Such integrated facilities remain highly viable despite the anticipated long lead-times involved in their development and construction. The baseline analysis adopts the following timeframes:

- **a.** imports of used fuel with interim storage and associated revenues commencing at year 11 after the project decision[82]
- **b.** transfers from the interim store to the geological disposal facility commencing 28 years after the project decision
- **c.** imports of used fuel and intermediate level waste ending 83 years after the project decision[83]
- **d.** post-closure monitoring phase for the geological facility commencing 120 years after the project decision.

90. Such facilities would need to be controlled and owned by government because of the long-term nature of the activity and the need to secure the long-term trust and confidence of customer countries. Further, because the society would carry the risks of the activity in the long term, it is entitled to the significant benefits. This does not mean the government would be precluded from sourcing appropriate private sector operational expertise.[84]

ECONOMIC IMPACTS

91. Financial assessments suggest that the integrated facilities could generate:

- **a.** total revenue (in undiscounted terms) of more than $257 billion, with total costs of $145 billion[85]
- **b.** expressed in annual terms, total revenue of more than $5 billion a year for the first 30 years of operation and about $2 billion a year until waste receipts are notionally planned to conclude[86]
- **c.** over the life of the project, a net present value of profits (the amount that would be accepted today for a stream of future payments) of more than $51 billion (at the intergenerational discount rate of 4 per cent)[87]
- **d.** approximately 1500 full-time jobs during a construction period of about 25 years, peaking to about 4500, and more than 600 jobs once operations begin.[88]

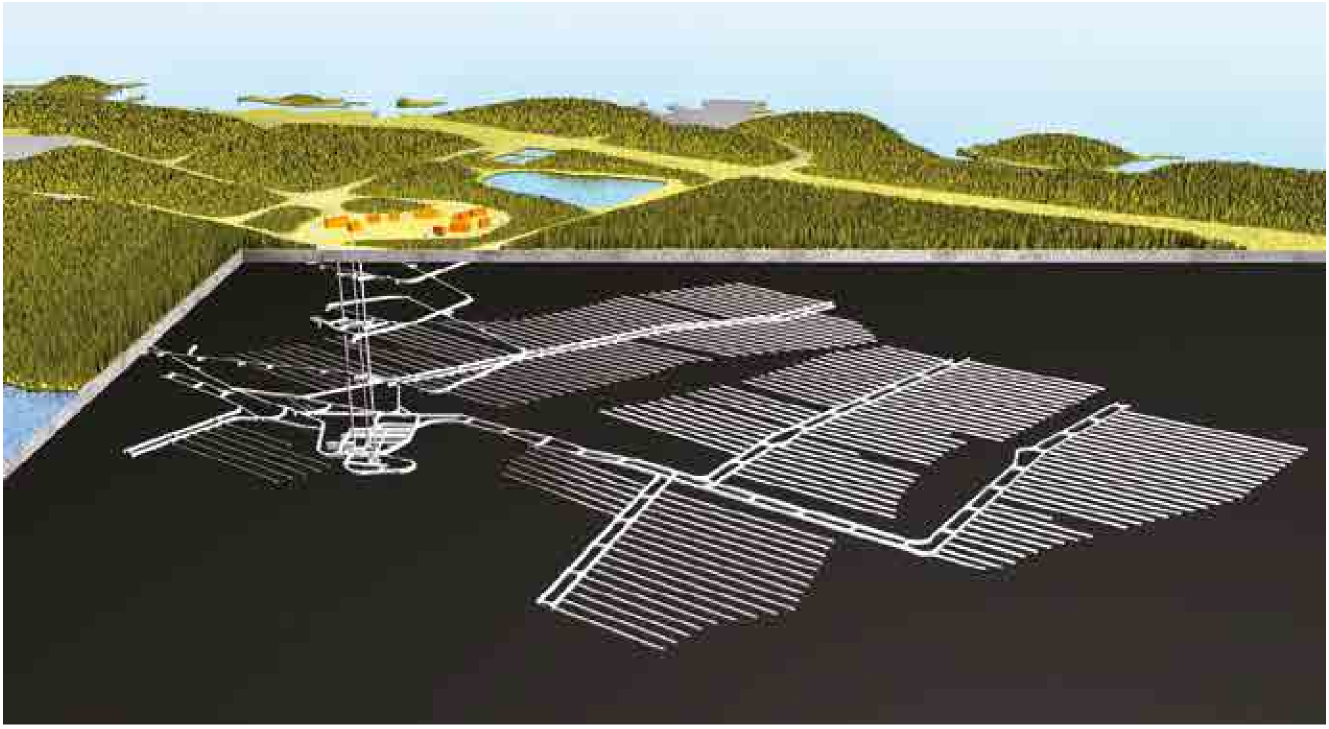


Figure 6: An illustration of Posiva's repository for the disposal of spent nuclear fuel at Olkiluoto, western Finland.
Image courtesy of Posiva Oy.

92. Investing in such facilities would have additional benefits for the whole South Australian economy. Modelling that analyses the economy-wide effects of investment in waste storage and disposal facilities suggests the addition to gross state product would be about 5 per cent by 2029–30 ($16.8 billion). The effect on employment would be about 9600 jobs by 2029–30 (including the direct employment numbers in the previous Tentative Finding). Substantial benefits are estimated to continue to 2049–50 and beyond, when revenues and interest are invested in projects in South Australia.[89]

93. Given the intergenerational nature of the proposed activity, it would be essential to develop enduring mechanisms to ensure that benefits are shared across the community. It would be necessary to[90]:

a. manage the proceeds of these activities for the benefit of current and future generations of South Australians. This would require a special mechanism, such as a state wealth fund. Such a mechanism would need to be legislatively segregated from consolidated revenue to ensure it delivered continuous benefits over the long term. The value of the fund would be substantial. For example, assuming profits accrue at a compound rate of 4 per cent and that 50 per cent of interest income earned each year remains in the fund, it would grow at more than $6 billion a year for more than 70 years (including interest) to reach about $445 billion before notional waste deliveries are planned to cease

b. establish a separate fund, in addition to the state wealth fund, to finance decommissioning, remediation, closure and long-term monitoring activities. Provision has been made in the financial assessment for a fund to start in year 45, which would generate about $32 billion by year 83 to apply to the closure and ongoing monitoring of facilities

c. develop an associated scientific research group focused on the long-term characteristics of used fuel; on processes for its management, storage and disposal; and on possible future use. It also would be necessary to establish an underground research laboratory that could be integrated into Australia's existing nuclear research and expertise capability. It could serve a global client base.

94. The capital costs for the facility would not require significant state investment if a pre-commitment to accept used fuel was secured. A separate analysis suggests that the capital costs of a minimal-scale facility would be met by a pre-commitment of 15 500 tHM of used fuel (about one-ninth of the amount used in the financial analysis to determine viability) at $1.75 million per tHM.[91]

95. As the storage and disposal of used fuel are presently prohibited in South Australia and unlawful without approval under federal laws, legislative amendments would be required and regulatory arrangements would need to be developed for the licensing, management and operation of a facility. There are, however, regulator models in other countries from which Australian regulations could be developed.[92]

FUEL LEASING

96. Storage and disposal of waste potentially offer a pathway to engaging in other fuel cycle activities in South Australia through the business model of fuel leasing.

IS THE ACTIVITY FEASIBLE?

97. Fuel leasing has been proposed in oral evidence and a number of submissions. At its simplest, the concept involves a take-back option for fuel supplied to a utility operating a nuclear plant. Ownership of fuel is maintained by one entity. It removes for the utility the significant operational cost of storing and managing used fuel over the long term. It might also help secure contracts for the storage and disposal of used fuel.[93]

98. The fuel leasing concept is not new and has generated global interest, including endorsement by the International Atomic Energy Agency Expert Group on Multilateral Approaches to the Nuclear Fuel Cycle. It has the potential to strengthen non-proliferation efforts, but is yet to be commercially applied outside Russia.[94]

IN WHAT CIRCUMSTANCES IS THE ACTIVITY VIABLE?

99. Fuel leasing based on an operating storage and disposal facility might resolve some of the significant economic barriers to new entrants seeking to provide global conversion, enrichment and fabrication services.[95]

100. The decision to progress any uranium processing aspect of fuel leasing would predominantly be a commercial one. Bearing in mind the significant capital and time required to establish conversion, enrichment and fuel fabrication facilities, and the current oversupply of these services, a staged process to the development of any fuel leasing program would seem to have the best prospects for success. Such a staged approach might involve:

- **a.** initially, a focus on storage and disposal of waste
- **b.** second, the sale of uranium, with agreement to dispose of used fuel, to utilities that have existing commercial arrangements for conversion, enrichment and fuel fabrication services
- **c.** finally, the development of international partnerships to establish South Australian facilities undertaking conversion, enrichment and fabrication, including the participation of those using these services.[96]

101. The most mature commercial processing technologies—wet conversion and centrifuge enrichment—would be a logical starting point for linking with the storage and disposal of waste. Although the assessments suggest that these processing options are marginal or not viable on a standalone basis, integration as part of fuel leasing might substantially alter the business model.
They should be carefully considered because they provide broader economic advantages in the form of new highly skilled employment and associated technology transfer opportunities.[97]

102. The economic analysis suggests fuel leasing, comprising conversion and enrichment facilities in South Australia, would provide modest additional economic benefits to the conduct of waste storage and disposal activities alone. Assuming both conversion and enrichment were established, modelling suggests the addition to gross state product would be about 0.5 per cent in 2029–30 ($900 million) and an increase in employment of approximately 1000 by 2029–30. Those benefits would continue for the operating life of those facilities.[98]

See also Social and community consent, page 21; Land, heritage and respecting rights, page 22; and Risks and challenges, page 23.

SOCIAL AND COMMUNITY CONSENT

103. Both social consent and community consent must be obtained for any new nuclear activity to commence in South Australia.

104. Social consent means obtaining broad public support culminating in legislative endorsement of an activity by the relevant parliament. Social consent and an associated process of public engagement would be necessary for:

a. the repeal or amendment of laws which prohibit the establishment of types of nuclear facilities in South Australia

b. the establishment of regulation to facilitate the potential undertaking of those activities.

105. In relation to a specific proposal, obtaining community consent, that is, informed agreement from an affected community, extends beyond meeting obligations to specific rights holders (such as landowners or native title holders or claimants). However, the scope of the relevant 'community', and what ought to constitute 'consent' from that community, will vary depending on what is proposed, who is affected, how they are affected and for how long. Community consent does not require unanimity.[99]

106. An expansion of uranium mining would involve the continuation of a lawful activity. The South Australian community has longstanding experience with mining, including uranium mining. Uranium industry participants are well aware of the importance of community consent to maintaining current operations, and the significance of broader support to any new proposal. No additional measures to further regulate community consent or community engagement with respect to new uranium mining projects appear required.[100]

107. Achieving community consent has proven to be a significant challenge for all countries considering the development of a new type of nuclear facility. Approaches that focus on technical considerations relevant to the siting and development of the project, without an equal or even greater emphasis on systematic engagement with the community, have invariably failed.[101]

108. Successful processes for engaging with a community to seek consent for a new type of nuclear facility have a range of key characteristics, such as[102]:

a. transparency of the decision-making framework and requirements for licensing and approval, and a willingness to adapt that framework as necessary to meet new or unforeseen developments

b. a willingness to accept longer community engagement timeframes than usual for typical developments and avoid fixing arbitrary interim deadlines

c. early and deep engagement with local communities to build their knowledge and understanding using a partnership model between the proponent and the community

d. an ability for local communities to engage in a learning process about hosting a facility without being required to commit to the facility

e. resourcing of a community organisation to:

i. deliberate and meet in relation to the proposal

ii. engage independent scientific advisors to assist it in relation to issues of importance and to review scientific information

f. the presence of a trusted, experienced regulator to license the proposal

g. a regulator that is accessible to the community and willing to provide information on both the regulatory process and its decision-making, the proposal and its views on that proposal

h. the availability of scientific evidence and, where necessary, multiple, corroborating bodies of evidence to demonstrate the effectiveness of steps taken to address risks

i. provision of a range of benefits, identified as important by the community, for the service it provides to the wider society for hosting that facility

j. consistency of individuals involved in the development and delivery of those projects.

109. Any engagement process with a potentially affected community needs to be designed with an understanding of and respect for the way in which that community has formed its views in the past. Relevant opinion leaders and historical events need to be identified and acknowledged. Provision of technical information needs to be accompanied by the opportunity for that information to be absorbed and debated in the community.[103]

110. Applied to the South Australian context, the impact of atomic weapons testing at Maralinga in the 1950s and 1960s remains very significant to many people. Those tests, and the subsequent actions of successive governments, have left many Aboriginal people in particular with a deep scepticism about the ability of government to ensure that any new nuclear activities would be undertaken safely. Many Aboriginal South Australians are generally cynical about the motivations of government, and its capability to deliver on commitments. As a result, many groups have communicated to the Commission their unwillingness to contemplate any further nuclear activities. Recognition of these views would be important in planning for, and community engagement on, any proposal.[104]

111. As part of a community engagement process, there are established and sophisticated frameworks through which Aboriginal communities in South Australia should be approached. These frameworks have successfully supported consideration and deliberation on complex issues to secure decisions in the communities' long-term interests. This experience should be incorporated in any community engagement process, as follows[105]:

   a. Any progress towards an activity is based on a principle of negotiation in good faith and on equal terms.

   b. There is a common and realistic understanding as to both the risks and opportunities of the proposed activity—it is essential that benefits are not oversold and risks are not underestimated.

   c. There is early engagement with interested native title holders and the local community about a proposed activity, including preparing a framework for further engagement.

   d. The proposals place particular emphasis on long-term risks and opportunities.

   e. The communication process is agreed by the community and is:

      i. as far as possible, face to face

      ii. intelligible, objective and supported as required by interpretation, trusted advisors, and site visits to similar facilities.

   f. Realistic—and potentially longer than usual—timeframes are set for the community engagement process and decision-making.

   g. The community is supported to make its own decision—whether yes or no—free from the influence or pressure of the proponent or lobby groups with their own agendas.

LAND, HERITAGE AND RESPECTING RIGHTS

112. The Commission has received many submissions that underscore the deep connection that Aboriginal people have with the land and their responsibility for its care. That strong relationship with land is central to the way that Aboriginal South Australians have considered projects, including proposed nuclear activities. It is critical that a proponent of any nuclear project understands and respects that connection.[106]

113. To the extent that any project would be proposed on land in which there are Aboriginal rights and interests, including native title rights and interests, they must be respected. It would be essential to engage early.[107]

114. Some projects create the potential for disturbance of sites of Aboriginal cultural or heritage significance. There are existing regulatory mechanisms for the protection and preservation of heritage. *The Aboriginal Heritage Act 1988* (SA) would apply to protect heritage in relation to any future nuclear developments. This excludes mining operations at Olympic Dam, to which a specific regime applies under the Indenture Act, the Olympic Dam Agreement, and a registered Indigenous Land Use Agreement under the *Native Title Act 1993* (Cth). Further, Aboriginal heritage is protected by the mining licensing process, including the Program for Environment Protection and Rehabilitation, which is required to obtain an exploration or mining licence.[108]

115. From a practical standpoint, bearing in mind the concerns expressed in many submissions about potential risks to heritage and culture posed by developments, any proponent must:

   a. ensure those with knowledge and responsibility for heritage in a community clearly understand the nature and extent of a proposal

   b. establish processes that exhaustively identify what must be protected

   c. provide for negotiation about proposals to accommodate concerns about heritage

   d. ensure that what is agreed is legally binding.

Early engagement with a community regarding those protections will be essential to building a meaningful relationship that may facilitate community consent for a project.

RISKS AND CHALLENGES

RADIATION RISKS[109]

116. The national radiation safety regime in Australia sets annual limits on the amount of ionising radiation that can be absorbed (in 'doses') by workers and the public. For the public, the limits are significantly lower than what an average Australian might expect to receive from natural sources in any year or from certain medical procedures, such as CT scans and xrays. Background radiation relates to the natural and artificial sources that all people are exposed to on a daily basis. These exposures can vary greatly depending on an individual's location. Projects or activities that have the potential to result in radiation releases to the environment are also assessed for their potential impact, and protective requirements imposed where a potential release may exceed a threshold.

117. This regulatory regime is underpinned by the precautionary principle that any increase in radiation exposure, even at very low levels, may increase the risk of cancer. At very high levels of exposure, adverse health impacts can be directly observed or inferred from statistical analysis. However, at low levels (in the range of ordinary exposures from natural sources) there is ongoing scientific debate on the extent of any health risk that radiation exposure might create. Despite that debate, for the purpose of reducing potential occupational and public risk, a precautionary approach is appropriate.

118. Any new nuclear facilities in South Australia would need to be designed and operated in a way that ensures the regulatory limits are not exceeded and that any human exposure is as low as reasonably achievable. The greater the risk, the greater the level of engineered barriers, automation of processes and protective work practices required.

119. Data from modern nuclear fuel cycle facilities demonstrates they operate well within the applicable regulatory limits for workers, the public and the environment. The levels of exposure to the public are in the vast majority of cases lower than what might be expected from natural sources.

120. Doses of radiation to the local community from any new nuclear facilities in South Australia can be expected to be in the range of those estimated from the international nuclear facilities set out in Figure 7. Doses of radiation to the public are calculated based on a representative person who is exposed to radiation by living near, or eating food sourced from around, a particular facility. To give an Australian example, the maximum annual effective dose of radiation that a member of the public would receive by continuously standing on the edge of the buffer zone around the Australian Nuclear Science and Technology Organisation (ANSTO) facility at Lucas Heights in New South Wales would be an additional 0.0026 millisievert (mSv), or about three-tenths of one per cent of average annual background sources. In the case of the Finnish deep geological disposal facility, which will be subject to an annual regulatory public dose limit of 0.1 mSv during normal operations, the annual dose to the most exposed members of the public has been modelled to be one hundred thousandth of that limit.

121. For workers at nuclear facilities, the annual dose of radiation received will vary depending on the nature of the tasks that are performed. The range of occupational exposures which might arise in South Australia from nuclear fuel cycle activities can be expected to be in the range of those recorded at the international nuclear facilities set out in Figure 8. Cumulative doses of radiation received by relevant workers are continuously measured by personal dosimeters attached to clothing. In Australia in 2014, the average annual dose (in addition to background radiation) received by a uranium mine worker was less than 1.5 mSv, or just below the level of average annual background radiation.

122. The more significant radiation risks are created in the event of an uncontrolled release of nuclear or radioactive material, for example, in the event of an accident at a nuclear power plant such as occurred at Chernobyl in 1986 and Fukushima Daiichi in 2011. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and World Health Organization (WHO) have evaluated the independent and peer-reviewed epidemiological studies undertaken by medical doctors and other scientists into the health effects of each accident. These investigations are ongoing.

123. Based on UNSCEAR and WHO reports, the observed health effects in people who were exposed to radiation as a result of the Chernobyl accident are as follows:

a. Of the plant staff and emergency workers who received very high doses of radiation, 134 people developed acute radiation syndrome (ARS), which caused the deaths of 28 of those people.

b. Of the ARS survivors, a further 19 had died by 2006 (two decades later), although their deaths were not directly attributable to radiation exposure. The remaining ARS survivors experience skin injuries and cataracts as a result of radiation exposure.

c. For the public, who received much lower doses of radiation than the plant staff and emergency workers, there were no cases of ARS or associated fatalities.

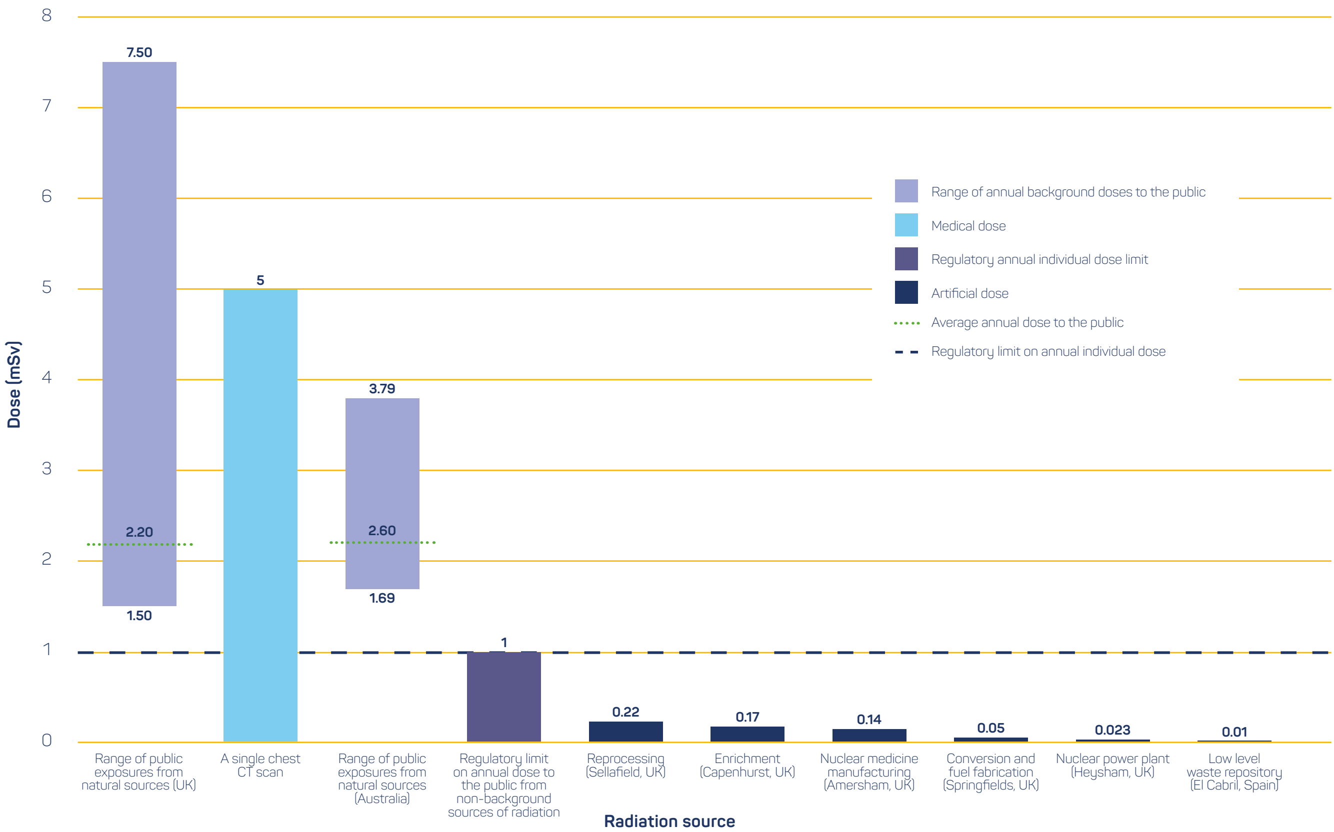


Figure 7: Expected radiation doses to the public from common sources and international nuclear fuel cycle facilities[110]

A significant increase in thyroid cancers was observed in members of the local population who were children or adolescents at the time of the accident. This was caused by the contamination of milk with radioactive iodine in the immediate days after the accident. While those who received high doses of radioactive iodine or were exposed as children or adolescents are at increased risk of developing radiation-related conditions, it has not been possible to confirm whether any further health impacts were caused by the release of radiation.

124. In relation to the Fukushima Daiichi accident in 2011, UNSCEAR concludes:

a. No plant staff, emergency worker or member of the public died or developed ARS as a result of radiation exposure. A small proportion of workers received higher doses during the accident and in the immediate clean-up period.

b. There may be an increased risk of thyroid cancer in more vulnerable groups in Fukushima (the most exposed workers, and infants and children in the evacuation zone). An increase in other types of cancer is not expected. Any such increase would be difficult to attribute to the accident, given the understood levels of exposure. To date, the most important health impact has been on psychological wellbeing.

NON-PROLIFERATION AND SECURITY[112]

125. Australia has sound non-proliferation and nuclear security credentials developed over many decades. They have been recently rated as first on an international comparison of nuclear security regimes. This reputation has been developed because of its active involvement in strengthening the international safeguards system and its demonstrated approach to managing non-proliferation and security risks in undertaking nuclear fuel cycle activities. Maintaining that reputation will be critical in contemplating participation in new nuclear fuel cycle activities.

126. Any nuclear fuel cycle facility to be built in South Australia would need to be constructed and operated in accordance with this strengthened international safeguards system,

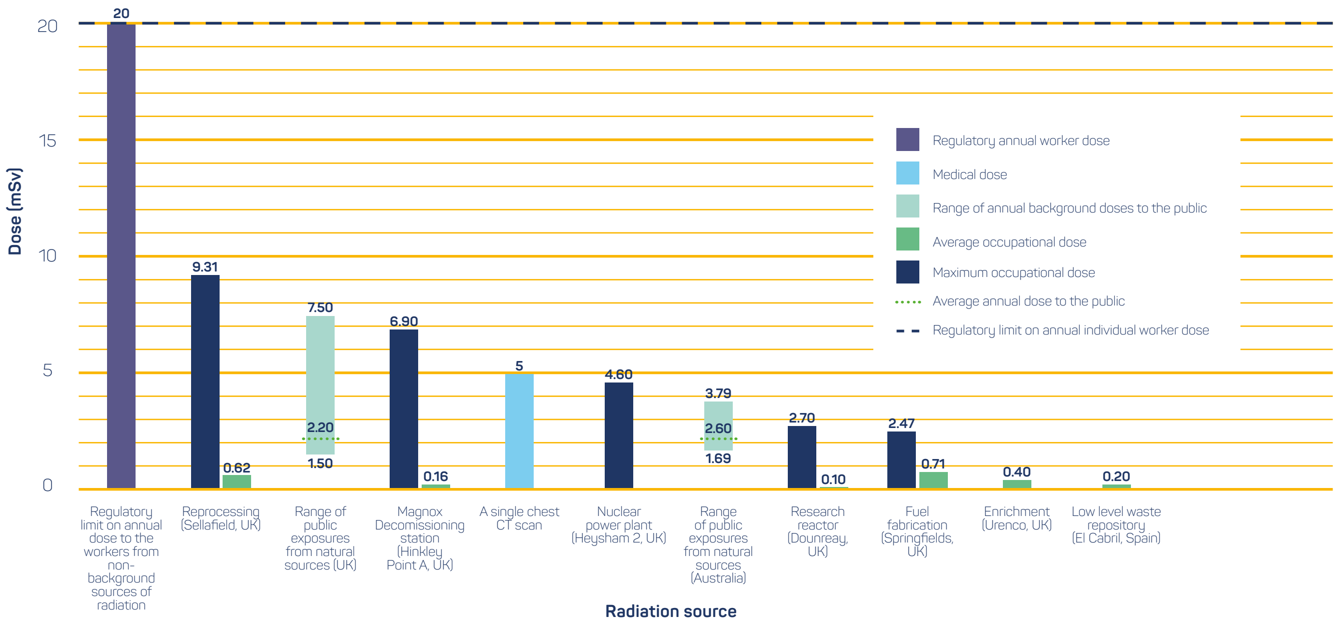


Figure 8: Expected radiation doses to workers from common sources and measured occupational doses at international nuclear fuel cycle facilities[111]

thereby assuring other countries that the facility is used solely for peaceful purposes. This would require taking steps to provide assurance, including participation in international inspection and facility monitoring.

127. The potential for proliferation and security risks from nuclear fuel cycle activities is greatest for enrichment or reprocessing because those facilities can produce highly enriched uranium or separated plutonium capable of use in nuclear weapons. The risks are lower for:

a. uranium mining or conversion, the products of which are not capable of use in a nuclear weapon without enrichment or irradiation and reprocessing

b. the storage and disposal of low and intermediate level wastes, being either contaminated materials or wastes immobilised in glass, ceramic or concrete. Even if some wastes contain trace amounts of sensitive materials, they are practically irrecoverable

c. the storage and disposal of high level wastes, which do not contain materials readily recoverable for use in nuclear weapons

d. the storage and disposal of used fuel. Although it contains plutonium, used fuel would require the further step of reprocessing before the plutonium could be utilised in a weapon

e. nuclear power plants. Although such plants produce plutonium in uranium fuel, it is not usable in nuclear weapons without reprocessing the fuel.

128. Engagement in new nuclear fuel cycle activities would require further regulation in Australia. Models of regulation addressing proliferation from other jurisdictions could be applied to an Australian context for any potential new activity.

129. In the event that a fuel leasing arrangement provided the basis to establish enrichment facilities, it would be desirable to undertake that activity under a multilateral arrangement with partner countries. The participation of other countries in those activities provides another level of assurance that any proliferation sensitive technology or material is not being used in the host country for non-peaceful purposes.

130. Nuclear fuel cycle activities give rise to security risks. Those risks are, however, manageable and well-managed. Australia has national arrangements for managing the protection of nuclear materials and facilities, supported by a mature international system that provides peer review and guidance. Under that regime, security is an integral part of the design, planning, management and operation of nuclear facilities. This extends to requirements for the design of casks for transporting nuclear materials to ensure their physical protection and the reinforcement of reactor buildings to withstand the force of an aircraft impact.

131. The security risks in Australia, comparatively lower than those in many parts of the world, are already managed at nuclear facilities. The framework for their management involves an assessment of the level of the threat and takes into account the sensitivity of the activity and the attributes of the materials. It requires planning for all credible risks. Such arrangements are already applied to manage security for Australian uranium mines and the ANSTO facilities in Sydney.

132. The development of a proposal to receive used fuel would require the construction of a new secured port and railway. However, the risk of intentional interference or misuse of used fuel is greatly limited by the characteristics of the fuel and the casks in which it is stored and transported. As the casks weigh more than 100 tonnes, they require cranes and heavy vehicles to move. Further, used fuel is highly radioactive and can only be handled with appropriate barriers and controls in place.

TRANSPORT[113]

133. Nuclear and radioactive materials are routinely transported between domestic and international destinations. Consignments include natural uranium, enriched uranium fuels, medical isotope products and radioactive waste materials. Shipments are made by road, rail, air and sea, depending on such factors such as the nature of the radioactivity and the size and weight of the material.

134. During the past 50 years, approximately 7000 international shipments of used nuclear fuel, including nine that have left Australia for reprocessing, have been undertaken. In this time, no accident involving a breach of the package and the release of its contents has occurred. The same record applies to international transport of high and intermediate level waste.

135. During the past 30 years, approximately 11 000 containers of uranium oxide concentrate (UOC) have been exported from Australia. There have been a number of incidents during the transport of UOC where containers have been knocked or dented. However, given that UOC has low radioactivity and is transported in sealed drums inside shipping containers, there has never been an accident in Australia resulting in the release of UOC to an extent that has adversely affected workers, the public or the environment.

136. ANSTO transports 9600 domestic consignments of nuclear medicine annually. There is also regular transportation of radioactive material within states in approximately the same number.

137. The transport of nuclear materials is undertaken in accordance with a mature international regulatory regime, which establishes minimum standards for transport packages, including that they are specifically designed to accommodate the physical, chemical and radiological properties of their contents. Transport package designs are rigorously tested in simulated accident conditions to assess and assure adequate robustness in such conditions.

138. Shipments of used fuel are routine and undertaken in accordance with international requirements which address the risks associated with the heat and radiation that the fuel produces. The requirements include that used fuel must be transported:

- **a.** in specially designed and tested packages or casks with a required ability to withstand the combined effects of external impacts, immersion and fire
- **b.** on vessels which have specific additional features that protect the cask from impact. In many cases shipments are conveyed on purpose-built vessels which incorporate double hulls and additional reinforcement, and are dedicated to the carriage of used fuel
- **c.** in accordance with binding international treaties and bilateral agreements which specify further requirements, including approvals to embark and disembark.

REGULATORY OVERSIGHT[114]

139. Effective regulatory oversight of nuclear activities is principally required to:

- **a.** protect workers, the public and the environment from the harmful effects of excessive levels of radiation
- **b.** physically secure nuclear material against theft or unlawful use
- **c.** safeguard against the proliferation of nuclear weapons
- **d.** provide public confidence that the activity is properly and safely managed.

140. The existing regulatory framework at state and federal level for the purposes of radiation protection, security and non-proliferation is appropriate for the limited scope of nuclear activities currently undertaken in South Australia—principally, exploration and mining for radioactive minerals, and the use of radioactive materials in some medical and industrial facilities.

141. Regulatory frameworks would need to be developed for new activities. Their planning and development would be necessary sufficiently in advance of any contemplated project to ensure that the regulator had the characteristics, skills and culture necessary to rigorously evaluate any proposal.

142. Effective regulatory oversight of nuclear activities requires the regulator to be:

a. independent of both industry and the executive government

b. transparent and consistent in its decision-making

c. committed to safety, and encouraging a safety culture, in all aspects of its operations

d. supported by and welcoming of international advice and peer review, including that provided through the International Atomic Energy Agency.

143. The types of nuclear fuel cycle activities proposed would be critical to the division of responsibility between the federal and state governments when expanding the regulatory infrastructure. Bearing in mind the legitimate interests of a host state in any nuclear facility, federal involvement would necessarily be significant where there is a greater need for international participation, involvement and oversight.

144. There are choices in terms of regulatory design—principally between an outcomes-based or prescriptive approach. The fundamental structure and guiding principles of regulatory arrangements should be settled and communicated at an early stage to provide confidence and certainty to the international community, the public and potential industry participants.

145. Sufficient flexibility should be built into the regulatory structure to allow advantage to be taken of credible overseas licensing processes of similar proposals or technologies. Overseas experience has shown that detailed regulatory requirements can be developed once an initial proposal is identified, providing efficiencies for both the proponents and the regulator.

INVESTMENT[115]

146. There is significant appetite in the private sector investment community to support new Australian infrastructure projects. Securing investment in long-term infrastructure projects in Australia requires:

a. stable policy at both the federal and state level (including bipartisan political support), along with consistency in regulatory frameworks and decision-making

b. credible project proposals that demonstrate a sound understanding of costs and a positive return for investors with certain revenue streams.

147. Securing investment in energy market infrastructure in Australia has been challenged by significant policy uncertainty and a sustained period of falling demand.

INSURANCE[116]

148. Insurance for nuclear activities in Australia is presently provided under a series of specific arrangements concerned with mining, transport and the operation of its research reactor. While sufficient for those purposes, it is not designed to address the new risks presented by additional nuclear activities, particularly commercial power generation.

149. An existing international regulatory framework provides guidance for compensating victims of damage from nuclear processing, power generation and waste, including strict and unlimited liability channelled to the operator that has the greatest control of the risk. The implementation of such laws is an expectation of the international community and a requirement of nuclear operators. In Australia, this would require new federal legislation.

150. The amount of commercial insurance cover mandated by the international agreements is apparently inadequate to fully compensate victims and remediate the environment in a catastrophic scenario at a nuclear power plant. While the amount of insurance required to be held by operators can be increased in domestic law, beyond that limit and the assets of the operator, the state and federal governments would become insurers of last resort.

151. A commercial market for insuring nuclear fuel cycle operations is available internationally. This market has been accessed in Australia in the past, and could be established locally if a nuclear industry were to be developed.

EDUCATION AND SKILLS DEVELOPMENT[117]

152. Australia's engineering and technical workforce would provide a sound base for the construction of new nuclear fuel cycle facilities. Additional skilling would be necessary to meet the more exacting standards of the nuclear industry.

153. Australia's existing base of nuclear engineering capability would need to be enhanced should additional nuclear activities be pursued. A partnering program with international universities that offer quality nuclear engineering courses could augment existing Australian courses.

154. Building up a sufficient level of local nuclear engineering expertise requires time, commitment and advanced planning. Such skills planning has been part of international programs to develop major nuclear projects, most notably in the energy sector. It would also be necessary from the initial planning phase of any major project in South Australia, to ensure an appropriately skilled workforce is available.

IMPACTS ON OTHER SECTORS[118]

155. There is no compelling evidence from any international experience that the development of nuclear facilities in South Australia would adversely affect other economic sectors, provided those facilities are operated safely and securely. There is a perception there would be an impact, which would need to be addressed in the process of obtaining community consent for any proposal. In the event of a major nuclear accident, adverse impacts on the tourism, agriculture and property sectors could potentially be profound.

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GUIDELINES FOR YOUR RESPONSE

The Commission invites all members of the community to respond to its Tentative Findings. In particular, we invite your response as to whether you agree or disagree with a Tentative Finding, why, and the evidence in support of that position.

There is no need to repeat material contained in any written submission to the Commission. Responses may refer the Commission to publicly available material that is not referred to in the Tentative Findings if that might bear upon that finding. Such material should not be enclosed; instead, a reference is sufficient.

The Commission will not accept responses that:

- contain defamatory or offensive material
- request confidentiality, unless the Commission has agreed prior to receiving the response. Any individual or organisation intending to request confidentiality should contact the Commission. The Commission will assess requests on a case-by-case basis; however, it does not anticipate any reason for a response to be confidential
- are not accompanied by a completed coversheet, see details below.

FORM OF RESPONSE

Responses must be in writing.

To best assist the Commission, identify by number and in order the Tentative Finding under discussion.

Only one response will be accepted from any individual or organisation. Modified or substituted versions will not be accepted.

Responses must be accompanied by a completed coversheet, available overleaf or to download at <http://nuclearrc.sa.gov.au/tentative-findings/>. The coversheet requires authors to provide their name and contact details, and authorise publication of the material. As responses to the Tentative Findings are not evidence, an oath is not required.

Electronic responses, preferably in pdf, can be uploaded through the Commission website www.nuclearrc.sa.gov.au or emailed to enquiries@nuclearrc.sa.gov.au.

Printed responses can be posted to Nuclear Fuel Cycle Royal Commission, GPO Box 11043, Adelaide SA 5001.

The Commission will acknowledge received responses.

PUBLICATION

The Commission will publish on its website responses to the Tentative Findings on 2 May 2016, in advance of delivering its report to the South Australian Government by 6 May 2016.

The Commission will not publish responses it has not accepted nor will it publish copyright material.

CLOSING DATE

The closing date for responses is 5pm Friday 18 March 2016.

ALTERNATIVE ARRANGEMENTS

If you require different arrangements to be made to respond to the Tentative Findings, please contact the Commission.

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TENTATIVE FINDINGS RESPONSE COVERSHEET

Name/organisation:

This name will be published with your comments.

These details will not be published:

Address ______________________________

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Telephone ______________________________

Email ______________________________

DECLARATION

1. I am:

- the person named as the author of this document; or
- authorised on behalf of the organisation named to submit this document, and the information and/or views expressed in this document are true and correct to the best of my knowledge and belief.

2. I believe this document is suitable for publication on the internet.

3. I understand that the Nuclear Fuel Cycle Royal Commission may contact me should it require further information.

Signed ______________________________

Date ______________________________

investigating opportunities and risks for South Australia

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