

**AUSTRALIA'S NUCLEAR POWER AND NUCLEAR SCIENCE OPTIONS
2005 AND BEYOND**

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INTRODUCTION

Current concerns about CO₂ levels and global warming have led to a renewal of the debate about the potential role of nuclear power for meeting the world's growing energy needs.

Australia is unique in having a range of energy resources; fossil fuel, oil and uranium as well as a variety of potential sources of renewable energy (wind, water etc). Although Federal and state government policies on matters nuclear have frequently changed direction, a constant feature of the debate over this period has been the fervour with which proponents and opponents have presented their views

This is well illustrated by the following quote from the First Report of the Ranger Uranium Environmental Inquiry (1976), AGPS, p.6:

We have found that many wildly exaggerated statements are made about the risks and dangers of nuclear energy production by those opposed to it. What has surprised us more is the lack of objectivity in not a few of those in favour of it, including distinguished scientists.

The aim of this paper is to make an informed contribution to the contemporary debate about nuclear power while avoiding the polarization which has characterized this discourse in the past. Accordingly, the paper provides some background information on the use of nuclear power around the world, along with a summary of Australia's nuclear science and technology record over the past 60 years. The paper reviews:

- the world's growing energy needs;
- Australia's growing energy needs and sources of supply;
- uranium mining in Australia and attempts to introduce nuclear power;
- Australian uranium resources and production in a world context;
- nuclear power and the nuclear fuel cycle;
- prospects for using nuclear power in Australia for electricity, desalination and hydrogen production; and
- the non-power applications of nuclear science in Australia and the role of the Australian Nuclear Science & Technology Organisation

The paper concludes that, as there has been no national review of Australia's nuclear power options since the Ranger Uranium Environmental Inquiry presided over by Mr Justice Fox in 1975-1977 and the Australian Science & Technology Council (ASTEC) review of the nuclear fuel cycle in the 1980s, it is timely to consider the need for a new national summit to involve all interested parties in reviewing the possible future role of nuclear power in meeting Australia's fast-growing energy needs.

1. World Future Energy Needs

The world population is predicted to increase from six to nine billion in the next 50 years, mainly in developing countries. These countries currently have low per capita incomes and expectations of an improved living standard requiring more energy. Most population growth will be in large urban areas in developing countries and will require large base load electricity generation capacity. The increasing energy need cannot be met by fossil fuels without serious problems arising due to air pollutants, greenhouse gases and depletion of reserves for use by future generations. While renewable sources of energy such as solar, wind, waves, biomass and geothermal, can make a contribution, many of these sources are limited by their dilute and intermittent nature, their cost and their large requirement for land area. To generate the required energy capacity with minimal air pollution and greenhouse gas emissions in the foreseeable future, many measures will need to be considered, including, energy conservation, greater energy efficiency in end use, cleaner use of fossil fuels, use of nuclear power, and renewable sources (solar, wind, waves) in favourable locations.

2. Australia's Future Energy Needs and Sources of Supply

Australia relies heavily (85%) on coal for its supply of electrical energy for residential and industrial use and on petroleum products for transport. Whilst renewable sources are becoming increasingly used they are unlikely to contribute more than a few percent over the next 10-20 years and will remain expensive relative to generation by fossil fuels and nuclear. Accordingly, Australia will continue to have high per capita greenhouse gas emissions when compared with other developed countries, partly due to the industrial use of electricity in the resource industries. The Electricity Supply Association of Australia estimates that electricity demand will probably increase at 3% per year to 2020. This represents a 70% increase on current demand and a need for construction of about 50,000 MWe of new capacity. If this increase were to be based on coal, the environmental impact could be considerable; if based substantially on gas it would require the discovery of one or more major new gas resource areas and still contribute heavily to greenhouse gas emissions. There are considerable technical and economic uncertainties in the search for solutions based on clean coal (basically gasifying coal) and on sequestration (capturing CO₂ from fossil fuelled power stations and disposing of it in underground or undersea strata). Nuclear power should therefore be evaluated as a part of Australia's future energy needs, taking into account cost competitiveness, including external costs and environmental factors for all energy technologies.

3. Uranium Mining in Australia and Attempts to Introduce Nuclear Power

Uranium was first discovered in Australia in 1894 in a cobalt deposit in Carcoar in NSW. This was just two years before Professor Becquerel in Paris discovered radioactivity in uranium minerals. The main use for uranium in the next 40 years was as a source of radium for cancer therapy and luminous paint and as a yellow colour in ceramics and glass. Uranium ores were mined at Radium Hill in SA in the 1930s for extraction of radium. The old mine was recommissioned in 1954 and produced 850 te U₃O₈ over 7 years for sale to the USA and UK.

Uranium exploration increased worldwide in the 1950s and was carried out in Australia by the Commonwealth's Bureau of Mineral Resources, private companies and individual prospectors. The most famous deposits found in Australia in the next few years were: Mary Kathleen, Qld, 1954; Ranger, NT, 1969; Beverley, SA, 1969; Nabarlek, NT, 1970; and Olympic Dam, SA, 1975.

The Australian Atomic Energy Commission (AAEC) was set up as a Statutory Authority in 1953 to administer all atomic energy matters including uranium production. As a result, the AAEC was responsible for producing uranium at Rum Jungle in the 1950s with a contractor undertaking the mining and processing of the uranium and copper. Under the 1972-1975 Labor Government, the AAEC was also responsible for constructing the Ranger mine but under the following Coalition government was instructed to sell the venture back to its original owners. After that time, all uranium mining in Australia at Ranger, at Olympic Dam and at Beverley was carried out by

private companies. Export of uranium was under strict Commonwealth government control and international safeguards to ensure its use only for peaceful purposes.

From 1975-1977 a major review of mining uranium and the use of nuclear power in Australia (the Ranger Uranium Environmental Inquiry) was presided over by Mr Justice Fox. This inquiry was in two parts: 1) a review of the generic issues of uranium mining and the use of nuclear power; 2) issues relating specifically to the proposal to mine uranium at the Ranger deposit in a sensitive environmental region. The outcome was that the Commonwealth Government allowed uranium mining to proceed at Ranger and instituted strict controls to safeguard the use of uranium and protect the environment in the region. Another major review, this time of costs, risks and benefits of the nuclear fuel cycle in the Australian and world context was carried out in the 1980s under the auspices of ASTEC (Australian Science & Technology Council) and chaired by Professor Slatyer. This review had little impact on the continued mining and export of Australian uranium and the Commonwealth government of the day did not accept that upgrading of uranium be permitted in Australia.

Several states were interested in evaluating nuclear power for Australia in the 1950s and South Australia had a team of three engineers located at Harwell, UK, in the early 1950s. The first serious proposal to build a nuclear power station was made in 1969 when the Commonwealth government called for tenders to build the first nuclear power station at Jervis Bay, NSW. The plan was for the station to be owned by the Commonwealth and to be operated by the Electricity Commission of NSW to supply electricity to NSW and the ACT. The closing date for tenders was 15 June 1969. The sizes of plants tendered by companies in Canada, Germany, the UK and the USA were from 450 – 610 MWe with capital costs of \$180M to \$218M and estimated generating costs of 0.60 – 0.68 c/kWh. However, the government deferred the project for 12 months in 1971 due to general budgetary problems and abandoned it a year later. The world situation at that time was that there were 116 nuclear power plants in operation in 17 countries, 124 under construction and an additional 99 on order. The AAEC then turned its main attention to the enrichment stage of the nuclear fuel cycle with the main objective of upgrading uranium for export, since large new deposits of uranium had been discovered in Australia in the early 1970s. Although this project achieved considerable technical success by the early 1980s and Australian industrial companies carried out detailed assessments to build a major enrichment plant in Australia, the Commonwealth Government of the day did not wish to proceed.

The AAEC was eventually abolished by the Commonwealth Government in 1988 and replaced by the Australian Nuclear Science & Technology Organisation (ANSTO) with a new charter which precluded it from studying nuclear power and the nuclear fuel cycle except for work on Synroc as a new means of disposing of high level nuclear waste and work connected with low level waste management in Australia. The Commonwealth Government also established the “Three Mines Policy” in 1988 to limit uranium production to the three existing mines of Nabarlek, Ranger and Olympic Dam, although it was effectively a “Two Mines Policy”, since Nabarlek was by then mined out and closed.

The two major nuclear science developments supported by Commonwealth Governments since 1983 are the construction of the National Medical Cyclotron at Camperdown, NSW, costing about \$20M, and a Replacement Research Reactor for the ageing HIFAR reactor operated by ANSTO at Lucas Heights, expected to be in operation in 2006 and costing over \$300M. The role of ANSTO is discussed later in section 9.

4. Australian Uranium Resources and Production in a World Context

In 1972, when the Jervis Bay Project was abandoned, Australia’s total uranium resources were about 90,000 te U_3O_8 out of a Western World total of about 1 million te, that is, only about 9%. In contrast, today Australia’s low cost uranium resources total over 823,000 te U_3O_8 and represent about 40% of the world’s low cost resources of about 1.5M te, with Canada having the second highest resources of about 18%.

Australia’s total uranium production in the calendar year 2004 was 10,591 te U_3O_8 made up of 5,137 te from Ranger, 4,370 te from Olympic Dam and 1,084 te from Beverley, the in-situ uranium mine in SA. This total

represented about 20% of the world's production from uranium mines in that year. The largest single uranium deposit in the world is at Olympic Dam, now owned by BHP-Billiton after the recent \$9.2B takeover of Western Mining Resources. Before the takeover, the previous owner had indicated that the mine would be expanded to double the production of copper, uranium and gold, and it is likely that this project will proceed under the new owners.

5. Nuclear Power Around the World and the Nuclear Fuel Cycle

A total of 439 nuclear power reactors are currently operating in the world in 31 countries and these produce about 16% of the world's electricity. These plants represent a mature technology with over 11,000 reactor-years of experience. In addition, there are 30 reactors under construction and 32 firmly planned. The ten countries with the highest reliance on nuclear power are: Lithuania, 80%; France, 78%; Slovakia, 57%; Belgium, 55%; Sweden, 50%; Ukraine, 46%; Slovenia, 40%; Korea, 40%; Switzerland, 40%; Bulgaria, 38%. The reliance in several other major countries is: Germany, 28%; Japan, 25%; UK, 24%; USA, 20%; Russia, 17%.

Currently, about 77,000 te U_3O_8 per year is required to supply fuel for the world's nuclear power plants and of this about 50,000 te is supplied from uranium mines with the rest coming from stockpiles and decommissioning of nuclear weapons. Over 90% of this uranium is converted into uranium hexafluoride in plants in Canada, France, Russia, the UK and the USA. The product is then enriched in enrichment plants in the USA, France, Russia and the three countries (Germany, Netherlands and UK) making up the Urenco Group. The balance of the uranium (10%) is used as natural uranium fuel mainly in the CANDU type of reactor used in Canada and a few other countries. When the spent fuel is discharged from power reactors after operating for about three years it is usually stored for a number of years in storage ponds at the reactors. There are then two main options, either to continue to store the spent fuel in wet or dry storage facilities at or away from the reactors, or to send it to reprocessing plants where it can be stored for a further period in ponds before reprocessing. At present, the only operating large reprocessing plants are in France, the UK and Russia, with a new large plant being expected to be operated in Japan in the near future. The three major products of these plants are recovered uranium and plutonium which can be re-used in new fuel, and a highly concentrated liquid high level waste product which can be converted into a vitrified solid. The plan is then to dispose of this vitrified waste in deep geological repositories.

Fast Breeder Reactors: Doubts have been expressed about the viability of nuclear power in the long term because of limited uranium resources. The world's reasonably assured and estimated additional resources of uranium (about 3.5 million tonnes) would, if used in today's conventional reactors, be sufficient to satisfy world demand for only 50 years or so. But as yet undiscovered conventional resources and speculative resources (at non-prohibitive cost and environmental impact) are expected to at least triple currently known supplies. The ultimate viability of nuclear energy depends, however, on the introduction of fast breeder reactors (FBRs) supplemented by thorium burning reactors. Breeder reactors are fuelled by plutonium which can be bred from the high quantities of uranium left over in today's nuclear fuel cycle. A much larger proportion of the energy potential of uranium, rather than the 2-3% used in today's reactors, can be utilized thus increasing considerably the useful life of the world's uranium. The widespread introduction of FBRs and thorium burning reactors (producing high-grade industrial heat as well as electricity) would extend the life of nuclear energy for centuries.

Plutonium: There are concerns that the more widespread use of plutonium fuel would enhance the risk of its diversion into nuclear weapons. As explained above, reactor grade plutonium is not suitable for nuclear explosives but ways of minimising its misuse were explored in detail in the International Nuclear Fuel Cycle Evaluation in the 1970s. A major initiative that could minimize the risk of misuse of plutonium and other risks associated with reprocessing of nuclear fuel in the final disposal of nuclear wastes, would be the establishment of a limited number of international centres where the reprocessing of the world's spent nuclear fuel, the storage of extracted plutonium, the fabrication of new fuel, and the disposal of wastes were located and carried out under international supervision and control. This concept, which originated in the early days of nuclear development,

but was regarded as too idealistic, is currently being re-examined and supported by the Director General of the IAEA. Australia has many advantages that would make it an ideal location for one such centre.

6. Nuclear Waste Management in Australia

There are three main sources of nuclear waste in Australia: the tailings from mining of uranium and, to a much lesser extent, the mining of mineral sands; the operations of the research reactor and research facilities by the Australian Nuclear Science & Technology Organisation (ANSTO); and the operation of nuclear medical facilities in a large number of hospitals around Australia. The wastes from the mining of uranium and mineral sands are usually disposed of in near-surface tailings dams at the mines or in underground workings in the case of underground mines. There are several examples of the satisfactory rehabilitation of these near-surface tailings and waste areas, eg. at Nabarlek, NT; Rum Jungle, NT; and Mary Kathleen, Qld.

The Commonwealth and States agreed many years ago to undertake a detailed technical study to locate a suitable site for construction of a low level radioactive waste repository to dispose of low level wastes from all regions. A site was recommended in South Australia but the state government strongly opposed construction at the site and eventually the Commonwealth abandoned the site and decided to concentrate its future efforts on finding a suitable site for a repository for only the Commonwealth's low level waste and a store for the intermediate level waste. This will leave responsibility with the states for disposing safely of their own wastes.

7. Opportunities for Nuclear Desalination and Hydrogen Production in Australia

Desalination

There is considerable concern in the major Australian states at the availability of water resources to supply residential, industrial and agricultural users even at their present level of demand, let alone the expected increase over the next decades. As examples, water levels in storage dams in NSW and near Sydney are at record low levels, and there is also concern at the poor availability of water to supply metropolitan Perth. Both NSW and WA are examining in detail the desalination of water to supply users in and near Sydney and Perth. However, there is some opposition to the use of fossil fuels to supply the energy required for large desalination plants, for which the energy demand would far exceed that which could be supplied by renewable energy sources.

The desalination of water with energy provided by nuclear power is technically and economically feasible and several studies have been carried out by international experts under the auspices of the International Atomic Energy Agency (IAEA). Russia pioneered the development of desalination plants coupled to nuclear power stations, A major desalination plant of 120,000 m³/day capacity has been operated for over 25 years by Russia at Shevchenko (now known as Aktau in Kazakhstan) on the Caspian Sea, the energy being supplied by power from a fast breeder reactor producing 125MWe and 1,000 MW thermal. The cost of the water was claimed to be about US\$1.00/m³. Small desalination plants have been operated at the sites of Japanese nuclear power plants mainly to provide water for on-site use, eg. ten plants are operating at plants owned by the Tokyo, Shikoku and Kyushu Electric Power Companies with capacities from 1,000-2,600m³/day. South Korea has developed a multi-purpose nuclear reactor (SMART 330MWt) for production of electricity and desalinated water at 40,000m³/day, and Indonesia is reported to be examining its applicability at Madura Island. Argentina has also developed a small dual-purpose reactor called CAREM (100MWt).

Studies published by the IAEA in 1996 for desalination plants at the request of several countries on the north coast of Africa concluded that water could be produced at a cost of US\$1-2 per mega-litre for small plants (about 24,000 m³/day) and US\$0.7-1.00 for large plants (720,000 m³/day) with the costs for nuclear power plants being about equal to fossil fuel plants.

Hydrogen production

Governments and industry are providing large amounts of funds for research and development of the “Hydrogen Economy”, which comprises the production and distribution of hydrogen to a variety of end-users. The advantages of hydrogen, which is an energy carrier like electricity, not a primary energy source like fossil fuels or nuclear power, is that the end-use does not produce carbon dioxide or pollutants, only water. However, this latter advantage is only realized if the primary feedstock for hydrogen production is water and not fossil fuels.

At

present, the only way of producing hydrogen from water at high efficiency is by electrolysis. Production of hydrogen from water by thermal splitting requires a high temperature (at least 900°C) for acceptable efficiency. Considerable development work is therefore underway (especially in Japan and China and planned in the USA) to produce hydrogen in high temperature gas-cooled nuclear reactors which operate at 850-1,000°C.

There is also considerable development work underway in Japan, Germany and the USA on the technology to use hydrogen in vehicles, including cars, trucks and buses. The main objectives are to reduce air pollution in cities and minimize the use of oil and petrol for energy security reasons given the rapidly increasing price of oil and concerns at security of supply from sensitive geographical regions. Prototype vehicles are being tested in several countries and in Australia, where a number of buses powered by hydrogen and fuel cells are under test in Perth. The Commonwealth government has funded a major study of hydrogen which was published in 2004 (see References).

There is therefore the possibility of using advanced high temperature nuclear power reactors for the multiple production of electricity, desalinated water and hydrogen, but the realization of this combination awaits further development work and would probably not be available within the next ten years.

8. Non-Power Applications of Nuclear Science and the Role of the Australian Nuclear Science & Technology Organisation

There are a large number of non-power applications of nuclear science as well as non-electricity uses of nuclear power. Examples of the latter are district heating using some of the waste heat from nuclear power reactors, desalination and hydrogen production. Examples of the former are the use of radioisotopes and radiation in nuclear medicine, industry, research, etc. The role of the Commonwealth’s national laboratory at Lucas Heights operated by ANSTO is to carry out research on the non-power applications of nuclear science and technology. ANSTO currently operates Australia’s only research reactor HIFAR and is constructing a replacement research reactor OPAL to operate in 2006 for research and production of radioisotopes. Additional roles of ANSTO are to provide advice to the Commonwealth on nuclear science and technology and to provide information to the public, but not, under the present arrangements, on nuclear power reactor design and safety and the nuclear fuel cycle.

CONCLUSION

There has been no national review of Australia’s nuclear power options since the Ranger Uranium Environmental Inquiry presided over by Mr Justice Fox in 1975-1977 and the Australian Science & Technology Council (ASTECC) review of the nuclear fuel cycle in the 1980s. With the re-emergence of the nuclear power debate in Australia, it is timely to consider the need for a new national summit to involve all interested parties in reviewing the possible future role of nuclear power in meeting Australia’s fast-growing energy needs.

APPENDIX: Some Arguments For and Against Nuclear Power

For an informed debate to take place, the arguments for and against, which are summarized briefly here, need further elaboration by commentators who are seen to be both independent and unbiased and who can support their views with contemporary data.

FOR

- * Reliable supply with high availability;
- * Favourable economics compared with coal or gas unless these are available close to the load centres;
- * Assured availability of uranium at a stable price compared with uncertain long-term prices of coal and gas and with the uranium cost only making up a small part of the overall generation cost;
- * The high level of safety in nuclear industries in the western world;
- * Safe and economic methods available for management of the small amounts of radioactive wastes compared with expensive and unproven methods of management of the large volumes of carbon dioxide and toxic wastes (including radioactive materials) from burning fossil fuels
- * Minimal emission of greenhouse gases or air pollution at the nuclear power station and in the associated fuel cycle.

AGAINST

- * The economics of nuclear power are not favourable in comparison with gas-fired combined cycle power plants or coal-fired plants due to the lower capital costs and shorter construction times for these fossil fuel plants.
- * Nuclear power plants pose a high risk for workers and the public from normal operations and severe accidents.
- * There is no safe way to manage highly radioactive nuclear waste.
- * A nuclear power program and even a program of non-power applications of nuclear science enables countries to develop nuclear weapons.
- * Nuclear power cannot make a significant contribution to reducing global warming by greenhouse gases and, if the energy used in the nuclear fuel cycle is taken into account, the use of nuclear power would only make a small saving in greenhouse gas emissions compared with the use of fossil fuels.

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ALPHABETICAL LIST OF CONTRIBUTORS

The following people (listed below in alphabetical order) have contributed to the content of this paper in various ways, according to their particular areas of interest and expertise. Their input has included providing information and ideas, preparing drafts, and reviewing or commenting on the content.

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Mr Bob Fry is a health physicist. He was manager of the IAEA (Vienna) Radiological Study Mururoa and Fangataufa French nuclear test sites from 1996 to 1998. Other positions have included: supervising scientist Alligator River Region (1978-1993); head of Environmental and Public Health AAEC (1973-1977); Atomic Energy Advisor, Australian High Commission, London (1969-1972)

Dr Clarence Hardy

Dr Hardy has had 40 years' experience in research and management in the nuclear industry in the UK, USA and Australia. He has held senior positions in a range of nuclear science organizations and is currently Vice-President of the Pacific Nuclear Council. He edited the History of the Australian Atomic Energy Commission (AAEC) which was published in 1999.

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Charles Kerr has been Head of the Department of Social and Preventive Medicine at the University of Sydney since 1968 and is currently Emeritus Professor, Social and Preventive Medicine, University of Sydney. He was also a Commissioner on the Ranger Uranium Environmental Inquiry (1974-1976).

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Dr D.G. (Terry) Walker AM

Dr Walker is a nuclear scientist with 40 years experience. He was Director and CEO of the Australian Atomic Energy Commission (AAEC) from 1983 to 1987, then Executive Director of the Australian Nuclear Science and Technology Organisation (ANSTO) from 1987 to 1988. He also served as Counsellor (atomic energy) at the Australian Embassy in Washington DC, USA (1973-1977).

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