SUBMISSION BY ANSTO TO INQUIRY ON NON-FOSSIL FUEL ENERGY BY HOUSE OF REPRESENTATIVES STANDING COMMITTEE ON INDUSTRY AND RESOURCES

CASE STUDY INTO THE STRATEGIC IMPORTANCE OF AUSTRALIA'S URANIUM RESOURCES

Summary

Global Demand for Australia's Uranium Resources and Associated Supply Issues

Predictions by the OECD International Energy Agency suggest that strong growth in the use of electricity around the world will continue. The International Atomic Eenergy Agency is projecting that at least 60 more nuclear power plants will come online by 2020, and nuclear power's share in the world electricity market will increase from 16 to 17 per cent. Beyond that time, nuclear power shows increasing signs of adoption on a global basis to replace the need to further expand the use of fossil fuels, thus minimising carbon dioxide emissions. The US has already expressed support, while debate has begun in the UK, many Asian countries and Europe on the wider use of nuclear energy. This is in addition to the large commitments from existing nuclear states, especially in Asia.

Global mine production is well below current demand, and is supplemented from uranium inventories and the transfer of materials from nuclear weapons programs. The latter is not sustainable. The price of uranium has increased, and it can be expected that existing mines will be expanded and new mines will be developed.

Over many years, ANSTO has provided ongoing scientific and other technical support to Australia's uranium mining industry, and will continue to do so. ANSTO has extensive technical expertise in the mining and processing of uranium ores, and has carried out process development projects for all of Australia's current, and past, uranium operations. Also, ANSTO has acquired significant expertise in the management of sulfidic mine wastes at sites on four continents over a period of three decades of continuous research and development.

Strategic Importance of Australia's Uranium Resources and Any Relevant Industry Developments

Australia is well placed to respond to increases in demand for uranium, given the size of our reserves. However, as some States proscribe the prospecting for, or the mining of, uranium, Australia may not be able to maximise the potential benefits from its uranium resources.

Potential Implications for Global Greenhouse Gas Emission Reductions from the Further Development and Export of Australia's Uranium Resources

Because nuclear power emits virtually no greenhouse gases, Australia's uranium exports reduce global greenhouse gas emissions at the present time. They will continue to do so when

used in existing nuclear plants, and further development and export of uranium will prevent additional emissions of greenhouse gases if used in new nuclear plants. It has been estimated that each nuclear power plant saves the emission of around 10 million tonnes of CO_2 annually.

Additional Issue No. 1: Radioactive Waste Management

Low level waste is already safely managed in many countries in storage or in a shallow repository. The consensus of waste management experts internationally is that geological disposal of high level and long-lived intermediate level radioactive waste is the best management option. All countries that have made a policy decision on a final step for the management of long-lived radioactive waste (and spent fuel if it is declared a waste) have selected disposal as the preferred option.

ANSTO has expertise in the management of highly active waste arising from the nuclear fuel cycle. For more than 25 years, ANSTO has been researching and developing a ceramic waste form, synroc, which has been specially designed for the immobilisation of high level radioactive waste. Synroc applications are now being developed in Russia, the United Kingdom and Australia.

Significant effort is currently being devoted to the development of new fuel cycles which will reduce long-term waste management burdens.

Additional Issue No. 2: Potential for Diversion of Australian Obligated Nuclear Material and Potential Use of Australian Obligated Radioactive Materials to be Used in "Dirty Bombs"

Significant effort is currently being devoted to the development of new fuel cycles which will enhance proliferation resistance.

Nuclear materials are controlled under safeguards agreements between national governments and the IAEA.

Fears about the use of radiation dispersal devices (dirty bombs) centre on the possible use of radioactive sources. These are not capable of being weapons of mass destruction, but need to be secured appropriately, because of their potential to cause panic and clean-up issues. The IAEA has developed detailed standards and Codes of Conduct for the regulation of the use of such sources, which are being adopted as global standards. Australia is assisting regional countries to implement these standards.

Introduction

1. In drafting this submission, we have had regard to the terms of reference and to two of the issues raised in a letter from the Chairman of the Committee to the Minister for Education, Science and Training dated 17 March 2005. Those issues are radioactive waste management and the effectiveness of safeguards and other regimes in addressing proliferation issues and the possible use of 'dirty bombs'.

Term of Reference No 1: Global Demand for Australia's Uranium Resources and Associated Supply Issues

2. The use of electricity around the world has been growing rapidly, and predictions suggest that strong growth will continue. This growth will be driven particularly by demand arising from economic and social development in developing countries where, today, close to two billion people have no access to electricity. It will also be driven by an increasing availability in all countries of technologies and products that rely upon electricity. As an example, electricity usage in a developed country such as France is around 7000 kWh per person, compared to only 70 kWh per person in developing countries. There is an increasing consensus that no potential source of electricity can be ignored.

3. World electricity production is currently dominated by the use of fossil fuels, which pose serious environmental threats as a result of the emission of greenhouse gases into the atmosphere. For the foreseeable future, the sources of energy that are available to meet the increasing demand for electricity are those which are presently available. Fossil fuels (primarily coal and natural gas), are widely available but pose the problems referred to above. Renewables (solar and wind) are freely available and produce very low emissions of greenhouse gases in their production chains, but produce relatively expensive power that is intermittent and therefore not suitable for very large energy demands. Hydropower is limited by the availability of suitable sites. Nuclear fission is suitable for large scale electricity base load production and emits virtually no greenhouse gases across its production chain, but is seen by many people around the world as being inherently risky. Around the middle of the present century, large scale electricity production from nuclear fusion might become available. None of these energy sources is without risk or without negative environmental impact, but technologies continue to improve and new reactor designs incorporate many inherent safety features. Somewhere along all energy chains pollutants are produced, emitted or disposed of, often with severe health and environmental impacts.

4. Nuclear fission currently provides about 16 per cent of the world's electricity, and uranium is used as the major fuel. In 2004, a quantity of about 78,000 tonnes of natural uranium was used for electricity production in 441 nuclear power reactors in 30 countries. The IAEA forecasts stronger growth in countries relying on nuclear power, projecting at least 60 more plants will come online over the next 15 years to help meet global electricity demands, of which 27 are currently under construction. "The current picture is one of rising expectations" IAEA Director General Dr ElBaradei told the most recent meeting of the IAEA Board of Governors in his introductory statement. Based on the most conservative assumption, the IAEA estimates around 430 gigawatts of global nuclear capacity in 2020, up from 367 gigawatts today. This translates into just over 500 nuclear power plants worldwide by 2020, and represents a slight rise in nuclear power's share in the world electricity market, from 16 to 17 per cent, reversing previous downward estimates.

5. Recently, plans for substantial increases in the use of nuclear power have been announced by China, India and Russia, and some other countries have also indicated that they plan to introduce, or expand present usage of, nuclear power. The production of electricity from fossil fuels in countries that are party to the Kyoto Protocol faces both cost increases and emissions constraints as a result of measures to curb greenhouse emissions, and this is likely to improve the economic attractiveness of nuclear power. It seems clear, therefore, that the proportion of the world's electricity that is derived from nuclear power will increase from

present levels during the next two or three decades, and the demand for uranium will increase correspondingly.

6. Recent years have seen a steady improvement in power plant performance, amounting to almost 20 per cent between 1990 and 2002 (and equivalent to more than 34 new 1000 MW nuclear power plants worldwide), and an associated improvement in industry economics. There have also been recent regulatory decisions to extend the operating licences of a significant number of plants, notably in the United States, where 19 plants received 20 year operating licence extensions between 1999 and 2004 – giving some plants operating lifetimes of up to 60 years. In Japan, 60 years is now seen as a minimum operating lifetime.

7. Global mine production is currently about 42,000 tonnes of uranium oxide annually, well below demand. The difference has been made up from a drawdown of uranium inventories that were accumulated in the past, and the transfer of materials withdrawn from nuclear weapons programs. The quantities available from these sources are, however, limited and such stockpiles of uranium, for example those in Russia, are fast diminishing. As a result, the price of uranium has increased and is now at levels not seen for many years. It can be expected that this will stimulate expansion of existing mines as well as the prospecting for uranium, and that the economics of mining known, but economically less attractive, ore bodies will improve, leading to the development of new mines.

Term of Reference No 2: Strategic Importance of Australia's Uranium Resources and any Relevant Industry Developments

8. Australia has 38 per cent of the world's lowest-cost uranium resources (under US$40/kg), and 28 per cent of known recoverable resources. Total reserves amount to almost one million tonnes of uranium. In 2003-04, Australian production was 9533 tonnes of uranium oxide. Prima facie, ANSTO believes that Australia is well placed to respond to increases in demand, given the size of our reserves. ANSTO notes, however, that current policy in some states precludes the development of new mines from known resources, and other states have legislation that prohibits the prospecting for, or the mining of, uranium. It is therefore possible that Australia will not be able to maximise the benefits that could be obtained from its uranium resources.

9. As noted above, world stockpiles of uranium are diminishing. An increase in reliance on mine production for uranium supplies by nuclear power plant operators should have the effect of increasing the significance of Australia's uranium reserves. Factors such as the size and quality of those reserves, and Australia's record as a stable and low-cost supplier, should ensure that Australia is well placed to continue to supply traditional customers and to achieve significant market penetration in Asia, which is the most rapidly growing area for use of nuclear power.

10. Sales of uranium must be within the context of the Government's nuclear safeguards policy, whereby an agreement on safeguards is an essential prerequisite for sales. ANSTO notes that Australia and China have commenced discussions on a nuclear safeguards agreement, and that China is, potentially, a very important customer for Australia. China has announced the intention of raising total installed nuclear electricity generating capacity from the present level of 6,587 MW(e) to between 32,000 MW(e) and 40,000 MW(e) by 2020.

<u>ANSTO's Role and Capabilities</u>

11. ANSTO's predecessor, the Australian Atomic Energy Commission (AAEC), was established under the Atomic Energy Act No. 31 (1953). The AAEC's functions included undertaking exploration for, and mining and treatment of, uranium and minerals found in association with uranium. The AAEC had responsibility, on behalf of the Commonwealth, for the Rum Jungle mine, including clean-up activities. For a time, it also held equity in both the Mary Kathleen and Ranger mines.

12. Over many years, the AAEC and, subsequently, ANSTO, have provided ongoing scientific and other technical support to Australia's uranium mining industry, including to the three mines that are operating at present - Ranger, Olympic Dam and Beverley. ANSTO, while having no direct involvement in uranium mining or processing, will continue to provide similar support to the industry into the future.

Mining and Processing of Uranium

13. ANSTO Minerals is a business unit of ANSTO which was established in 2004 to exploit the expertise that ANSTO has acquired over 25 years in the treatment of uranium and other radioactive ores, including environmental sustainability issues such as water management and management of sulfidic mine wastes. ANSTO has carried out process development projects for all of Australia's current, and past, uranium operations. This work

has ranged from process optimisation to the investigation of processes to treat waste waters. We have also contributed to several committees of the International Atomic Energy Agency (IAEA) set up to propose criteria for sustainable development of uranium mining and milling operations and to investigate options for waste water treatment.

14. ANSTO has carried out site surveys of uranium milling operations and has knowledge of the range of contaminants, including heavy metals and radionuclides, present in all process and waste streams. ANSTO has the expertise and experience to analyse for, and to advise on the management of, all such elements. ANSTO is confident that such contaminants can be managed in such a way as to minimise their impact on the environment and to meet the regulatory requirements of all Australian jurisdictions.

15. Finally, ANSTO also has capabilities in assessing and advising on mine closure strategies. Advice was provided to Mary Kathleen Uranium on the design of covers for tailings to limit the release of radon gas. More recently, ANSTO was for example a consultant to WISMUT, providing expertise relating to the rehabilitation of several uranium mine sites in the former East Germany.

Management of Sulfidic Mine Wastes

16. Sulfidic minerals such as pyrite are often associated with mine ore bodies, including uranium. Ore stockpiles, open cut pits, waste rock dumps and tailings storage facilities may contain sulfides as a result of mining. These entities need to be carefully managed to prevent the contamination of groundwater and surface streams by pollutants that are generated by the exposure of sulfides.

17. ANSTO has acquired significant expertise in the management of sulfidic mine wastes at sites on four continents over a period of three decades of continuous research and development.

18. ANSTO began developing its capabilities in the early 1970s, with the quantification of pollutant generation rates at the abandoned Rum Jungle copper/uranium mine in the Northern Territory. At Rum Jungle, ANSTO was able to show that it was the sulfidic wastes at the site that were responsible for the very severe environmental degradation in the area.

19. One of the world's first purpose-built 'store and release' covers was applied to two waste rock dumps at Rum Jungle in the early 1980s. The purpose of the cover was to control the generation and release of pollutants. ANSTO developed novel instrumentation that enabled the effectiveness of the covers in controlling water infiltration and oxygen flux to be quantified over the medium term. Ecological studies carried out by ANSTO showed a rapid improvement in conditions downstream of the site after the extensive rehabilitation works had been completed – a new species of fish was even identified. This landmark site provided a benchmark for mine site rehabilitation for many years.

20. Subsequently, ANSTO has refined its skills through working at over 25 operating mine sites in North and South America, Europe, South-East Asia and Australasia. This experience has led to an in-depth understanding of the processes that govern the oxidation of sulfidic materials, the chemical composition of effluent and environmental impact. ANSTO Minerals is in a position to provide practical advice on dump design, closure strategies and

monitoring programs, through the application of computational tools, measurement technologies and specialist expertise.

21. ANSTO is confident that new uranium mines could be developed and operated sustainably with respect to sulfidic waste management.

22. Further information about the capabilities of ANSTO Minerals is available at http://www.ansto.gov.au/ansto/minerals/index.html.

Term of Reference No 3: Potential Implications for Global Greenhouse Gas Emission Reductions from the Further Development and Export of Australia's Uranium Resources

23. Australia's uranium exports reduce global greenhouse gas emissions at the present time. The further development and export of Australia's uranium resources will serve to maintain the present extent of inhibition if the uranium is used in existing nuclear power plants. To the extent that the uranium is used in new nuclear power plants which are constructed instead of plants that use fossil fuels, further development and export of Australia's uranium will prevent additional emissions of greenhouse gases.

24. This situation arises because nuclear power emits virtually no greenhouse gases. The IAEA has estimated that the complete nuclear power chain, from uranium mining to waste disposal, and including reactor and facility construction, emits only 2-6 grams of carbon per kilowatt-hour. This is about the same as wind and solar power, and compares with 228 g/kWh for lignite, 206 g/kWh for coal, and 106 g/kWh for natural gas[1]. It has been estimated that each nuclear power plant saves the emission of around 10 million tonnes of CO_2 annually. Recent calculations by the International Energy Agency has concluded that 36 billion tonnes of CO_2 are required to be saved to avoid increasing the atmospheric CO_2 levels beyond levels considered to pose serious risks for the planet.

[1] Spadaro et al, IAEA Bulletin Vol 42, No2; 2000

Term of Reference No 4: Current Structure and Regulatory Environment of the Uranium Mining Sector (noting the work that has been undertaken by other inquiries and reviews on these issues)

25. ANSTO has no comment in relation to these issues.

Additional Issue No. 1: Radioactive Waste Management

Radioactive Waste from Uranium Mining

26. Three codes of practice for uranium mining in Australia have been developed by a joint Commonwealth-State Consultative Committee to cover:

- Radiation protection in the mining and milling of radioactive ores.
- Management of radioactive wastes from the mining and milling of radioactive ores.
- Transport of radioactive substances.

These regulations were drawn up by the Commonwealth in line with recommendations of the International Commission on Radiological Protection (ICRP), but they are administered by state health and mines departments.

Spent Fuel and Radioactive Waste from Nuclear Power Reactors

27. The IAEA has fostered international co-operation in the waste management field since it was established in 1957. The IAEA categorises radioactive waste into the classes of low, intermediate (Australia's current radioactive wastes are in these two categories), and high level waste (HLW).

28. Disposal methods for treated and conditioned low and short-lived intermediate level wastes are typically in shallow concrete-lined trenches or engineered surface structures. The isolation period is usually up to 300 years, thus facilitating institutional and administrative control of the disposal site. The IAEA says that, worldwide, about 40 near-surface disposal facilities have been operating safely during the past 35 years, and an additional 30 facilities are expected to be in operation over the coming 15 years. Some intermediate level waste contains long-lived radionuclides in quantities that require a high degree of isolation from the biosphere. This is typically provided by disposal in geologic formations at a depth of several hundred metres. Such wastes currently remain in storage pending ultimate disposal.

29. HLW contains high levels of radioactive materials which require a high degree of isolation from the biosphere for long periods of time. Their decay also generates significant quantities of heat. Such wastes normally require both special shielding and cooling-off periods. The major source of non-military HLW is nuclear power generation and, in particular, the management of spent nuclear fuel.

30. Once spent fuel has been removed from a nuclear reactor, it is placed in interim storage at the reactor site for some years. This allows both heat and very high levels of radioactivity to decline, thus making the spent fuel easier to manage. In some countries, the spent fuel is then sent for reprocessing, to recover unused uranium for recycling as reactor fuel (and as such is considered a resource and not classified internationally as HLW). The waste products, which include fission products, are immobilised in borosilicate glass which is packaged in heavily shielded containers in preparation for disposal in repositories deep underground. In other countries, the spent fuel is destined for direct disposal.

31. The IAEA has estimated that the cumulative inventory of stored spent fuel amounts to 183,000 tonnes of heavy metal and the amount of reprocessed spent fuel is about 88,000 tonnes of heavy metal, which means that about one third of the spent fuel that has ever

been discharged has been reprocessed. The IAEA has noted that the spent fuel produced from all the world's reactors in a year, even without any being processed for re-use, would fit into a structure the size of a soccer field and 1.5 meters high. This amount is about 12,000 tonnes per year, and the IAEA contrasts it with the 25 billion tonnes of carbon waste released directly into the atmosphere every year from the use of fossil fuels.

32. International experts meeting under the aegis of the IAEA say that there is broad scientific agreement that deep geologic disposal, using a system of engineered and natural barriers to isolate the waste, is the best method of disposal[2].

33. A radioactive waste management strategy consists of a plan for managing radioactive wastes produced nationally. The strategy may involve a range of processes and facilities, and arrangements for the development, operation and control and regulation of those processes and facilities.

34. The plan for any single waste type may include a number of steps, including chemical and physical treatments, conditioning or immobilisation, containment/packaging and disposal. Storage may be needed at or between several of the steps. Article 2 of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management[3] provides the following definitions:

- **Storage** means the holding of spent fuel or of radioactive waste in a facility that provides for its containment, with the intention of retrieval;
- **Disposal** means the emplacement of spent fuel or of conditioned radioactive waste in an appropriate facility without the intention of retrieval.

These definitions indicate that storage is an interim step undertaken while awaiting some further step or steps. In contrast, disposal is the final expected step within a waste management plan, although additional steps – such as reprocessing of spent fuel - might be possible. Another distinction is that storage implies continued supervision, so that safety is provided by a combination of engineered features and *active controls*; whereas disposal implies a move towards reliance on the conditioning or immobilisation of the waste and the *passive safety functions* of the disposal system's engineered and natural barriers, making active controls unnecessary.

35. In 2004, Australia exported uranium to the following countries: Canada, Japan, South Korea, USA, and the EU (including Belgium, Finland, France, Germany Spain, Sweden and the United Kingdom). Using the definitions above, the table below shows the policies and positions of these countries on the long-term management of long-lived, solid radioactive waste and spent nuclear fuel.

2 www-pub.iaea.org/MTCD/publications/PDF/LTS-RW_web.pdf. .
3 http://www.iaea.org/Publications/Documents/Conventions/jointconv.html.

MANAGEMENT OF HIGH LEVEL RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL
Policies and Positions of Selected Countries

Country	Policy or position
Belgium	Policy of geological disposal.
Canada	Previously investigated geological disposal. Now in formal consultation where a decision in principle will be made between options of geological disposal, storage in a centralised facility and storage at reactor sites. Legislation expected in 2005.
Finland	Policy of geological disposal. Investigations begun at the Olkiluoto candidate site.
France	Policy of research on equal footing into geological disposal, long-term storage and partitioning and transmutation (P&T). Decision expected in 2006.
Germany	Policy of geological disposal. Official objective of operational repository by 2030.
Japan	Policy of eventual geological disposal of HLW and preference for geological disposal of TRU waste.
Korea	Policy of eventual geological disposal.
Spain	Decision expected in 2010. Geological disposal is the reference long-term option.
Sweden	Policy of geological disposal. A repository for L/ILW has been in operation since 1988, and investigations for disposal of SNF are on-going at two sites.
United Kingdom	Previous position of deferring a decision on HLW and investigating geological disposal of ILW and some LLW. Now in formal consultation where decisions in principle will be made between a wide range of options, including storage, for a range of radioactive waste and materials. Decision expected in 2008.
United States	Defence TRU waste is being disposed of deep underground at the WIPP facility (operating since 1999). Currently, investigating geological disposal of civilian HLW and SNF, plus defence HLW, at Yucca Mountain.

Information based on the National Reports on their implementation of the Joint Convention submitted by States Party to the first review meeting, November 2003[4]
HLW = high-level waste; ILW = intermediate-level waste; LLW = low-level waste;
TRU = transuranic-bearing waste (long-lived ILW); SNF = spent nuclear fuel.

Storage

36. Storage has long been incorporated as a step in the management of many types of radioactive waste and materials, especially in the management of the most highly active and long-lived materials, such as spent nuclear fuel and the wastes from the reprocessing of spent nuclear fuel. Storage activities in the above countries are firmly regulated and the principles for regulation are developed at international level.

37. Conventionally, storage has been seen as an interim step, only needed until disposal of the waste or re-use of materials became possible. More recently, however, the question is being asked in several countries as to whether longer-term storage might have some role to play in radioactive waste management.

38. Some countries are undertaking research on the feasibility of long-term storage (up to several hundred years). In Canada and the United Kingdom, formal consultations are currently taking place with a view to defining policy within the next few years, and long-term storage is an option under consideration. In the Netherlands, a policy decision has been taken

[4] http://www-ns.iaea.org/conventions/rw-national-reports.htm.

to store radioactive waste for up to 100 years, and a facility has been commissioned for this purpose.

39. Storage is not considered an endpoint for radioactive waste management. Planning for very long periods of storage, involving possible multiple renewals of storage facilities, is unrealistic and introduces significant uncertainties over which the present generation can have no control.

40. A range of storage facilities of various types are in operation around the world. ANSTO can provide further details if requested.

Disposal

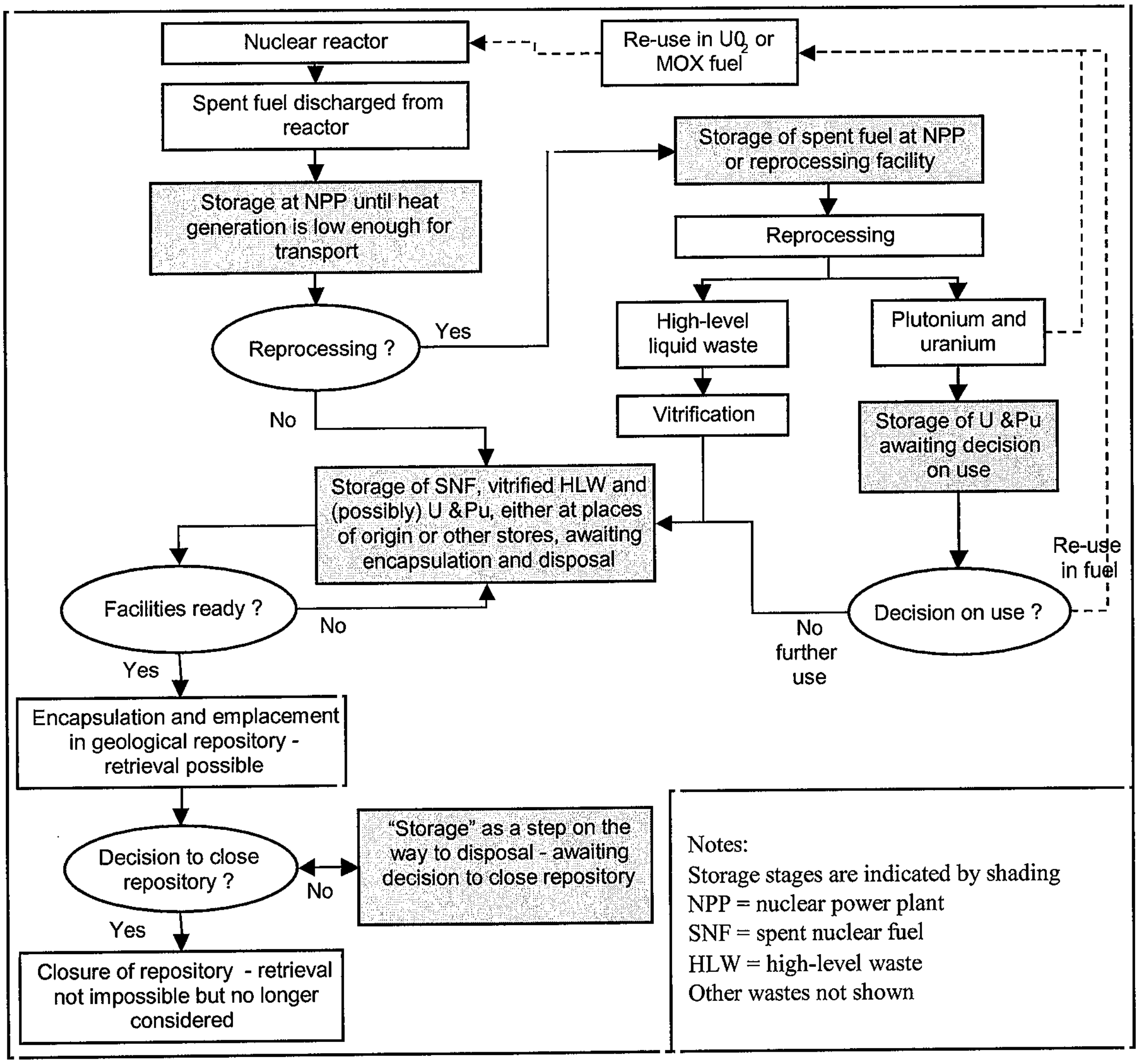
41. As noted above, for high level and long-lived intermediate level radioactive waste, the consensus of waste management experts internationally is that immobilisation and disposal in engineered deep underground facilities - geological disposal - is the best option that is currently available or likely to be available in the foreseeable future. All countries that have so far made a policy decision on a final step for the management of long-lived radioactive waste (and spent fuel if it is declared a waste) have selected geological disposal as the endpoint.

42. Although there are repositories for low level and short-lived intermediate level radioactive waste, presently only one permanent disposal facility for long-lived intermediate level radioactive waste is in operation – the Waste Isolation Pilot Plant in New Mexico USA, for long-lived transuranic wastes from US military programs. The US also plans to build a facility at Yucca Mountain, in Nevada, for spent nuclear fuel and high-level radioactive waste. On July 9, 2002, the US Senate cast the final legislative vote approving the development of a repository at Yucca Mountain. The Yucca Mountain Project is currently focused on preparing an application to obtain a license from the U.S. Nuclear Regulatory Commission to construct a repository.

43. Finland is an example of a country that is in the process of managing waste from a modest nuclear power program. Finland has taken an approach that has been successful in meeting its milestones so far. Finland's deep geological disposal site for spent nuclear fuel (Olkiluoto) was selected in 2000 (ratified by Parliament in 2001). Construction of an underground rock characterisation facility started in 2004, in anticipation of issue of a construction licence in 2010 and readiness for operation in 2020. This site also includes disposal facilities for low and intermediate level wastes from Finland's nuclear power program.

44. The figure below[5] shows general strategies leading to geological disposal (with and without reprocessing) for the management of spent nuclear fuel, high-level waste and recovered materials. Further developments in fuel cycle technology (see paragraph 64) may lead to a simplification of those strategies.

[5] Drawn from OECD NEA Radioactive Waste Management Committee Report - The Roles of Storage in the Management of Long-lived Solid Radioactive Waste and Spent Nuclear Fuel (2005).



Notes:
Storage stages are indicated by shading
NPP = nuclear power plant
SNF = spent nuclear fuel
HLW = high-level waste
Other wastes not shown

ANSTO's role

45. ANSTO has expertise in radioactive waste management, both in terms of waste management at mine sites and in terms of management of highly active waste arising from the nuclear fuel cycle and other nuclear activities.

46. The mining and refinement of radioactive ores may present challenges in waste management. ANSTO is exploring the use of cements, geopolymers and high temperature calcination to incorporate and/or encapsulate and immobilise such wastes. For example, ANSTO scientists have carried out a scaled up demonstration of the use of cement to immobilise radioactive wastes under the control of the Malaysian Institute of Nuclear Research. These wastes were derived from rare earth extraction from naturally occurring radioactive minerals. ANSTO works with the mining industry on waste issues.

47. For more than 25 years, ANSTO has been researching and developing a ceramic waste form - synroc - which has been specially designed for the immobilisation of HLW. Synroc technology can safely immobilise high-level radioactive waste from various sources. The technology, which has now entered the commercialisation stage, is discussed below. ANSTO has internationally recognised expertise and practical experience in the design and plant requirements of waste forms such as synroc. ANSTO, and thus Australia, has a significant role to play in the management of radioactive waste.

48. Around the world, a variety of criteria apply both for the immobilisation of HLW into waste forms, and for the eventual disposal of such waste forms into repositories. However there are common overriding requirements that the waste form should prevent groundwater causing any significant movement of radionuclides back to the biosphere and that nuclear material contained within the waste form should not be able to be removed. Therefore, the aqueous durability and chemical resistance of the waste form is of extreme importance.

49. In 1978, based on geochemically stable natural titanates that immobilise uranium and thorium in nature, Professor Ted Ringwood of the Australian National University (ANU) suggested a 'synthetic rock' waste form, an advanced ceramic composed of titanate minerals that are found in nature, and as such are both highly stable and groundwater resistant. This waste form would incorporate waste fission products and associated actinides in the crystalline lattices of the synthetic minerals, keeping them 'locked up' for millions of years.

50. This led to an ANU joint venture with the AAEC and, subsequently, with ANSTO, to develop 'synroc' as a possible containment material for HLW. Although ANU has ceased its research in this area, research and development has continued at ANSTO, with the original formulations of synroc being exposed to various durability and leaching tests under varying conditions of simulated groundwater and self-irradiation. ANSTO has also responded to other potential applications of synroc by developing different forms of ceramic and glass/ceramic compositions in response to different types of waste.

51. Ringwood's original composition, now referred to as synroc-A, consisted of the minerals hollandite, perovskite, zirconolite, barium-feldspar, kalsilite and leucite. A second composition, synroc-B was formulated to reduce caesium leachability. Synroc-C, D and other variations have followed, with synroc-C now seen as the 'standard' synroc waste form.

Synroc Applications

52. The phases of synroc are used to immobilise specific elements, and therefore combinations of phases can be designed and tailor-made for specific waste streams. Significant synroc development at ANSTO has been in designing, fabricating and testing such waste forms for specific applications world-wide.

US and Russia

53. 'Synroc-D' was originally developed by ANSTO for defence wastes stored at the Savannah River Plant (SRP) in the US. While borosilicate glass was eventually chosen over synroc in the early 80's for the SRP wastes, Synroc-D has since been found to be suitable for various waste streams in Russia and discussions concerning a potential 20t/yr synroc plant in Russia have been held.

Excess US Weapons Plutonium

54. A synroc waste form for immobilisation of surplus weapons plutonium was selected by a competitive process over 70 other candidate waste forms by the US government in 1997. The US Department of Energy (USDOE) then called for bids to build a plutonium immobilisation plant. ANSTO set up an American company (ANSTO Inc.) and a joint venture with Cogema of France through their US subsidiaries to bid for the contract to build the plant. The venture also included US companies Burns & Roe, and Battelle. After bids were submitted, the USDOE announced that it was deferring immobilisation plans. This was due to a number of factors, chiefly a change in the US Administration, and the associated change in policy with regard to weapons plutonium.

UK wastes - BNFL

55. It was announced on 15 April 2005 that British Nuclear Fuels has formally approved funding for the design and construction of a demonstration facility at Sellafield in the UK to immobilise 5 tonnes of plutonium-containing residues in a glass-ceramic matrix developed by ANSTO. ANSTO will also provide input into the design of the plant[6].

ANSTO's own waste from molydenum-99 production

56. Technetium-99m (^{99m}Tc) is a widely used medical diagnostic agent that is produced by ANSTO. In the production process, uranium targets are irradiated with neutrons in the HIFAR reactor, to produce fission products, one of which is molybdenum-99 (^{99}Mo). The targets are processed to extract the ^{99}Mo as molybdenum oxide, which is incorporated into 'generators', wherein it decays to ^{99m}Tc. These generators are transported to hospitals and nuclear medicine clinics and the ^{99m}Tc is extracted in a saline solution by medical practitioners for use in patients.

57. Over many years, the process of extracting the ^{99}Mo from the targets has resulted in ANSTO accumulating a quantity of liquid intermediate level waste. In recent years, ANSTO has undertaken a processing of solidifying those wastes into uranyl nitrate. ANSTO recently commenced constructing the first stage of a 'mini-synroc' plant for the long-term immobilisation of the wastes from ^{99}Mo production.

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[6] http://www.ansto.gov.au/info/press/2005/anstomedia009_150405.pdf

58. Further information about ANSTO's capabilities in radioactive waste management is available at www.synrocANSTO.com.

Additional Issue No. 2: Potential for diversion of Australian obligated nuclear material and potential use of Australian obligated radioactive materials to be used in "dirty bombs"

59. The submission of the Australian Safeguards and Non-proliferation Office has dealt in detail with the web of agreements designed to prevent the diversion of Australian fissile material, and ANSTO has nothing to add in that regard. However, there is another way of reducing the risk of diversion – the creation of a more "proliferation-resistant" fuel cycle. One element of such a fuel cycle has been in place for some time – the CANDU nuclear power reactor, which runs on natural uranium and therefore does not require the use of enrichment facilities, which are potentially dual use. The drawbacks of the use of natural uranium are that more plutonium is produced in the reactor, and greater volumes of spent fuel and waste arising.

Generation IV and the Advanced Fuel Cycle Initiative

60. The next series of nuclear power reactors, called Generation IV, are being designed to be proliferation-resistant through improvements in the fuel cycle (Advanced Fuel Cycle Initiative), to better integrate waste management issues and to enhance physical protection. Work on such designs is underway through the Generation IV International Forum (GIF)[7], with the input of IAEA Member States through the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)[8].

61. Generation IV connotes the next generation of nuclear energy systems. Three previous generations of reactors existed from the 1940s to the present. Generation I consisted of the early prototype reactors of the 1950s and 1960s. Generation II systems, patterned after Generation I, began operation in the 1970s and comprise most of the large commercial power plants currently in operation in the United States. Generation III nuclear systems were developed in the 1980s and include a number of evolutionary designs that offer significant advances in safety and economics. A number of Generation III systems have been built, primarily in East Asia.

62. In addition to improving reactors, achieving sustainable growth of nuclear energy will require transition from the current once-through fuel cycle to an advanced fuel cycle that recycles nuclear materials. The Advanced Fuel Cycle Initiative (AFCI) is a US research and development program to achieve this transition in the most efficient manner[9]. AFCI technologies will support both current and future nuclear energy systems, including Generation IV systems, and emphasise proliferation resistant, safe, and economic operations. The AFCI is emphasising the central role of systems analysis to define and assess the optimal deployment strategies, as well as the best possible transition from the current system to a future nuclear fuel cycle. The AFCI strategy for fuel cycle evolution is presently being drafted in two reports to the US Congress.

63. Both Generation IV and AFCI will develop the next generation of nuclear energy systems by:

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[7] http://nuclear.gov/infosheets/geni.pdf.

[8] http://www.iaea.org/OurWork/ST/NE/NENP/NPTDS/Projects/INPRO/index.html.

[9] http://nuclear.gov/infosheets/afci.pdf.

- Developing and demonstrating advanced nuclear energy systems that meet future needs for safe, sustainable, environmentally responsible, economical, proliferation-resistant, and physically secure energy.
- Developing and demonstrating technologies that enable the transition to a stable, long-term, environmentally, economically, and politically acceptable advanced fuel cycle.

64. Proliferation resistance, integrated waste management and physical protection are also essential priorities in the expanding role of nuclear energy systems.

- *Proliferation Resistance* is that characteristic of a nuclear energy system that impedes the diversion or undeclared production of nuclear material, or misuse of technology, by the host State in order to acquire nuclear weapons or other nuclear explosive devices.
- *Integrated Waste Management* implies the minimisation and management off radioactive waste, including reduction of the long-term stewardship burden, through for example the design and development of fuel that is directly disposable after use.
- *Physical Protection* is that characteristic of a nuclear energy system that impedes the theft of materials suitable for nuclear explosives or radiation dispersal devices, and the sabotage of facilities and transportation, by sub-national entities and other non-host State adversaries.

R&D Collaboration and Schedule

65. The objective for Generation IV nuclear power systems is to have them available for international deployment around the year 2030. The R&D for new systems is expected to span as much as 30 years for some of the systems. The R&D priorities over the next 10 years are focused on four key areas of development:

- Systems Design and Evaluation
- Fuel and Fuel Cycles
- Energy Conversion
- Materials.

The R&D will be performed in collaboration with GIF partner countries. The division of responsibilities for specific R&D tasks is still being negotiated, along with the enabling multilateral agreements.

US Budget Commitments

66. For FY 2005, the US Government has appropriated US$34.8 million and US$67.5 million to Generation IV and AFCI respectively. The request for FY 2006 is $39.8 million for Generation IV and $70.0 million for AFCI.

Other Proliferation-resistant technologies

67. Since the 1970s, the United States has opposed current reprocessing technologies because they result in the production of separated (albeit not weapons-grade) plutonium. The US Department of Energy (DOE) has been pursuing alternative technologies which would not result in such separation. In March this year, DOE told a US House of Representatives

Appropriations subcommittee that they should know by the end of this year whether the spent fuel separation process it is developing is proliferation-resistant. The chemical separations process being pursued under the AFCI would extract a mixture of plutonium and neptunium that would be unusable for weapons purposes from Generation IV spent fuel[10].

"Dirty bombs"

68. As noted in the submission of the Australian Safeguards and Non-proliferation Office, the issue of 'dirty bombs', or radiation dispersion devices, relates more to radioactive material than to nuclear material. Nuclear (or "fissile") material is not highly radioactive and therefore would be unsuitable for use in a "dirty bomb".

69. Fears of the use of radiation dispersal devices centre on the possible use of radioactive sources. However, such devices have been called weapons of mass disruption not destruction, since the major consequence would be panic and disruption of areas where they might be exploded. The IAEA has made significant strides in recent years in developing detailed standards for the regulation of the use of such sources, including security standards. Under ANSTO chairmanship, a Code of Conduct on the Safety and Security of Radioactive Sources, and supplementary Guidance on the Import and Export of Radioactive Sources have been negotiated[11]. Implementation of these standards should significantly reduce the risk of employment of highly active radioactive sources in such devices.

70. ANSTO is also playing a significant regional role in this regard. On behalf of the Australian Government, ANSTO has initiated a regional project on the security of radioactive sources with the following objectives:

a. to improve and maintain the security of radioactive sources in regional countries, (and concomitantly, to improve and maintain the associated occupational and public radiation safety, and environmental protection);
b. to identify and secure uncontrolled or poorly controlled radioactive sources in regional countries; and
c. to reduce the security threat to regional countries potentially arising from malevolent use of radioactive sources.

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[10] Nuclear News Flashes, Tuesday, March 15, 2005.
[11] http://www-ns.iaea.org/home/rtws.asp.