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'The Strategic Importance of Australia's Uranium Resources'

by

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Executive Summary

"Even though Australia has 40 per cent of the world's uranium, we only have about 20 per cent of the world's uranium market. Now, we need to address that as a country...".

- The Hon Ian Macfarlane MP, Minister for Industry, Tourism and Resources, ABC, 16 February 2005

"In the last 12-18 months there has been a dramatic change in price. A number of nuclear plants are under construction. All of a sudden, nuclear power is back on the agenda internationally."

- Mr Martin Ferguson MP, Shadow Resources Spokesperson, The Age, 12 March 2005

The significance and true value of uranium as a strategic and clean resource is only just beginning to be realised globally. The potential for Australia - with one third of the world's uranium - is therefore enormous, particularly considering that the world is already reliant on nuclear power to supply 16% of its electricity, and the world's energy needs will likely double in the next 30 years.

Government and the nation's Parliament can play a key role in helping industry further capitalise on uranium as one of our most important and strategic energy and export assets. This is particularly so in regard to appropriate regulation; project and development support - financial and otherwise; more reasonable reporting requirements and conditions; public education; and essential co-operation between the States and Commonwealth.

The committee might like to also consider these key points in its deliberations:
* World demand for uranium is strengthening and uranium prices are increasing.
* Nuclear power is a greenhouse-friendly source of energy, with considerable environmental benefits.
* Uranium provides a counterbalance to any threat to Australia's thermal energy exports arising from international treaties to reduce carbon production.
* Growing global demand for uranium, particularly from Asia, will play an increasingly significant role in Australia's economic and export future.
* China, India and Japan alone will build more than 50 new nuclear power units in the next decade.
* China represents one of Australia's most significant future markets for trade relations. With an increasingly industrialised population, China's power needs are paramount, and as such their interest in clean energy sources like uranium is significant.
* Australia's current uranium exports are an important strategic positive for our balance of payments, and are valued at $400 million annually.
* Uranium is a vital part of our exploration, research and development efforts in the resources sector.

Finally, uranium's history is also an important guide for any consideration of its future potential. The world has been using nuclear power to produce electricity for almost 50 years. The safety record, compared with other energy producing industries, is outstanding. In all of this time, Australia has been an important international influence in seeking to ensure that uranium has been used only for peaceful purposes.

Outlining these key points against your specific terms of reference:

<u>Term of reference 1:</u> Global demand for Australia's uranium, and associated supply issues.

World electricity consumption is forecast to grow from a current annual 15,000 billion kWh to almost 24,000 billion kWh by 2025.

Industry experts forecast that between 2004 and 2020, because of a decline in secondary supply, annual primary production of uranium oxide will have to rise by nearly 28,000 tonnes or 60%, to 74,500 tonnes to meet demand.

Australia is well positioned to take advantage of the expected growth in demand for uranium and the expected increase in uranium prices. Australia has about one third of the world's economically recoverable resources of uranium. Seven of the top twenty known uranium deposits in the world are in Australia.

Even the significant extent of Australia's known uranium reserves probably understates the potential because of the very limited amount of exploration that has been undertaken over the past two decades due to policy constraints on the ability to develop a discovery into a mine.

<u>Term of reference 2:</u> Strategic importance of Australia's uranium resources and any relevant industry developments

Uranium is a very energy-intense and efficient energy source. Every kilogram of natural uranium provides 500,000 megajoules of heat value (in a conventional reactor), compared with 39 megajoules for gas, 45 for oil and 20-30 for coal. One tonne of uranium in uranium oxide from a mine generates the same amount of heat as 20,000 tonnes of typical black coal. On this basis, the current economically-recoverable uranium (ie ore reserves) at the Olympic Dam mine in South Australia's north has about 4.5 times the energy contained in the Northwest Shelf Gas Project.

Australia retains the right to be selective regarding the countries with which it is prepared to conclude bilateral safeguards agreements. As such, and with the extent of the world's uranium resources it controls, Australia is uniquely placed to exercise even greater international influence to maintain the safety and security of the nuclear fuel cycle.

Uranium is an important 'hedge' for Australia's balance of payments. It will help offset the negative impact on Australia's coal exports of any international move to reduce global carbon emissions, with any fall in coal-fired power generation stimulating demand for alternative fuel sources such as uranium.

Globalisation of the mining industry means that Australia has the potential to attract significant foreign investment for new mines. Such investment, particularly from North American and European financial markets, has been deterred by concern that government policy may restrict production. Australian financial institutions have also been reluctant to provide limited recourse debt to finance uranium operations, not because of credit risks but because of a concern about public opposition to uranium mining. A more consistent public policy approach to uranium would help to address this issue.

The concentration of Australian uranium production in a small number of rural locations means that the industry makes a significant contribution to regional economies.

<u>Term of reference 3:</u> Potential implications for global greenhouse gas emission reductions from the further development and export of Australia's uranium resources.

Nuclear power plants are the single most significant means of limiting increased greenhouse gas emissions while enabling access to economic electricity and providing for energy security.

The nuclear reactors currently operating in the world are estimated to currently avoid 2.5 billion tonnes of carbon dioxide emissions on an annual basis. Every 22 tonnes of uranium used (26 t uranium oxide) saves one million tonnes of carbon dioxide emissions relative to coal.

<u>Term of reference 4:</u> Current structure and regulatory environment of the uranium mining sector.

The industry's view is that legislative and regulatory requirements should ensure the highest possible standards of occupational and public safety and environmental protection, while avoiding duplication and unnecessary administrative burdens and costs.

In this respect, the industry would encourage the Commonwealth, states and territories to continue to work together to ensure a transparent and efficient method of environmental assessment of major projects.

The industry would encourage the Committee to take into account the long experience of State (particularly South Australian) authorities, in regulating uranium mining and associated activities, including radiation protection.

The industry would also urge governments at all levels to ensure that they do not impose reporting requirements on the industry that mitigate against public understanding of industry impacts.

The industry recognises the need to take action itself to encourage greater public understanding of its activities and its impacts. To this end, industry participants are considering the enhancement of a program of public education and information to augment work already being undertaken in this respect.

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Introduction

The world is facing an energy crisis, albeit one which does not claim the attention of most people in the western world. At least one third of the world's population has no access to reliable and affordable energy, and the challenge is to meet this demand without exacerbating global warming.

Uranium is one of Australia's most important and strategic energy and export assets.

Uranium already comprises about 40% of Australia's energy exports (4800 PJ in 2004) in thermal terms. With more economically recoverable uranium than any other country, Australia has the potential to become an even more significant provider of energy to a world already reliant on nuclear power to supply 16% of its electricity.

The world has been using nuclear power to produce electricity for almost fifty years. The safety record, compared with other energy producing industries, is outstanding. Since the advent of Nuclear Non-Proliferation Treaty in 1970, Australia has been an important international influence in ensuring that uranium has been used only for peaceful purposes.

Australia was a member of the preparatory commission which established the International Atomic Energy Agency in 1957. In more recent years, the stringency of Australian safeguards against diversion of uranium for military purposes has been internationally recognised.

Now, as uranium's potential as an alternative and greenhouse-gas-friendly source of energy generation is increasingly recognised in many developed and developing nations, its strategic significance for Australia becomes even greater.

Uranium, through nuclear power, is an important energy resource to Australia, primarily because –

- world demand for uranium is strengthening and uranium prices are increasing
- nuclear power is environmentally benign, since all its wastes are contained and managed - in particular it accounts for virtually no greenhouse gas emissions
- uranium provides a counterbalance to any threat to Australia's fossil fuel energy exports arising from international treaties to reduce carbon production

Growing global demand for uranium, particularly from Asia, will play an increasingly significant role in Australia's economic and export future.

It is important that state constraints on uranium mining and on proper consideration of nuclear power for Australia be removed.

Responses to the Committee's Terms of Reference

(Note – Appendices give further background to the nuclear fuel cycle, current Australian mines, prospective mines, world uranium prices and markets, and other issues on which the Committee has sought advice.)

1. Global Demand for Australia's uranium and associated supply issues

Future uranium demand needs to be assessed against overall electricity consumption trends.

The latest International Energy Outlook published by the United States Department of Energy forecasts that world electricity consumption will grow from a current annual 15,000 billion kWh to almost 24,000 billion kWh by 2025. This increase is attributed to growth in world population and the industrialisation of developing nations, in particular China and India.

Current shares of world electricity consumption by fuel type are –

- coal, 39%
- hydro, 16%
- natural gas, 19%
- nuclear, 17%
- oil, 7%
- non-hydro renewables, 2%

(2002 data, OECD/IEA *World Energy Outlook 2004*)

The most recent data published by the World Nuclear Association shows there are 440 commercial nuclear power plants in operation throughout the world at the end of March 2005, with an aggregate installed generating capacity of more than 366 GWe. Another 24 plants (capacity 18.5 GWe) are under construction, and planning is well advanced on a further 40 (42 GWe) - in some cases bids have been received. This new construction is currently centred in Asia with China, South Korea and India in the forefront. More than 70 more power reactors are proposed, with varying degrees of likelihood of construction.

Substantial gains in effective capacity of individual nuclear plants are being achieved in many countries, resulting in much increased output. The increase over the last five years (234 billion kWh) is equal to the output from 33 large new nuclear plants. Yet between 1998 and 2003 there was a net increase of only three reactors. The increased output requires more fuel.

Furthermore, a considerable number of reactors are being granted life extensions. For example, in the United States, 30 reactors have been granted operating licence renewals. This adds 20 years to the originally-licensed plant life of 40 years. Operating licence extension applications have been filed for more reactors and eventually about 85 US units are expected to be granted renewals. In addition, American utilities continue to apply for licence amendments to allow for increased plant capacity. To March 2004 the incremental capacity increase was 3.81 GWe

In Europe, nuclear generators are implementing capacity upgrade programs ranging from Finland (19.5%), Spain (11%) to Switzerland (12%).

In 2005 , total world demand for uranium oxide is about 80,600 tonnes, all of it used by the nuclear power industry to generate electricity. World Nuclear Association projections (reference case, 2003 market report) put world demand at 88,200 tonnes in 2010 and 97,000 tonnes in 2020. The upper scenario for 2020 is 22% higher. With diminishing secondary supplies (which now meet about 41% of demand) "primary uranium production will need to rise sharply".

International Nuclear, Inc (iNi) an independent consulting organisation specialising in forecasting uranium supply-demand-price trends, broadly supports this. It has estimated that global uranium oxide requirements will rise to 84,000 tonnes per year by 2010, and to almost 91,900 tonnes by 2020. These forecasts are considered conservative in that they make no allowance for a potential increase in nuclear power generation arising from concerns over greenhouse gas emission issues associated with other forms of electricity generation. According to iNi, between 2004 and 2020, because of a decline in secondary supply, primary production of uranium oxide will have to rise by nearly 28,000 tonnes or 60%, to 74,500 tonnes to meet demand.

Uranium supplies for nuclear fuel are provided by a mix of primary production and secondary supplies, Primary production accounted for an estimated 46,450 tonnes of uranium oxide in 2004. The shortfall of 32,150 tonnes was made up of secondary supplies.

Until the early 1980s, primary uranium production exceeded uranium consumption (for military as well as civilian purposes) by a substantial margin. The excess supply was represented by the fuel in nuclear weapons and uranium inventories. The dissolution of the former Soviet Union coupled with a series of disarmament treaties triggered the dismantling of weapons and significant quantities of uranium entered the market and drove down prices. In addition commercial inventories built up in the 1980s were drawn on, and some recycling of fissile materials recovered from reprocessing continues to supply a portion of the market. However, input of secondary supplies has now peaked and will decline progressively. Russia is not likely to undertake a further major sell-off of military inventories to the West, and has indicated an intention to increase uranium production from mines. Accordingly, additional primary production will be needed to meet uranium demand.

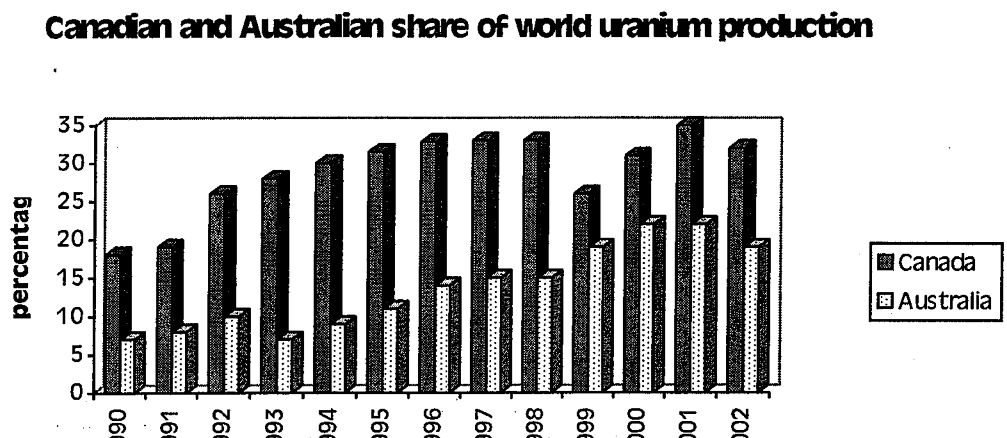
The proportion of demand covered by secondary supplies is estimated to fall from 2004's 41% to about 17% by 2025.

Australia is well positioned in terms of its identified resources to take advantage of the expected growth in demand for uranium and the expected increase in uranium prices. Australia has about one third of the world's low cost uranium. Seven of the top 20 known uranium deposits in the world are in Australia. However Australia may fail to take advantage of positive trends if it allows the present level of anti-uranium policies, which are presently sterilizing much of the resource base, to stay in place.

iNi predicts that over the period 2005 to 2020, the average spot price for uranium oxide will be around US$22.50/lb for uranium oxide, rising to over US$26/lb in the longer term. This is approximately double the average spot price of US$13.25/lb achieved over the last decade.

Even the significant extent of Australia's known uranium reserves probably understates the potential because of the very limited amount of exploration that has been undertaken over the past two decades due to policy constraints on the ability to develop a discovery into a mine.

Canada has less than half of the reserves of Australia but its annual production of uranium oxide has been substantially higher. Kazakhstan has larger reserves than Canada and has said that it is aiming for a fourfold mine production increase. However, Australia has good relations with the most rapidly growing markets for uranium, those in East Asia, and is a preferred supplier into those markets. Australia is currently negotiating a safeguards agreement with China.



Japan, already the world's third largest consumer of uranium after the United States and France, confronts the hardest task amongst the countries that have ratified the Kyoto Protocol in meetings its emissions target, with relatively few opportunities to increase its already very high level of energy efficiency. It plans a doubling of nuclear share and nuclear capacity by 2050 in order to address this. In addition, some 20 GW of nuclear heat is expected to be required for hydrogen production by then. Australia has both a well-developed trading relationship with Japan and a partnership agreement that includes coverage of greenhouse issues.

Another supply consideration is the geographic location of energy resources. More than 60% of the world's oil and 40% of its gas is concentrated in the Middle East region where historically, political instability has translated into very volatile prices. On the other hand, potentially economic deposits of uranium can be found in North America, Europe and Africa as well as in the Asia-Pacific region meaning that in the event of interruption to production in one region, the impact on the entire market would be much less severe than for oil or gas.

2. Strategic importance of Australia's uranium resources and any relevant industry developments

Uranium is a very energy-intense and efficient energy source. Every kilogram of natural uranium provides 500,000 megajoules of heat value (in a conventional reactor), compared with 39 megajoules for gas, 45 for oil and 20-30 for coal. One tonne of uranium in uranium oxide from a mine generates the same amount of heat as 20,000 tonnes of typical black coal. On this basis, the current economically-recoverable uranium (ie ore reserves) at the Olympic Dam mine in South Australia's north - the world's largest known uranium resource, has the energy equivalent of 6.6 billion tonnes of steaming coal, or if the whole resource is considered: 25 billion tonnes of steaming coal. Thus the reserves have about 4.5 times the energy contained in the Northwest Shelf Gas Project.

Known Recoverable Resources of Uranium

	tonnes U	% of world
Australia	989,000	28%
Kazakhstan	622,000	18%
Canada	439,000	12%
South Africa	298,000	8%
Namibia	213,000	6%
Russian Fed.	158,000	4%
Brazil	143,000	4%
USA	102,000	3%
Uzbekistan	93,000	3%
World total	3,537,000	

Reasonably Assured Resources plus Estimated Additional Resources - category 1, to US$ 80/kg U, 1/1/03, from OECD NEA & IAEA, *Uranium 2003: Resources, Production and Demand.*

The above figure for Australia in this table will increase in the 2005 edition of the "Red Book" due to reappraisal of Olympic Dam taking the total to 1.15 million tonnes. But as is evident from the graph in Appendix 2, virtually no new uranium exploration has been undertaken in Australia since 1983, due in part to confused government policies on uranium mining and export.

However, one aspect of Australia's uranium export policy has been constant since 1977, and acknowledges the potential military significance which distinguishes uranium from other energy commodities.

This policy is based on the requirements of the Nuclear Non-Proliferation Treaty (NPT) and the IAEA safeguards invoked under it. Superimposed on these are additional conditions which are required by bilateral agreement with customer countries[1] and implemented by the Australian Safeguards and Non-proliferation Office (ASNO). This means that Australian uranium may only be exported for peaceful purposes and bilateral safeguard agreements provide for:

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[1] Australia has 18 bilateral safeguards agreements covering 36 countries (the Euratom agreement covering 25).

- Coverage of uranium exports by International Atomic Energy Agency (IAEA) safeguards from the time they leave Australian ownership
- Continuation of coverage by IAEA safeguards for the full life of the material or until it is legitimately removed from safeguards
- Fallback safeguards in the event that IAEA safeguards no longer apply for any reason
- Prior Australian consent for any transfer of AONM (Australian-Obligated Nuclear Material to a third party, for any enrichment beyond 20 per cent of uranium-235 and for reprocessing of AONM
- Physical security arrangements

The stringency of Australia's approach, ensuring Australian involvement in regulating for the full life of its nuclear material through ASNO, is internationally recognised for the contribution it has made to ensuring such material is not diverted for military purposes. **Australia retains the right to be selective regarding the countries with which it is prepared to conclude bilateral safeguards agreements. As such, and with the extent of the world's uranium resources it controls, Australia is uniquely placed to exercise even greater international influence to maintain the safety and security of the nuclear fuel cycle.**

As it is, while an incident in a uranium mine or elsewhere in the nuclear industry will generate much publicity, this by no means indicates that the industry is unsafe in comparison with other energy producers, as illustrated by the tables below –

Energy Accidents – Highest Fatalities (1969 – 1996)

Energy	Date	Country	Phase	Fatalities
Oil	Dec 1987	Philippines	Transport	3,000
Oil	Nov 1982	Afghanistan	Distribution	2,700
Hydro	Aug 1979	India	Power Plant	2,500
Hydro	Aug 1993	China	Power Plant	1,250
Hydro	Sept 1980	India	Power Plant	1,000
Chernobyl;				
Nuclear	April 1986	Ukraine	Power Plant	31

Energy Accidents – Highest Injuries (1969 – 1996)

Natural Gas	Nov 1984	Mexico	Distribution	7,231
Oil	Jan 1980	Nigeria	Extraction	3,000
Oil	April 1982	Mexico	Distribution	1,400
Oil	Oct 1988	Russia	Distribution	1,020
Oil	Dec 1982	Venezuela	Power Plant	1,000
Chernobyl;				
Nuclear	April 1986	Ukraine	Power Plant	370

Source: Paul Scherrer Institute – Severe Accidents in the Energy Sector, First Edition

In addition to these catastrophic events, it should be noted that 6027 workers died in 3639 separate accidents in Chinese coal mines last year. *(China's State Administration of Work Safety – Jan 17 2005)* On average, there were 4.2 fatalities per million tonnes of coal mined in China. This compares with 7 fatalities/Mt in Ukraine, 0.034 /Mt in USA, and 0.009 /Mt in Australia.

To put this number into perspective, China's plans to more than quadruple its nuclear power capacity to 40 GWe (to 4% of total projected electricity demand) by 2020 will obviate the need to mine an additional 17 million tonnes per year of coal for power generation.

In relation to Chernobyl, all of the 13 remaining Soviet-designed RBMK reactors, identical to the Chernobyl reactor, have now been substantially modified, making them more stable and adding safety features like faster automatic shut-down mechanisms. The accident was the result of a flawed reactor design that was operated with inadequately trained personnel and without proper regard for safety. It has led to a profound change in operational culture in the former Soviet Union.

The authoritative source of information on the effects of the Chernobyl accident is the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) - notably annex J of its 2000 report: As well as the 31 deaths at the time of the accident, there have since been about ten deaths so far attributed to it from thyroid cancer. No increase in leukaemia is discernible yet, although this is expected to show up in the next few years along with greater, though not statistically discernible incidence of other cancers. There has been no substantiated increase in congenital abnormalities, adverse pregnancy outcomes or any other radiation-induced disease in the general population, either in the contaminated areas or further afield attributable to Chernobyl.

While the psycho-social effects of this accident are also acknowledged, and have been similar to those arising from major disasters such as earthquakes and floods, the above comments seek to put the Chernobyl issue into perspective.

In terms of Australian domestic strategic considerations, uranium is an important 'hedge' for the balance of payments. It will help offset the negative impact on Australia's coal exports of any international move to reduce global carbon emissions, with any fall in coal-fired power generation stimulating demand for alternative fuel sources such as uranium.

Globalisation of the mining industry means that Australia has the potential to attract significant foreign investment for new mines. Such investment, particularly from North American and European financial markets, has been deterred by concern that public policy may restrict production. Australian financial institutions have also been reluctant to provide limited recourse debt to finance uranium operations, not because of credit risks but because of a concern about public opposition to uranium mining. A more consistent public policy approach to uranium would help to address this issue.

The concentration of Australian uranium production in a small number of rural locations means that the industry makes a significant contribution to regional economies. The minerals industry accounts for over 30% of the gross product of the Northern Territory, with uranium accounting for around 10% of this. Over the period it has operated, the industry in the Northern Territory has delivered almost $200 million in royalty payments to local Aboriginal communities. Australia's other operating mines are in South Australia, which has a substantially larger and more diversified economy, but the local impact of the industry is still marked. The Olympic Dam and Beverley mines annually contribute more than $30 million in royalties to the state government and support direct and indirect employment of more than 5,000 people. The potential expansion of the Olympic Dam mine will create more than 10,000 jobs during the construction phase. Beverley is also responsible for up to $1.0 million per year in Native Title royalties and other payments made to the traditional owners of the Northern Flinders Ranges.

Industry developments in Australia in response to the emerging rise in world demand and prices have included –

- increasing investment in exploration for uranium
- the proposed expansion of the Olympic Dam mine at a cost of more than $4 billion

However, there are some factors which hinder the industry in Australia. One of these is difficulty in shipment of product. The nuclear industry and some other industries have been experiencing difficulties transporting uranium oxide concentrates and other raw materials in bulk quantities that contain very low concentrations of naturally occurring radioactive material (NORM), which are categorised as 'Class 7'. Denial of transport services is evident and appears to be increasing.

Reasons for denial of transport include the following:

- Vessel owners – uneducated re product, easier to ship other cargo
- Shipping Companies – excess paperwork, consortium will not give authorization, uneducated re product and regulations, insurance difficulties
- Transport carriers (rail and sometimes road) – unable to obtain insurance
- Rail – delays, uneducated re product, excess paperwork, regulations.
- Ports of discharge – nuclear free zones – political, uneducated (lack of awareness) and regulations
- Ports of transit – "nuclear free" zones – political, uneducated (lack of awareness)

Further details for South Australian producers in Appendix 9.

3. Potential implications for global greenhouse gas emission reductions from the further development and export of Australia's uranium resources

The burning of fossil fuels to provide two thirds of the world's electricity also generates one third of human-induced greenhouse gases.

Inevitably, international pressure will continue for limits to be imposed. In the context of the Kyoto Protocol, a carbon cost of at least one US cent per kWh needs to be factored for coal generation, and at least half that for gas (on the basis of various proposals and European Union Emissions Trading Scheme transactions). This would effectively increase costs by 20 to 30%. By comparison, nuclear energy has zero cost for carbon emissions. **Nuclear power plants are the single most significant means of limiting increased greenhouse gas concentrations while enabling access to predictable and economic electricity.**

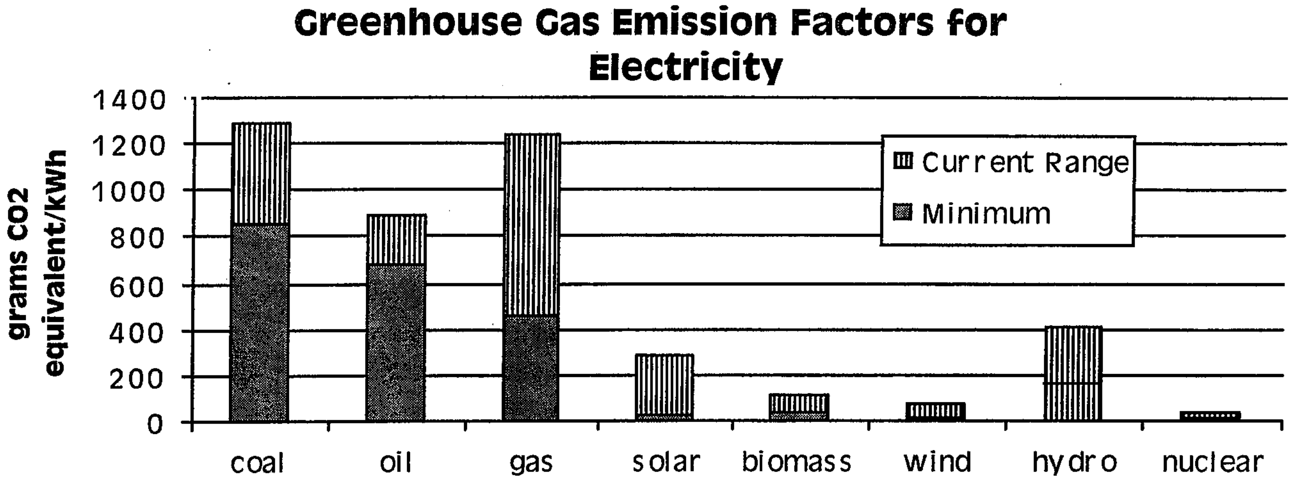
Even without a cost for carbon, nuclear is already competitive with other forms of energy in many areas. Wind power, the main no-carbon alternative to nuclear, typically costs significantly more per kWh generated with its unpredictable availability requiring additional investment in back-up capacity.

The nuclear reactors currently operating in the world are estimated to now avoid 2.5 billion tonnes of carbon dioxide emissions on an annual basis. Every 22 tonnes of uranium used (26 t uranium oxide) saves one million tonnes of carbon dioxide emissions relative to coal.

At its World Energy Congress held in Sydney in September 2004, the World Energy Council concluded that - 'All energy options must be kept open and no technology should be idolised or demonised. These include the conventional options of coal, oil, gas, nuclear and hydro (whether large or small) and the new renewable energy sources, combined of course with energy efficiency.'

The eminent British scientist and environmental leader, James Lovelock, creator of the Gaia hypothesis of the Earth as a self-regulating organism, has said – 'by all means, let us use the small input from renewables sensibly, but only one immediately available source does not cause global warming and that is nuclear energy. Opposition to nuclear energy is based on irrational fear fed by Hollywood-style fiction, the Green lobbies and the media. These fears are unjustified, and nuclear energy from its start in 1952 has proved to be the safest of all energy sources. We have no time to experiment with visionary energy sources; civilisation is in imminent danger and has to use nuclear – the one safe, available energy source – now or suffer the pain soon to be inflicted by our outraged planet.' *(http://argument.independent.co.uk/commentators/story.jsp?story)*

There are many published sets of figures for emissions from various ways of generating electricity and while each depends on specific assumptions, they agree well. No reputable figures depart very much from about 950 g/kWh for black coal, around 500 g/kWh for gas and some 20 g/kWh for nuclear (using centrifuge enrichment), all considering whole life cycle (and in the case of gas, ignoring carbon dioxide emissions at the wellhead). The following bar chart shows a range of values.



source: Bertel & van de Vate, IAEA Bulletin 4/95

The following numbers are from UIC briefing papers quoting Japan's Central Research Institute of the Electric Power Industry, Vattenfall (1999) - a popular account of life cycle studies based on the previous few years experience and its certified Environmental Product Declarations (EPDs) for Forsmark and Ringhals nuclear power stations in Sweden, and Kivisto (2000) reporting a similar exercise for Finland. They show the following CO_2 emissions:

g/kWh CO_2	Japan	Sweden	Finland
coal	975	980	894
gas thermal	608	1170 (peak-load, reserve)	-
gas combined cycle	519	450	472
solar photovoltaic	53	50	95
wind	29	5.5	14
nuclear	22	6	10 - 26
hydro	11	3	-

The Japanese gas figures include shipping LNG from overseas, and the nuclear figure is for boiling water reactors, with enrichment 70% done in USA (diffusion plant), 30% in France & Japan, and one third of the fuel to be MOX. The Finnish nuclear figures are for centrifuge and diffusion enrichment respectively, the Swedish one is for 80% centrifuge.

A further significant environmental consideration for nuclear power is radioactive waste management. Waste is created in relatively small quantities because of the efficiency of nuclear fission. A 1,000 MW plant operating for one year will discharge about 27 tonnes of used fuel, or two truckloads. However, this used fuel is hot and radioactive and is therefore contained and managed rather than dumped. It must be stored and eventually disposed of carefully, and the industry's record of managing used civil fuel over nearly 50 years has been uneventful.

The industry routinely contains and manages all its wastes with the cost (including eventual disposal) internalised in power prices. There is international consensus that deep geological repositories are the safest, most appropriate way to dispose of high-level wastes. No technical impediments to this technology have been demonstrated. Interim storage has allowed the radioactivity of used fuel and separated high level wastes to decrease significantly - to about 0.1% of the original level after about 40 years - before disposal. High level waste repositories will be operational in several countries by about 2020 to provide for final disposal.

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)

The requirement for high standards of safety and environmental performance by the uranium mining industry is appropriate, but no more so than for any other industrial activity involving people as workers or neighbours, or having a potential impact on the environment.

The current regulatory regime is onerous for the industry, particularly in comparison with industries such as agriculture, forestry, tourism and manufacturing.

The sector is already extensively reviewed as well as regulated.

Since 1996 there have been two Senate inquiries and two major reviews in South Australia. In this period, the Olympic Dam and Beverley mines have also been extensively assessed through the publication of environmental impact statements. Before it commenced production, the Ranger mine was subject to the public Fox inquiry lasting two years.

The industry is subject to a range of Commonwealth and State/Territory legislation and regulations. For as long as Australia has a federal system of government, the industry assumes that the states and territories will maintain regulatory responsibility for mining and mineral processing operations and that the Commonwealth will continue to exercise export controls and administer Australia's safeguards policy. An area of potential duplication between the jurisdictions remains environmental assessment and regulation.

The industry's view is that legislative and regulatory requirements should ensure the highest possible standards of occupational and public safety and environmental protection, while avoiding duplication and unnecessary administrative burdens and costs. In this respect, the industry would encourage the Commonwealth, states and territories to continue to work together to ensure a transparent and efficient method of environmental assessment of major projects.

The industry would encourage the Committee to take into account the long experience of State (particularly South Australian) authorities, in regulating uranium mining and associated activities, including radiation protection. While there have been environmental and safety incidents, no adverse health or environmental effects have been demonstrated. One indicator of industry performance in relation to occupational health and safety is radiation exposure to mine and process plant workers. Such exposure is extensively monitored and regulated. The outcomes demonstrate that the industry has minimised exposures to levels well below those stipulated by international limits. Any radiation exposures to the public as a result of the industry's activities are also kept well below these limits and are clearly insignificant.

The industry would also urge governments at all levels to ensure that they do not impose reporting requirements on the industry that mitigate against public understanding of industry impacts. For example, some operations are required to publicly report spills that have no environmental or safety significance. Such reporting can lead to unnecessary public concern or misrepresentation of operational impacts. If corresponding requirements were placed on other industries handling hazardous materials there would be an outcry. The right of the public to be informed about matters that can affect safety or the environment is acknowledged but this needs to be balanced with the right of the industry to have its reputation protected from exaggerated or misleading public comment about its operations.

The industry recognises the need to take action itself to encourage greater public understanding of its activities and its impacts. To this end, industry participants are considering the enhancement of a program of public education and information to augment work already being undertaken in this respect.

It is relevant to note here that the current anti-uranium stance of several states clearly hinders the exploration for and development of uranium resources, as does a lack of bipartisan support at federal level.

Appendix 1.

The Nuclear Fuel Cycle

The various stages associated with the production of electricity from nuclear reactions are referred to collectively as the nuclear fuel cycle and are described below. The cycle starts with the mining of uranium and ends with the disposal of nuclear waste. With the reprocessing of used fuel as an option for nuclear fuel, the stages form a true cycle. In Australia, the cycle is undertaken up to the stage of uranium milling to produce uranium oxide concentrate for export.

1. Uranium

Uranium is a slightly radioactive metal that occurs throughout the earth's crust. It is about 500 times more abundant than gold and about as common as tin. It is present in most rocks and soils as well as in many rivers and in sea water. It is, for example, found in concentrations of about four parts per million (ppm) in granite, which makes up 60% of the earth's crust. In fertilisers, uranium concentration can be as high as 400 ppm (0.04%) and some coal deposits contain uranium in concentrations greater than 100 ppm (0.01%) Most of the radioactivity associated with uranium in nature is in fact due to other minerals derived from it by radioactive decay processes, and which are left behind in mining and milling.

There are a number of areas around the world where the concentration of uranium in the ground is sufficiently high that extraction of it for use as nuclear fuel is economically feasible. Such concentrations are called ore.

2. Uranium Mining

Both excavation and in situ techniques are used to recover uranium. Excavation may be underground and open pit mining.

In general, open pit mining is used where deposits are close to the surface and underground mining is used for deep deposits, typically greater than 120 m deep. Open pit mines require large holes on the surface, larger than the size of the ore deposit, since the walls of the pit must be sloped to prevent collapse. As a result, the quantity of material that must be removed to secure access to the ore may be large. Underground mines have relatively small surface disturbance and the quantity of material that must be removed to gain access to the ore is considerably less than in the case of an open pit mine.

An increasing proportion of the world's uranium now comes from in situ leaching (ISL), where groundwater with added peroxide is circulated through a very porous orebody to dissolve the uranium and bring it to the surface. ISL may be with slightly acid or with alkaline solutions to keep the uranium in solution. The uranium is then recovered from the solution as in a conventional mill.

The decision on which mining method to use for a particular deposit is governed by the nature of the orebody, safety, environmental and economic considerations.

3. Uranium Milling

Milling, which is generally carried out close to a uranium mine, extracts the uranium from the ore. Most mining facilities include a mill, although where mines are close together, one mill may process the ore from several mines. Milling produces a uranium oxide concentrate which is shipped from the mill. It is sometimes referred to as 'yellowcake' and generally contains more than 80% uranium. The original ore may contain as little as 0.1% uranium.

In a mill, uranium is extracted from the crushed and ground-up ore by leaching, in which either a strong acid or a strong alkaline solution is used to dissolve the uranium. The uranium is then removed from this solution and precipitated. After drying and usually heating, it is packed in 205 litre drums as a concentrate.

Typically 70 to 90% of the uranium in the ore is recovered.

The remainder of the ore, containing most of the original radioactivity and nearly all the rock material, becomes tailings, which are deposited in engineered facilities near the mine. These are closely monitored and regulated. Tailings contain long-lived radioactive materials in low concentrations and toxic materials such as heavy metals. However, the total quantity of radioactive elements is less than in the original ore, and their collective radioactivity will be much shorter-lived. These materials are isolated from the environment for the period necessary to allow their radioactivity to reduce to background levels.

4. *Conversion*

The product of a uranium mill is not directly usable as a fuel for a nuclear reactor. Additional processing, generally referred to as enrichment, is required for most kinds of reactors. This process requires uranium to be in gaseous form and the way this is achieved is to convert it to uranium hexafluoride, ready for the enrichment plant.

5. *Enrichment*

Natural uranium consists, primarily, of a mixture of two isotopes (atomic forms) of uranium. Only 0.7% of natural uranium is 'fissile', or capable of undergoing fission, the process by which energy is produced in a nuclear reactor. The fissile isotope of uranium is uranium 235 (U-235). The remainder is uranium 238 (U-238).

In the most common types of nuclear reactors, a higher than natural concentration of U-235 is required. The enrichment process produces this higher concentration, typically between 3.5% and 5% U-235, by removing over 85% of the U-238. This is done by separating gaseous uranium hexafluoride into two streams, one being enriched to the required level and known as low-enriched uranium. The other is depleted in U-235 and is called 'tails.'

There are two enrichment processes in large scale commercial use, each of which uses uranium hexafluoride as a feed – gaseous diffusion and gas centrifuge. They both use the physical properties of molecules, specifically the 1% mass difference, to separate the isotopes. The product of this stage of the nuclear fuel cycle is enriched uranium hexafluoride, which is reconverted to produce enriched uranium oxide.

It is often claimed that enrichment technology can be misused to produce nuclear weapons. However, while nuclear reactors require uranium enrichment to no more than 5%, nuclear weapons must have U-235 enriched to about 90%. Based on the technologies available, this is not only a difficult process to master, but a very expensive one to operate.

The initial barrier to stopping enrichment beyond 5% is the complexity of the technology. Then there is the work of the International Atomic Energy Agency, the international body responsible for the inspection and audit of nuclear facilities, and the non-proliferation treaty, signed by 186 countries, pledging that no plant or material would be diverted to weapons use.

The original safeguards system was based on material accountability, physical security, containment and surveillance. An additional protocol agreed in 1997 provides for more disclosure of nuclear-related activities, greater inspection rights and more co-operation with inspectors.

These barriers have meant that in no case has the civil nuclear fuel cycle been used to produce weapons grade material.

6. Fuel Fabrication

Reactor fuel is generally in the form of ceramic pellets. They are formed from pressed uranium oxide which is sintered (baked) at a high temperature (over 1400°C). The pellets are then encased in metal tubes to form fuel rods, which are arranged into a fuel assembly ready for introduction into a reactor. The dimensions of the fuel pellets and other components of the fuel assembly are precisely controlled to ensure consistency in the characteristics of fuel bundles.

In a fuel fabrication plant great care is taken with the size and shape of processing vessels to avoid criticality (a limited chain reaction releasing radiation). With low-enriched fuel, criticality is most unlikely, but in plants handling special fuels for research reactors this is a vital consideration.

7. Power Generation

Inside a nuclear reactor the nuclei of U-235 atoms split (fission) and, in the process, release energy. This energy is used to heat water and turn it into steam. The steam is used to drive a turbine connected to a generator which produces electricity. Some of the U-238 in the fuel is turned into plutonium in the reactor core, and this yields about one third of the energy in a typical nuclear reactor. The fissioning of uranium is used as a source of heat in a nuclear power station in the same way that the burning of coal, gas or oil is used as a source of heat in a fossil fuel power plant.

8. Used Fuel

Over time, the concentration of fission fragments and heavy elements, formed in the same way as plutonium in a fuel bundle, will increase to the point where it is no longer practical to continue to use the fuel. So after a period typically 18 to 24 months, this 'spent fuel' is removed from the reactor. The amount of energy that is produced from a fuel bundle varies with the type of reactor and the policy of the reactor operator.

Typically, more than 45 million kilowatt-hours of electricity are produced from one tonne of natural uranium. The production of this amount of electrical power from fossil fuels would require the burning of about 20,000 tonnes of black coal or 13 million cubic metres of gas.

9. Used Fuel Storage

When removed from a reactor, a fuel bundle will be emitting both radiation, principally from the fission fragments, and heat. Used fuel is unloaded into a storage pond immediately adjacent to the reactor to allow the radiation levels to decrease. In the ponds the water shields the radiation and absorbs the heat. Used fuel is held in such pools for several months to several years.

Depending on policies in particular countries, some used fuel may be transferred to central storage facilities. Ultimately, used fuel must either be reprocessed or prepared for permanent disposal.

10. Reprocessing

Used fuel is about 95% U-238 but it also contains about 1% U-235 that has not fissioned, about 1% plutonium and 3% fission products which are highly radioactive, with other transuranic elements formed in the reactor. In a reprocessing facility the used fuel is separated into its three components: uranium, plutonium, and waste containing fission products. Reprocessing enables recycling of the uranium and plutonium into fresh fuel, and produces a significantly reduced amount of waste (compared with treating all used fuel as waste).

11. Uranium and Plutonium Recycling

The uranium from reprocessing, which typically contains a slightly higher concentration of U-235 than occurs in nature, can be reused as fuel after conversion and enrichment, if necessary. The plutonium can be directly made into mixed oxide (MOX) fuel, in which uranium and plutonium oxides are combined.

In reactors that use MOX fuel, plutonium-239 substitutes for the U-235 in normal uranium oxide fuel.

12. Used Fuel Disposal

The longer used fuel is stored, the easier it is to manage final disposal, due to the progressive diminution of radioactivity. After 40 to 50 years of storage, the radioactivity level of the fuel falls to 0.1% of its original level. This, and the fact that the volumes of waste involved are not, relatively, large, have meant that final disposal facilities (as opposed to storage facilities) have not been operated since civil nuclear power programs were introduced. Technical issues related to disposal have been addressed and a number of countries have determined their own optimum approach to the disposal of used fuel and waste from reprocessing. The most commonly favoured method for disposal is placement into deep geological repositories. The United States is now building a national repository under Yucca Mountain in Nevada. It is scheduled to be operational by 2012. Sweden is proposing to have a deep geological repository in operation by about 2017 and Finland by 2020.

13. Wastes

Wastes from the nuclear fuel cycle are categorised as high, medium or low level by the amount of radiation they emit. These wastes come from a number of sources and include

- low level waste produced at all stages of the fuel cycle and from a wide variety of nuclear applications (though note that uranium mill tailings are not normally classified as wastes in this categorisation, as they simply contain left-over radionuclides from the original orebody, not radionuclides arising from nuclear technology)
- intermediate level waste produced during reactor operation and arising from reprocessing
- high level waste containing fission products from reprocessing, or the used fuel itself in those countries where there is no reprocessing.

All of these wastes are highly regulated in each country where they arise as a result of the use of uranium, including Australian uranium. Where they have any potential weapons proliferation significance those arising from Australian uranium are designated Australian Obligated Nuclear Material (AONM) and are tracked through ASNO safeguards accounting and auditing procedures.

A fuller account of waste management is in Appendix 6.

14. Energy yield

A consideration regarding the whole fuel cycle is how much net energy it yields, since some extravagant and unsubstantiated assertions have cast doubt on this in some of the anti-nuclear folklore. Using centrifuge enrichment, which is rapidly becoming the industry norm as 1950s plants are phased out, about two percent of the energy output from nuclear power is required for fuel cycle inputs.

See UIC briefing paper *Energy Analysis of Power Systems.*

Appendix 2.

Uranium Exploration and Mining in Australia

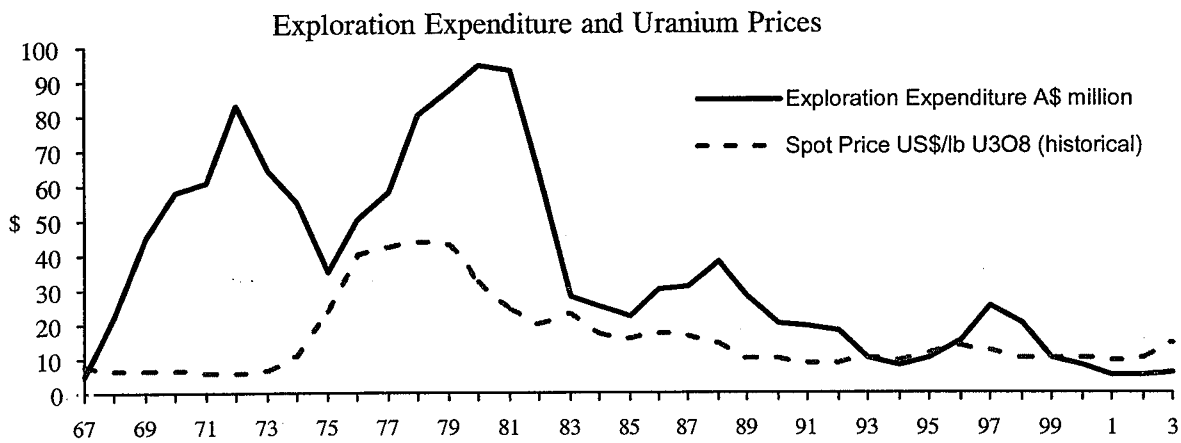
The existence of uranium ore in Australia has been known since the 1890s. In the 1930s uranium ores were mined at Radium Hill and Mount Painter in South Australia to recover minute amounts of radium for medical purposes.

Following the realisation during the second world war of the commercial and military potential of uranium, uranium ores as such were mined and treated from the 1950s until 1971 in Australia's first phase of uranium mining. Radium Hill, Rum Jungle in the Northern Territory and Mary Kathleen in Queensland were the largest producers. Production ceased either when ore reserves were exhausted or contracts were filled. Sales were to supply material primarily intended for the military programs of the United States and the United Kingdom. However, much of it was used in civil electricity production when it began in the 1950s.

The development of civil nuclear power stimulated a second wave of exploration activity in Australia in the late 1960s. New contracts for uranium sales (to be used only for electric power generation) were made by Mary Kathleen Uranium Ltd., Queensland Mines Ltd. And Ranger Uranium Mines Pty. Ltd. In the years 1970-72, successive Coalition and Labor federal governments approved these contracts. Mary Kathleen began recommissioning its mine and mill in 1974 and production recommenced in 1976. At the end of 1982, the Mary Kathleen mine was depleted and finally closed down.

Following the Ranger Uranium Environmental Inquiry initiated in 1975, the Federal Government announced in 1977 that new uranium mining could proceed. The Ranger mine in the Northern Territory opened in 1981.

In 1979, Queensland Mines opened Nabarlek in the same region of the Northern Territory. The orebody was mined out in one dry season and the ore stockpiled for treatment from 1980.



In 1988 the Olympic Dam mine in South Australia commenced production, and late in 2000 the Beverley mine, also in South Australia, started operations.

Mary Kathleen and Nabarlek mine sites have been rehabilitated to a high standard.

- ***currently operating mines***

a) Ranger – Its initial production capacity was 3,300 tonnes of uranium oxide, subsequently expanded to 5,000 tonnes per annum (tpa). Sales are to Japan, South Korea, France, Spain, Sweden, the United Kingdom, Canada and the United States. Ranger is owned by Energy Resources of Australia Ltd (ERA), a subsidiary of Rio Tinto Ltd.

b) Olympic Dam – Initial production was 1,800 tonnes of uranium oxide. It is now 4,500 tpa with plans now being developed for further major expansion. The mine also produces copper, gold and silver. Uranium sales are to the United States, Canada, Sweden, the United Kingdom, Belgium, France, Finland, South Korea and Japan. In March 2005, the Board of WMC Resources Limited, the mine's owner, recommended shareholder acceptance of an offer from BHP-Billiton for all of the WMC's assets.

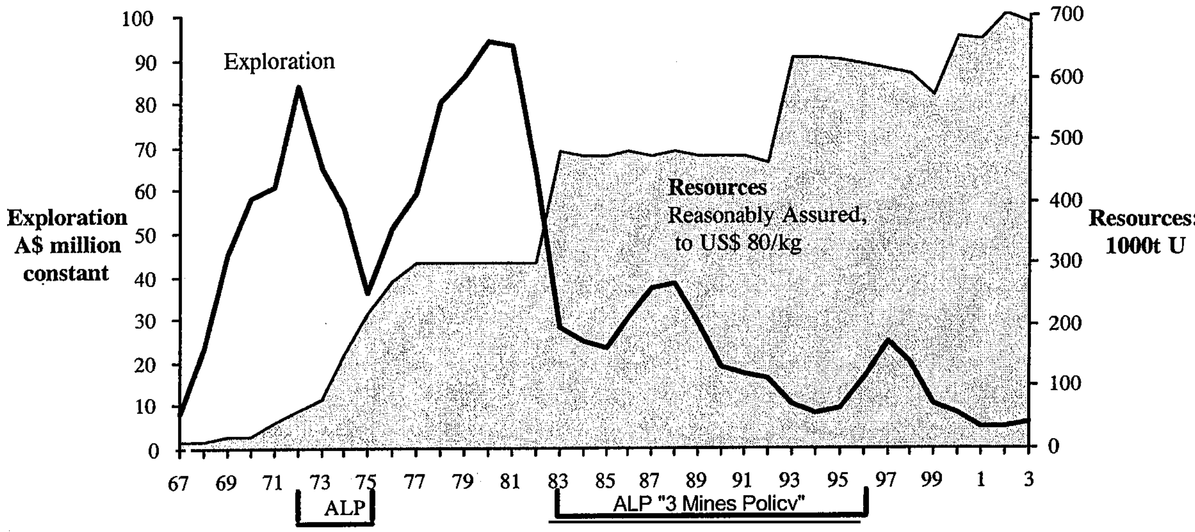
c) Beverley – Australia's first in situ leach (ISL) mine is licensed to produce 1,180 tpa of uranium oxide. It reached this level in 2004. The mine is operated by Heathgate Resources Pty Ltd, an affiliate of General Atomics based in San Diego, California. General Atomics is a miner, processor of uranium and a designer of innovative nuclear power reactors. The Beverley mine has markets in Japan, South Korea, Europe and the United States

- ***Australia's other major deposits and prospective mines***

Deposit	Grade U_3O_8	Contained U_3O_8	Category
Jabiluka – Northern Territory	0.51%	71,000 t	reserves
	0.57%	88,000 t	measured and indicated resources
	0.48%	75,000 t	inferred resources
Kintyre – Western Australia	0.2 – 0.4%	35,000 t	reserves and resources
Honeymoon – South Australia	0.11%	3,300 t	resources
Billeroo West (Gould Dam) – South Australia	0.12%	2,000 t	Indicated resources
Koongarra – Northern Territory	0.8%	14,540 t	reserves
Yeelirrie – Western Australia	0.15%	52,000 t	Indicated resources
Westmoreland – Queensland/Northern Territory	Up to 0.2%	21,000 t	Inferred resources
Ben Lomond – Queensland	0.25%	4,760 t	resources
Maureen - Queensland	0.123%	3,000 t	resources
Manyingee – Western Australia	0.12%	7,860 t	Indicated & inferred resources
Oobagooma – Western Australia	Not known	9,950 t	resources
Valhalla - Queensland	0.144%	16,500 t	indicated resources
		25,000 t	inferred resources
Angela – Northern	0.13%	11,500 t	reserves

Territory			
Lake Way – Western Australia	Not known	4,000 t	resources
Curnamona – South Australia	Not known	Not Known	-
Prominent Hill – South Australia	0.01% (as by-product of copper mining)	9,000 t	inferred resources

Exploration Expenditure and Known Uranium Resources in Australia



First phase: 1944 - 56	Second phase: 1966 - 72	Third phase: 1975 - 81	1982 on
1949 Rum Jungle 1953 South Alligator 1954 Valhalla, Mary Kathleen 1956 Westmoreland	1969 Ranger, Beverley 1970 Koongarra, Nabarlek 1971 Jabiluka 1972 Yeelirrie, Honeymoon	1975 Olympic Dam 1975-81 proving reserves	1985 Kintyre 1992 upgrading Olympic Dam reserves

It can thus be seen that Australia's known uranium resources largely reflect exploration efforts more than 25 years ago. Very little exploration for uranium has been carried out since. There is now significant potential for increasing exploration in the light of higher uranium prices, but state government policies need to be positive.

The potential for new discoveries is great. Not only have many prospective areas not been explored at all thoroughly, but also geological knowledge evolves and exploration technology improves, so that there is increased sophistication and effectiveness of the exploration effort going into the future. A significant example of this is that in the mid 1970s when the main uranium discoveries were made in Canada's Athabasca Basin, airborne electromagnetic surveys there were effective only to 100 metres depth below the surface, today they yield useful data down to one kilometer. This is particularly relevant to uranium exploration in NT, much of which targets similar geological formations.

The following companies are the main ones involved in uranium exploration in Australia, or are holding assets pending their development as mines.

Company	**Management base for U**	**Main Australian Uranium Interests**
AFMEX P/L (COGEMA Australia P/L)	Perth	plans for SA; Ben Lomond*, near Townsville, Qld
Arrowfield Resources NL ♦	Perth	Lagoon Creek, NT
Cameco Australia P/L	Darwin	Arnhem Land, NT and WA near Kintyre
Curnamona Energy Ltd ♦ (from Havilah Resources)	Adelaide	Curnamona/Kalkaroo, SA
Eaglefield Holdings P/L	Perth	Mulga Rock WA (U-Sc)*
Energy Resources of Australia Ltd♦	Darwin	Jabiluka, NT*
Heathgate Resources P/L	Adelaide	Beverley* extensions
Koongarra Mines P/L (COGEMA Australia P/L)	Perth	Koongarra*, Alligator Rivers, NT
Laramide Resources Ltd	Toronto	Westmoreland*, NW Qld
Maple Minerals Inc	Brisbane	Purchasing Ben Lomond*
Marathon Resources Ltd ♦	Adelaide	Mt Gee, Mulga Well, Coondambo SA
Oxiana Ltd ♦	Adelaide	Prominent Hill*, SA
Paladin Resources NL ♦	Perth	Manyingee* & Oobagooma*, WA, also Frome Basin, SA (with Heathgate Resources).
Quasar Resources P/L	Adelaide	Arkaroola, SA
Rio Tinto Ltd ♦	Perth	Kintyre*, WA.
Scimitar Resources ♦	Perth	Near Kintyre & Manyingee, WA
Southern Cross Resources Inc	Adelaide	Honeymoon*, Frome Basin, SA
Summit Resources Ltd ♦	Perth	Valhalla*, near Mount Isa, Qld
WMC Resources Ltd ♦	Melbourne	Yeelirrie*, WA

♦ Listed on Australian Stock Exchange

* Identified and quantified deposit, see UIC Mines paper # 2.

Assessing the extent of federal subsidies, rebates and other mechanisms used to facilitate uranium mining and resource development.

There are no subsidies, rebates or other financial mechanisms provided specifically for the uranium industry.

In fact state and federal geological surveys and scientific organisations have directed virtually no resources to uranium over the last 20 years, constituting a negative subsidy when compared with other mineral commodities which provide large parts of the Australian resource economy.

Appendix 3.

Australian Uranium Production and Exports relative to World Production and Exports

Australian production and exports

		96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04
Production	Tonnes U3O8	5995	5797	6396	8199	9645	7717	9149	9533
Exports	Tonnes U3O8	5701	6415	5989	8023	9723	7366	9592	9099
Exports	A$million, FOB	245	288	288	367	497	361	427	364

In calendar year 2004 production was 10,592 tonnes U_3O_8 and exports 9402 tonnes, averaging A$43,710 per tonne.

Australian exports over the past two years have averaged about 22% of world supply of mined uranium. In the five years to mid 2004, Australia exported almost 44,000 tonnes of uranium oxide concentrate with a value of more than $2 billion.

Australia's uranium is sold strictly for electrical power generation only. Safeguards (international accounting and auditing procedures) are in place to ensure this. Australia is a party to the Nuclear Non-Proliferation Treaty (NPT) as a non-nuclear weapons state. Its safeguards agreement under the NPT came into force in 1974.

Australia is a preferred uranium supplier to the world. The following shows Australia's major customers by area of destination and the extent of their use of nuclear power.

Australian exports by destination

Country	Australian U_3O_8 supplied per year (approx tpa.)	Number of reactors in operation	% of total electricity supplied by nuclear
USA	4500	103	20
Japan	2500	54	25
South Korea	1000	20	40
European Union	2600		
Spain		9	24
France		59	78
United Kingdom		23	24
Sweden		11	50
Germany		18	28
Belgium		7	55
Finland		4	27

Australia could readily increase its share of the world market because of its low cost reserves and its political and economic stability.

Nearly all of Australia's 702,000 tonnes of Reasonably Assured Resources of uranium alone to US$80/kg U (US$30/lb U_3O_8) are in the under US$40/kg U category. This figure compares with Kazakhstan (384,000 tU), Canada (334,000 tonnes), South Africa (232,000 tonnes) and Namibia (139,000 tonnes). The following table shows these plus Estimated Additional Resources –

World's known recoverable resources of Uranium*

	Tonnes U	Percentage of world
Australia	989,000 #	28% #
Kazakhstan	622,000	18%
Canada	439,000	12%
South Africa	298,000	8%
Namibia	213,000	6%
Russian Federation	158,000	4%
Brazil	143,000	4%
United States of America	102,000	3%
Uzbekistan	93,000	3%
World Total	3,537,000	

*Reasonably Assured Resources plus Estimated Additional Resources – category 1, to US$ 80/kg U, 1/1/03, from OECD NEA and IAEA, *Uranium 2003: Resources, Production and Demand*
#figure excludes the recent announced increase in uranium resources at Olympic Dam. Using NEA's methodology it is estimated that the 2004 recoverable resource for Australia will be about 1.15 million tonnes. Assuming no changes in other countries, Australia's share of the world's total will rise from 28% to around 31%

In the 1980s, large stockpiles were built up by utilities, totalling about four times annual consumption. Prices dropped and mine production fell. Today, annual world uranium consumption is approaching 80,000 tonnes U_3O_8 and production is only just over half of this, the balance being stockpiles and recycled military uranium.

Appendix 4.

World Uranium Prices and Markets

All mineral commodity markets tend to be cyclical. Prices rise and fall substantially in the shorter term against a longer term background of decline in real prices. In the uranium market, very high prices in the late 1970s gave way to very low prices in the early 1990s, spot prices being below the cost of production for most mines. In 1996, spot prices recovered to the point where most existing mines could produce profitably, though they then declined again and only recovered from late in 2003.

'Spot prices' apply to marginal trading from day to day. In 2003, they represented less than 12% of total sales. Most trade is three to seven year term contracts, with producers selling direct to utilities.

The reasons for fluctuation in mineral prices relate to demand and perceptions of scarcity. The price cannot indefinitely stay below the cost of production, nor will it remain at very high levels for longer than it takes to price signals to encourage new producers to enter the market.

- *Demand*

The world's 440 reactors, with combined capacity of some 366 GWe, require an annual 80,600 tonnes of uranium oxide concentrate (or the equivalent from stockpiles or secondary sources). The capacity is growing, and at the same time the reactors are being operated more productively, with higher capacity factors, and reactor power levels. Factors increasing fuel demand have been offset by increased efficiencies, dampening demand. For example, over the 20 years from 1970 there was a 25% reduction in uranium demand per kWh output in Europe.

Fuel burnup is measured in MW days per tonne U, and many utilities are increasing the initial enrichment of their fuel (eg from 3.3% to more than 4% U-235) and then burning it longer or harder to leave only 0.5% U-235 in it.

Because of the cost structure of nuclear power generation, with high capital and low fuel costs, (current United States electricity production costs are 5.77 US cents/KWh for gas; 5.53c, oil; 1.80c coal; 1.72c nuclear) the demand for uranium fuel is much more predictable than with probably any other mineral commodity. Once reactors are built it is very cost-effective to keep them running at high capacity and for utilities to make any adjustments to load trends by cutting back on fossil fuel use. Demand forecasts for uranium thus depend largely on installed and operable capacity, regardless of economic fluctuations. For instance, when South Korea's overall energy use decreased in 1997, nuclear energy output actually rose, to replace imported fossil fuels.

- *Supply*

Mines in 2003, the latest full year for which reliable figures are available, supplied some 42,300 tonnes of U3O8 containing almost 36,000 tU. Indicative figures for 2004 are nearly 10% higher. This was far less than the annual requirement of power utilities. The balance was made up from secondary sources, including stockpiled uranium held by utilities, but those stockpiles are now largely depleted. The other main secondary source is diluted weapons-grade uranium from military sources. At present half of the uranium used in the USA comes from Russian weapons, under a US$ 12 billion contract for 500 tonnes of high-enriched uranium. This is now about half filled, and no follow-on Russian arrangement is expected, due to Russia's own increasing needs. A smaller amount of ex-military uranium from US sources is starting to become available. See also UIC briefing paper: *Military Warheads as a Source of Nuclear Fuel.*

A perception of imminent scarcity drove the 'spot price' for uncontracted sales to US$16.40 per pound U_3O_8 in mid 1996. Due to an expectation of increased secondary supplies, the spot price then declined to around US$ 7 per pound before price recovery from 2001. It is now (25/4/05) US$ 26.00 per pound.

At current prices, only a quarter of the cost of the fuel loaded into a nuclear reactor reflects the mined cost. The balance is mostly the cost of enrichment and fuel fabrication.

See also UIC briefing paper: *Uranium markets.*

Appendix 5

<u>The effectiveness of safeguards regimes</u> in addressing the proliferation of fissile material, the potential diversion of Australian obligated fissile materials, and the potential for Australian obligated radioactive materials to be used in 'dirty bombs'.

Australia's main interest in international nuclear safeguards is in relation to the use of its uranium in overseas nuclear power programs. It has long been a strong proponent of a robust international non-proliferation regime to enhance national and international security. It is rigorous in seeking assurances that nuclear exports will only be used for legitimate and peaceful nuclear energy purposes.

In the 1960s Australia participated in the drafting of the Statute of the UN's International Atomic Energy Agency (IAEA). Since then it has been continuously represented on the IAEA's Board of Governors, and remains active in many of the various technical committees and advisory groups of the IAEA.

In Australia the Ranger Uranium Environmental Inquiry commissioners pointed out quite clearly in their first report (1976) the importance of adequate safeguard measures being applied to Australia's uranium. The Australian Government then decided on the basic principles of an Australian safeguards policy, and these were announced during 1977. Australia was involved in the International Nuclear Fuel Cycle Evaluation Program in the 1970s and continues to use its status as a uranium supplier to press for high safeguards standards to be applied. In so doing, Australia is allied with Canada, the Western world's largest uranium producer.

Australian nuclear safeguards policies

1. Selected countries

Non-weapons states must be party to NPT and must accept full-scope IAEA safeguards applying to all their nuclear-related activities.

Weapons states to give assurance of peaceful use, IAEA safeguards to cover the material.

2. Bilateral agreements are required

IAEA to monitor compliance with IAEA safeguards requirements
Fallback safeguards (if NPT ceases to apply or IAEA cannot perform its safeguards functions)
Prior consent to transfer material or technology to another country
Prior consent to enrich above 20% U-235
Prior consent to reprocess
Control over storage of any separated plutonium
Adequate physical security

3. Materials exported or re-exported to be in a form attracting full IAEA safeguards.

4. Commercial contracts to be subject to conditions of bilateral agreements.

5. Australia will participate in international efforts to strengthen safeguards.

6. Australia recognises the need for constant review of standards and procedures.

The Australian policy as outlined is based on the requirements of the Nuclear Non-Proliferation Treaty (NPT) and the IAEA safeguards invoked under it. Superimposed on these are additional conditions which are required by bilateral agreement with customer countries[2] and implemented by the Australian Safeguards and Non-proliferation Office (ASNO).

The legally-binding bilateral safeguard measures are directed towards preventing any unauthorised or clandestine use of exported uranium or any materials derived from it - "Australian-obligated nuclear materials". They are designed to deter possible diversion of fissile material or misuse of equipment and technology more effectively than standard IAEA safeguards on their own.

ASNO is responsible for administering the agreement between Australia and the IAEA for the application of safeguards in Australia. It assists the IAEA by arranging access to our nuclear facilities and installation of safeguards equipment at the sites. It also reports regularly to the IAEA on nuclear materials held in Australia. ASNO also manages the Australian Safeguards Assistance Program.

International nuclear safeguards have been an outstanding success story in the UN context. With the wisdom of hindsight, they might have been more ambitious when they came into effect in 1970, but the deficiencies - related to undeclared nuclear activities rather than simply traded fissile materials - have been addressed in the 1990s through the Additional Protocol which countries are encouraged to sign and ratify supplementary to their agreements with IAEA.

Particular questions related to safeguards

• *Bomb-grade materials*

Both uranium and plutonium were used to make bombs. At the same time it was recognised that they could be important for making electricity and radioisotopes. But the type of uranium and plutonium needed for bombs is different from that in a nuclear power plant. Bomb-grade uranium has to be highly enriched (>90% U-235, instead of about 3-5% for power reactors); bomb-grade plutonium was fairly pure (>90% Pu-239, instead of about 65% in reactor-grade plutonium) and was made in special reactors.

Today, a lot of military high-enriched uranium is becoming available for electricity production. It is diluted with depleted uranium before being used as reactor fuel.

• *Depleted uranium*

Every tonne of natural uranium produced and enriched for use in a nuclear reactor gives about 130 kg of enriched fuel (3.5% or more U-235). The balance is depleted uranium (U-238, with 0.25-0.30% U-235). This major portion has been depleted in its fissile U-235 isotope by the enrichment process. It is commonly known as DU.

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[2] Australia has 18 bilateral safeguards agreements covering 36 countries (the Euratom agreement covering 25).

DU is stored either as UF_6 or it is de-converted back to U_3O_8 which is more benign chemically and thus more suited for long-term storage. It is also less toxic. Every year over 50,000 tonnes of depleted uranium joins already substantial stockpiles in the United States, Europe and Russia.

Some DU is drawn from these stockpiles to dilute high-enriched (>90%) uranium released from weapons programs, particularly in Russia, and destined for use in civil reactors. This weapons-grade material is diluted about 25:1 with depleted uranium, or 29:1 with depleted uranium that has been enriched slightly (to 1.5% U-235) to minimise levels of (natural) U-234 in the product.

Depleted uranium is not classified as a dangerous substance radiologically. Its emissions are very low, since the half life of U-238 is the same as the age of the earth (4.5 billion years). There are no reputable reports of cancer or other negative health effects from radiation exposure to ingested or inhaled natural or depleted uranium.

Some military personnel involved in the 1991 Gulf War later complained of continuing stress-like symptoms for which no obvious cause could be found. These symptoms have at times been attributed to the use of depleted uranium in shells and other missiles, which are said to have caused toxic effects. Similar complaints arose from later fighting in the Balkans, particularly the Kosovo conflict.

Depleted uranium is a heavy metal and, in common with other heavy metals, is chemically toxic. Because it is also slightly radioactive, there is therefore said to be a hypothetical possibility that it could give rise to a radiological hazard under some circumstances such as dispersal in a finely divided form so that it is inhaled. However, because of the latency period for the induction of cancer for radiation, it is not credible that any cases of radiation induced cancer could yet be attributed to the Gulf and Kosovo conflicts. Furthermore, extensive studies have concluded that no radiological health hazard should be expected from exposure to depleted uranium.

The risk from external exposure is essentially zero, even when pure metal is handled. No detectable increase of cancer, leukaemia, birth defects or other negative health effects have ever been observed from radiation exposure to inhaled or ingested natural uranium concentrates, at levels far exceeding those likely in areas where depleted uranium munitions are said to have been used. This is mainly because the low radioactivity per unit mass of uranium means that the mass needed for significant internal exposure would be virtually impossible to accumulate in the body, and depleted uranium is less than half as radioactive as natural uranium.

- *Australian Obligated Nuclear Material*

The following extract from the latest annual report of the Australian Safeguards and Non-Proliferation Office (ASNO) provides useful information about Australian Obligated Nuclear Material (AONM)

> "A characteristic of the civil nuclear fuel cycle is the international interdependence of facility operators and power utilities. Apart from the nuclear-weapon states, it is unusual for a country to be entirely self-contained in the processing of uranium for civil use – and even in the case of the nuclear-weapons states, power utilities will

seek the most favourable financial terms, often going to processors in other countries. Thus it is not unusual, for example, for a Japanese utility buying Australian uranium to have the uranium converted to uranium hexafluoride in Canada, enriched in France, fabricated into fuel in Japan and reprocessed in the United Kingdom. The international flow of nuclear material enhances safeguards accountability, through 'transit matching' of transfers at the different stages of the fuel cycle.

"The international nature of nuclear material flows means that uranium from many sources is routinely mixed during processes such as conversion and enrichment. Uranium is termed a 'fungible' commodity, that is, at these processing stages uranium from any source is identical to uranium from any other – it is not possible physically to differentiate the origin of uranium. This is not unique to uranium, but is also the case with a number of other commodities. The fungibility of uranium has led to the establishment of conventions used universally in the industry and in the application of safeguards, namely equivalence and proportionality. These are discussed below.

"Because of the impossibility of physically identifying 'Australian atoms' and also because Australian obligations apply not just to uranium as it moves through the different stages of the nuclear fuel cycle, but also to material generated through the use of that uranium, - e.g plutonium produced through the irradiation of uranium fuel in a reactor, the obligations under Australia's various bilateral safeguards agreements are applied to AONM. AONM is a shorthand way of describing the nuclear material which is subject to the provisions of the particular bilateral agreement.

"This approach is also used by those other countries applying bilateral safeguards comparable to Australia's, principally the United States and Canada. These countries attach a safeguards 'obligation' to nuclear material which they upgrade, hence giving rise to the situation of 'multi-labelling', for example, AONM enriched in the US will also become US obligated nuclear material (USONM) and its subsequent use will have to meet the requirements of both Australian and US agreements. This is a common situation, that is, a significant proportion of AONM is also characterised as USONM and is accounted for both to ASNO and its US counterpart (DOE).

"The equivalence principle provides that where AONM loses its separate identity because of process characteristics (eg mixing) an equivalent quantity is designated AONM, based on the fact that atoms or molecules of the same substance are indistinguishable, any one atom or molecule being identical to any other of the same substance. In such circumstances, equivalent quantities of the products of such nuclear material may be derived by calculation or from operating plant parameters. It should be noted that the principle of equivalence does not permit substitution by a lower quality material – eg enriched uranium cannot be replaced by natural or depleted uranium.

"The proportionality principle provides that where AONM is mixed with other nuclear material, and is processed or irradiated, a proportion of the resulting material will be regarded as AONM corresponding to the same proportion of AONM initially.

"Some people are concerned that the operation of the equivalence principle means there cannot be assurance that 'Australian atoms' do not enter military programs. This overlooks the realities of the situation, that uranium atoms are indistinguishable from one another and there is no practical way of attaching 'flags' to atoms. The objective of Australia's bilateral agreements is to ensure that AONM in no way materially contributes to or enhances any military purpose. Even if AONM were to be in a processing stream with nuclear material subsequently withdrawn for military use, the presence of the AONM would add nothing to the quantity or quality of the military material (NB as noted elsewhere in this Report, those nuclear-weapon states eligible for the supply of Australian uranium have ceased production of fissile material for nuclear weapons).

• *Accounting for AONM*

"Australia's bilateral partners holding AONM are required to maintain detailed records of transactions involving AONM, and ASNO's counterpart organisations are required to submit regular reports, consent requests, transfer and receipt documentation to ASNO. ASNO accounts for AONM on the basis of information and knowledge including –

- reports from each bilateral partner
- shipping and transfer documentation
- calculations of process losses and nuclear consumption, and nuclear production
- knowledge of the fuel cycle in each country
- regular liaison with counterpart organisations and with industry; and
- reconciliation of any discrepancies with counterparts."

• *Use of AONM in dirty bombs*

In the light of the above, the probability of AONM being used in a dirty bomb is miniscule. Substantial amounts of spent medical and industrial radiation sources such as cobalt-60, and in some countries spent research reactor fuel, would be more readily available. This threat underlines the importance of IAEA programs to find and secure such sources in countries with less rigorous accounting and surveillance than Australia.

See also: UIC briefing paper on *Safeguards to prevent proliferation.*

Appendix 6.

<u>Whole of life cycle waste management assessment</u> of the uranium industry, including radioactive waste management at mine sites in Australia, and nuclear waste management overseas consequent to use of Australian exported uranium.

- *Nuclear power is the only energy-producing technology which takes full responsibility for all its wastes and fully costs this into the product*
- *The radioactivity of all nuclear wastes diminishes with time*
- *Safe methods for the final disposal of high level waste are technically proven: the international consensus is that this should be deep geological disposal*

- *<u>Fundamental Principles of Radioactive Waste Management</u>*

The International Atomic Energy Agency has established the following fundamental principles of radioactive waste management.

1. Protection of Human Health.

Radioactive waste shall be managed in such a way as to secure an acceptable level of protection for human health.

2. Protection of the environment

Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment.

3. Protection beyond national borders

Radioactive waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will be taken into account.

4. Protection of future generations

Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today.

5. Burdens on future generations

Radioactive waste shall be managed in such a way that will not impose undue burdens on future generations.

6. National legal framework

Radioactive waste shall be managed within an appropriate national legal framework including clear allocation of responsibilities and provision for independent regulatory functions.

7. Control of radioactive waste generation

Generation of radioactive waste shall be kept to the minimum practicable.

8. Radioactive waste generation and management interdependencies

Interdependencies among all steps in radioactive waste generation and management shall be appropriately taken into account.

10. Safety of facilities
The safety of facilities for radioactive waste management shall be appropriately assured during their lifetime.

- *Introduction*

Uranium mining and nuclear energy produce operational and decommissioning radioactive wastes which are contained and managed. Although experience with radioactive waste storage and transport over half a century has clearly demonstrated that civil nuclear wastes can be managed without adverse environmental impact, the question has become political with a focus on final disposal. In fact, nuclear power is the only energy-producing industry which takes full responsibility for all its wastes and costs this into the product – a key factor in sustainability.

At each stage of the fuel cycle there are proven technologies to manage and dispose of the radioactive wastes safely.

The radioactivity of all nuclear waste decays with time. Each radionuclide contained in the waste has a half-life – the time taken for half of its atoms to decay and thus for it to lose half of its radioactivity. Radionuclides with long half-lives tend to be alpha emitters, making their handling easier. Those with short half lives tend to emit more of the more penetrating gamma gays.

Eventually, all radioactive wastes decay into non-radioactive elements. The more radioactive an isotope is, the faster it decays.

The main objective in managing and disposing of radioactive (or other) waste is to protect people and the environment. This means isolating or occasionally diluting the waste so that the rate or concentration of any radionuclides returned to the biosphere is harmless. To achieve this, practically all wastes are contained and managed – some clearly need deep and permanent burial. None is allowed to cause harmful pollution.

In the OECD some 300 million tonnes of toxic wastes are produced each year, but conditioned radioactive wastes amount to only 81,000 cubic metres per year. In countries with nuclear power, radioactive wastes comprise less than 1% of total industrial toxic wastes. Most toxic industrial wastes remain hazardous indefinitely.

- *Types of radioactive wastes*

Mines wastes are generated by traditional uranium mining as fine sandy tailings which contain virtually all the naturally occurring radioactive elements naturally found in uranium ore. These are collected in engineered tailings dams and finally covered with a layer of clay and rock to inhibit the leakage of radon gas and ensure long-term stability. In the short term, the tailings material is often covered with water. After a few months, the tailings material contains about 75% of the radioactivity of the original ore.

Low-level wastes (LLW) are generated from hospitals and industry as well as the nuclear fuel cycle. They comprise items such as paper, rags, tools, clothing and filters which contain small amounts of mostly short-lived radioactivity. They do not require shielding during handling and transport and are suitable for shallow land burial. To reduce their volume, they are often compacted or incinerated before disposal. They comprise some 90% of the volume but only 1% of the radioactivity of all radioactive wastes.

Intermediate-level wastes (ILW) contain higher amounts of radioactivity and some require shielding. They typically comprise resins, chemical sludges and metal fuel cladding as well as contaminated materials from reactor decommissioning. Smaller items and any non-solids may be solidified in concrete or bitumen for disposal. They make up some 7% of the volume and have 4% of the radioactivity of all radioactive wastes.

High-level wastes (HLW) arise from the use of uranium fuel in a nuclear reactor. They contain the fission products and transuranic elements generated in the reactor core. They are highly radioactive and hot, so require cooling and shielding. They can be considered as the 'ash' from 'burning' uranium. HLW account for over 95% of the total radioactivity produced in the process of electricity generation. There are two distinct kinds of HLW, as described below.

- *Conversion, enrichment, making fuel*

Uranium oxide concentrate from mining, essentially 'yellowcake' (U3O8) is not significantly radioactive, barely more so than the granite used in buildings. It is refined then converted to uranium hexafluoride gas (UF6). As a gas, it undergoes enrichment to increase the U-235 content from 0.7% to about 3.5 to 5%. It is then turned into a hard ceramic oxide (UO2) for assembly as reactor fuel elements.

The main by-product of enrichment is depleted uranium, principally the U-238 isotope, which is stored either as UF6 or U3O8. Some depleted uranium is used in applications where its extremely high density makes it valuable, such as radiation shielding and even the keels of yachts. It is also used, with recycled plutonium, for making mixed oxide fuel and to dilute highly-enriched uranium from dismantled weapons in its conversion to reactor fuel.

- *Managing HLW from used fuel*

Used fuel gives rise to HLW which may be either:

- The used fuel itself in fuel rods, or
- the principal waste arising from reprocessing fuel rods

In either case, the amount is modest – about 25 tonnes of used fuel or three cubic metres per year of vitrified waste for a typical large nuclear reactor. Both can be effectively and economically isolated, and have been handled and stored safely and virtually without incident in 31 countries since nuclear power began almost 50 years ago.

To ensure that no significant environmental releases occur over tens of thousands of years, 'multiple barrier' disposal is used. This immobilises the radioactive elements in HLW and some ILW and isolates them from the biosphere. The main barriers are:

- immobilisation of waste in an insoluble matrix such as borosilicate glass or ceramic
- sealing inside a corrosion-resistant container, such as stainless steel
- location deep underground in a stable rock structure
- containers surrounded with an impermeable backfill such as bentonite clay if the repository is in a wet environment

If the used fuel is reprocessed, as occurs with fuel from British, French, Swiss, Japanese and German reactors, high-level wastes comprise highly-radioactive fission products and some transuranic elements with long-lived radioactivity. These are separated from the used fuel, enabling the uranium and plutonium to be recycled. They generate a considerable amount of heat and require cooling. They are vitrified in borosilicate (Pyrex) glass, encapsulated into heavy stainless steel cylinders about 1.3 metres high and stored for eventual disposal.

If used reactor fuel is not reprocessed, it will still contain all the highly radioactive isotopes. The entire fuel assembly is accordingly treated as HLW for direct disposal. It too generates a lot of heat and requires cooling. However, since it largely consists of uranium (with a little plutonium) it represents a potentially valuable resource. Hence there is an increasing reluctance to dispose of it irretrievably.

Either way, after between 40 and 50 years the heat and radioactivity have fallen to one-thousandth of the level at when the reactor was switched off to enable their removal. This provides a technical incentive to delay further action with HLW until the radioactivity has reduced to a small fraction of its original level.

After storage for about 40 years the used fuel assemblies are ready for encapsulation or loading into casks ready for indefinite storage or permanent disposal underground.

Direct disposal has been chosen by the United States, Finland and Sweden, although evolving concepts lean towards making the used fuel recoverable in the event future generations see it as a resource. This requires allowing for a period of management and oversight before a repository is closed.

Increasingly reactors are using fuel enriched to over 4% U-235 and burning it longer, to end up with less than 0.5% U-235 in the used fuel. This provides less incentive to reprocess.

- *Recycling uranium and plutonium from used fuel*

Any used fuel will still contain some of the original U-235 as well as various plutonium isotopes which have been formed inside the reactor core, and the U-238. In total these account for some 96% of the original uranium and over half of the original energy content (ignoring U-238). Reprocessing undertaken in Europe and Russia (and planned for Japan) separates this uranium and plutonium from the wastes so they can be recycled for re-use in a nuclear reactor as mixed oxide (MOX) fuel. This is the ‘closed fuel cycle’ and represents very much what is to happen with the small quantities of used fuel from the Australian research reactor at Lucas Heights in Sydney, and the new replacement reactor. Some used fuel from Lucas Heights has already been shipped to Europe for reprocessing, and the small amount of separated waste will be returned to Australia for disposal as ILW.

Plutonium arising from neutron capture in the fuel comprises only about 1% of commercial used fuel. After separation in reprocessing, it is recycled through a MOX fuel fabrication plant where it is mixed with depleted uranium oxide to make fresh fuel. European reactors currently use over 5 tonnes of plutonium a year in fresh MOX fuel, although all reactors routinely burn much of the plutonium which is continually formed in the core by neutron capture. The use of MOX simply means that some separated plutonium is incorporated into fresh fuel. (Plutonium arising from the civil nuclear fuel cycle is not suitable for bombs. It contains far too much of the Pu-240 isotope because of the length of time the fuel has used in the reactor).

Major commercial reprocessing plants operate in France, Britain and Russia, with a capacity of some 5000 tonnes per year and cumulative civilian experience of 80,000 tonnes over 50 years. France and Britain also undertake reprocessing for utilities in other countries, notably Japan, which has made over 140 shipments of used fuel to Europe since 1979. At present, most Japanese used fuel is reprocessed in Europe with the vitrified waste and the recovered uranium and plutonium (as MOX) being returned to Japan to be used in fresh fuel. Russia also reprocesses some used fuel from Soviet-designed reactors in other countries.

- *Costs of radioactive waste management*

The cost of managing and disposing of nuclear power wastes represents about 5% of the total cost of the electricity generated. Most nuclear utilities are required by governments to put aside a levy (eg 0.1 cents per kilowatt hour in the United States) to provide for management and disposal of their wastes. So far more than US$20 billion has been committed to the United States waste fund by electricity consumers.

- *Disposing of used fuel and other HLW*

The world has about 270,000 tonnes of used fuel in storage, much of it at reactor sites. Annual arisings of used fuel are about 12,000 tonnes, and one quarter of this goes for reprocessing. Final disposal is therefore not urgent in any logistical sense.

HLW from reprocessing must be solidified. France has two commercial plants to vitrify HLW left over from reprocessing oxide fuel, and there are also significant plants in Britain and Belgium. The capacity of these western European plants is 2,500 canisters (1,000 tonnes) a year, and some have been operating for two decades.

An Australian-designed wasteform, Synroc (synthetic rock) is a more sophisticated way to immobilise such waste and may eventually come into commercial use for civil wastes.

To date, there has been no practical need for final HLW repositories as surface storage for 30 to 50 years is first required so that heat and radioactivity can dissipate to levels which make handling and storage safer and easier.

The process of selecting appropriate deep geological repositories for HLW is now underway in several countries with the first expected to be commissioned in the next decade. Finland and Sweden are well advanced with plans and site selection for direct disposal of used fuel. The United States has opted for a final repository in Nevada. (A deep geological repository - WIPP - for military transuranic wastes is in operation in New Mexico.)

After being buried for about a thousand years, most of the radioactivity from HLW will have decayed. The amount of radioactivity then remaining would be similar to that of the equivalent naturally-occurring uranium ore from which it originated, though it would be more concentrated.

The following table indicates the measures that some countries have in place or planned to store, reprocess and dispose of used fuel and other radioactive wastes –

Country	Policy	Facilities and progress towards final repositories
Belgium	Reprocessing	Central waste storage and underground laboratory established. Construction of repository to begin about 2035
Canada	Direct disposal	Underground repository laboratory established. Repository planned for use in 2025
China	Reprocessing	Central used fuel storage in LanZhou
Finland	Direct disposal	Used fuel storages in operation. Low and intermediate-level repositories in operation since 1992. Site near Olkiluoto selected for deep repository for used fuel from 2020
France	Reprocessing	Two facilities for storage of short-lived wastes. Site selection studies underway for deep geological repository for commissioning in 2020
Germany	Reprocessing but moving to direct disposal	Low-level waste sites in use since 1975. Intermediate-level wastes stored at Ahaus. Used fuel storage at Ahaus and Gorleben. High-level repository to be operational after 2010
India	Reprocessing	Research on deep geological disposal for high-level waste
Japan	Reprocessing	Low-level waste repository in operation. High-level waste storage facility at Rokkasho-mura since 1995. Investigations for deep geological repository site begun, to operate from 2035
Russia	Reprocessing	Sites for final disposal under investigation. Central repository for low and intermediate-level wastes planned from 2008
South Korea	Direct disposal	Central interim high-level waste store planned for 2016. Central low and intermediate-level repository planned from 2008. Investigating deep high-level

		waste repository sites.
Spain	Direct disposal	Low and intermediate-level waste repository in operation. Final high-level waste repository site selection program for commissioning in 2020
Sweden	Direct disposal	Central used fuel storage facility in operation since 1985. Final repository for low to intermediate waste in operation since 1988. Underground research laboratory for high-level waste repository. Site selection for repository in two volunteered locations.
Switzerland	Reprocessing	Central interim storage for high-level wastes at Zwilag since 2001. Central low and intermediate-level storages operating since 1993. Underground research laboratory for high-level waste repository, with deep repository to be finished by 2020
United Kingdom	Reprocessing	Low-level waste repository in operation since 1959. High-level waste is vitrified and stored at Sellafield. Underground high-level waste repository envisaged.
United States	Direct disposal	Three low-level waste sites in operation. Decision in 2002 to proceed with Yucca Mountain geological repository for 70,000 tonnes used fuel & HLW.

- *Disposing of other radioactive wastes*

Generally, short-lived intermediate-level wastes (mainly from decommissioning reactors) are disposed of through near surface burial while long-lived intermediate-level wastes (from fuel reprocessing) will be disposed of deeper underground. Low-level wastes are also disposed of in near surface burial sites.

A small proportion of low-level liquid wastes from reprocessing plants are discharged to the sea. These include radionuclides which are distinctive, notably technetium-99 (sometimes used as a tracer in environmental studies), which can be discerned many hundreds of kilometres away. However, such discharges are regulated and controlled, and the maximum dose anyone would receive from them is a small fraction of natural background.

Nuclear power stations and reprocessing plants release small quantities of radioactive gases (e.g. krypton-85 and xenon-133) and trace amounts of iodine-131 to the atmosphere. However, they have short half-lives, and the radioactivity in the emissions is diminished by delaying their release. Also, the first two are chemically inert. The net effect is too small to warrant consideration in any life-cycle analysis.

- *Wastes from decommissioning*

In the case of nuclear reactors, about 99% of the radioactivity is associated with the fuel which is removed before invoking decommissioning options. Apart from any surface contamination of plant, the remaining radioactivity comes from 'activation products' in steel components which have been exposed to neutron irradiation for long periods. Their atoms are changed into different isotopes such as iron-55, cobalt-60, nickel-63 and carbon-14. The first two are highly radioactive, emitting gamma rays, but correspondingly with short half-lives so that after 50 years from closedown their hazard is much diminished. Some caesium-137 may also be in decommissioning wastes.

Some scrap material from decommissioning may be recycled, but for uses outside the industry very low clearance levels are applied, so most is buried.

- *Natural precedents for disposal*

Nature has already proven that geological isolation is possible through several natural examples (or 'analogues'). The most significant case occurred almost 2 billion years ago at Oklo in what is now Gabon in West Africa, where at least 17 small natural nuclear reactors operated spontaneously within a rich deposit of uranium ore. Each operated at about 20 kW thermal. (At that time the concentration of U-235 in all natural uranium was about 3.7%). These natural nuclear reactors continued for about 500,000 years before dying away. They produced all the radionuclides found in HLW, including over 5 tonnes of fission products and 1.5 tonnes of plutonium, all of which remained at the site and eventually decayed into non-radioactive elements.

The study of such natural phenomena is important for any assessment of geologic repositories, and is the subject of several international research projects. However, it must be noted that the Oklo reactions proceeded because groundwater was present as a moderator in the 'enriched' and permeable uranium ore. This meant that many radionuclides dissolved in that groundwater. HLW disposal today will be of insoluble materials in corrosion-resistant packaging.

Appendix 7.

The adequacy of social impact assessment, consultation and approval processes with traditional owners and affected Aboriginal people in relation to uranium mining resource projects.

- *The industry seeks to ensure that local and regional communities in particular, benefit from its presence*

Australia's three operating mines were, prior to receiving regulatory approval, subject to extensive assessment processes directed by government which included public input and consultation with communities living in the vicinity of the proposed developments.

In relation to Aboriginal communities, proponents of the mines were required to demonstrate that any potential impacts on cultural heritage were identified and minimised.

In conducting their activities, the operators of the three mines have recognised that the sustainability of their operations is closely linked to the sustainability of their local and regional communities. Accordingly, the mine operators seek to –

- respect cultural diversity and protect cultural heritage
- maintain strong and mutually beneficial relations with local and regional communities based on open and transparent communications
- support local and regional communities in their development and sustainability through sponsorships and company-funded, jointly run programs to provide social benefits in areas such as health, education and the environment
- identify and facilitate opportunities for employment, training and businesses directly and through their contractors

As well as consultative meetings, the operators provide regular information to local and regional communities through annual reports and site-specific web sites.

As a general statement of intent, the industry would assert that it seeks to ensure that local and regional communities in particular, benefit from the industry's presence in any particular area and that its presence is supported rather than imposed.

The Inquiry should pursue questions on this issue with the companies concerned, since the UIC is not their spokesman on matters concerning their operations.

Appendix 8

Health risks to workers and to the public from exposure to ionising radiation from mining

- *There have been more than 40 years of experience in applying international radiation safety regulations at uranium mines*
- *Australian radiation safety regulations today are among the most comprehensive and stringent in the world*
- *Radiation doses at Australian uranium mines are well within regulatory limits*
- *Uranium mining companies have taken active steps to reduce radiation doses wherever and whenever they can, and have voluntarily adopted the most recent international recommendations on dose limits long before they became a regulatory requirement*

Everyone receives a small amount of radiation all the time from natural sources such as cosmic radiation, rocks, soil and air. Uranium mining does not increase this discernably for members of the public, including communities living near uranium mines.

In Australia mining operations are undertaken under the country's Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores, administered by state and territory governments (and applying also to mineral sands operations).

- *The basis of radiation protection standards*

In practice, radiation protection is based on the understanding that small increases over natural levels of exposure are not likely to be harmful but should be kept to a minimum. To put this into practice, the International Commission for Radiological Protection (ICRP) has established recommended standards of protection (both for members of the public and radiation workers) based on three basic principles:

- *Justification.* No practice involving exposure to radiation should be adopted unless it produces a net benefit to those exposed or to society generally
- *Optimisation.* Radiation doses (a dose is the amount of medically significant radiation a person receives) and risks should be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account
- *Limitation.* The exposure of individuals should be subject to dose or risk limits above which the radiation risk would be deemed unacceptable.

These principles apply to the potential for accidental exposures as well as predictable normal exposures.

Underlying these is the application of the 'linear hypothesis' based on the assumption that any level of radiation dose, no matter how low, involves the possibility of risk to human health. This assumption enables 'risk factors' derived from studies of high radiation dose to populations (eg from survivors of the two atom bombs dropped on Japan in 1945) to be used in determining the risk to an individual from low doses. However, the weight of scientific advice does not indicate any cancer risk or immediate effects at doses below about 50 millisieverts (mSv) per year.

Based on these conservative principles, the ICRP recommends that the additional dose above natural background and excluding medical exposure, should be limited to prescribed levels. These are –

- 1 mSv per year for members of the public
- 20 mSv per year averaged over 5 years for radiation workers who are required to work under closely-monitored conditions

The frameworks of radiation safety in countries where most uranium is mined are based on the full adoption of international recommendations.

Radiation dose records compiled by mining companies under the scrutiny of regulatory authorities have shown consistently that mining company employees are not exposed to radiation doses in excess of the limits. In Australia, the maximum dose received is about half of the 20 mSv .per year limit.

Doses are minimised by programs of education and training, as well as engineering design of mining and processing operations.

A number of precautions are taken to protect the health of workers.

Dust is controlled, so as to minimise inhalation of gamma or alpha-emitting minerals. In practice, dust is the main source of radiation exposure in an open cut uranium mine and in the mill area.

Radiation exposure of workers is minimal in an open cut mine because there is sufficient natural ventilation to remove the radon gas. At Ranger, the radon level seldom exceeds one percent of the levels allowable for continuous occupational exposure. In an underground mine a good forced-ventilation system is required to achieve the same result. At Olympic Dam, radiation doses to designated workers in the mine in 2004 averaged 3.7 mSv/year.

Strict hygiene standards are imposed on workers handling uranium oxide concentrate. If it is ingested it has a chemical toxicity similar to that of lead oxide. In effect, the same precautions are taken as in a lead smelter, with use of respiratory protection in particular areas identified by air monitoring. At Olympic Dam, packing uranium oxide concentrate is automated, so no human presence is required.

- *Radiation safety regulation in Australia*

When the current era of uranium mining began in Australia in the 1970s, a review of the regulatory framework for radiation safety was undertaken. This resulted in the production of the 1975 Commonwealth *Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores* (the 'Health Code'). The Health Code was formulated from recommendations made by the ICRP and the radiation dose limits adopted by the National Health and Medical Research Council. (NH&MRC).

The Health Code has legal force in the States and Territories where it is adopted under State and Territory Acts or Regulations.

Responsibilities for administration of the Health Code are held by relevant agencies in the States and Territories. This includes ensuring that the basic radiation exposure standards are complied with, day-to-day oversight of the general occupational health and safety requirements at mine sites, and regular reporting of monitoring results.

In addition to the Health Code there is the *Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores* (1982) – (the 'Waste Code'), and the *Code of Practice for the Safe Transport of Radioactive Substances* (1990). These codes are given legal force in the States and Territories in much the same way as the Health Code.

The Health Code and the Waste Code have been undergoing review through a process co-ordinated by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), and a draft of the new combined Code is published. This will be a combined Code of Practice and Safety Guide.

- *Radiation Protection Standards*

Following recommendations published in 1991 by the ICRP, the NH&MRC and the National Health and Safety Commission jointly prepared new Australian recommendations for limiting exposure to ionising radiation and a National Standard for limiting occupational exposure. These are consistent with the Basic Safety Standards for radiation protection adopted in 1994 by various United Nations Agencies. In the light of emerging scientific knowledge of the effects of low-dose and low dose-rate radiation, they are very conservative and evidently more than adequate.

The revised exposure limit is 20 mSv per year averaged over five consecutive years. Exposure limits for members of the public from radiation-related activities remained at 1 mSv per year, which is less than the average radiation background from the environment.

All Australian mining companies voluntarily agreed to adopt the revised limits without waiting for the imposition of the regulatory requirement to do so.

Appendix 9

History of transporting uranium oxide concentrate for South Australian producers

2000 and prior years – Only one South Australian uranium oxide concentrate (UOC) producer, and two shipping companies available to transport 'Class 7' from Port Adelaide. Charter vessels were used in the early days, and the shipping companies in the last decade.

2001 – Second South Australian UOC producer started contacting shipping companies. Only one shipping company would transport 'Class 7' cargo via East-about fortnightly service from Port Adelaide to Europe. Shipments were transshipped in Europe by specialist freight forwarder also on a limited number of vessels.

2002 - At the end of 2002, the fortnightly service was restructured and rerouted to bypass Port Adelaide. The shipping company planned an alternative route using the new west-about vessels on a three weekly basis, connecting with feeder vessels in Singapore, which discharged in Europe. All west-about vessels were chartered instead of owned by the shipping company. This is common practice for shipping companies to charter vessels instead of owning the whole fleet.

2003 – The vessel owners of the west-about route decided that they would NOT permit 'Class 7' material to be carried on their vessels. This reflects a growing worldwide sentiment following on from September 11 attacks that has resulted in reluctance by many vessel owners' operators and shipping companies to be involved with the carriage of 'Class 7' cargo.

2003 – One shipping company permitted limited containers to be shipped from Adelaide to Singapore and transshipped onto feeder vessels to Europe. This shipping company only has one vessel, which is fully owned (not chartered).

2003 – In May a new direct service between Adelaide and Vancouver began. Two shipping companies out of Port Adelaide would take 'Class 7' out of the five who called into Port Adelaide.

2004 – In February the direct service between Adelaide and Vancouver cancelled its Port Adelaide call entirely. Due to the restriction of moving class 7 cargo between states this route could no longer be used.

2004 – In March the shipping line (Adelaide - Singapore - Europe) service agreed to take extra six 20-foot containers on each sailing.

2004 – In April the vessel was put into dry dock for maintenance and the replacement vessel would not accept 'Class 7' as it was chartered (not owned).

2004 – Due to a shortage of shipping services out of Port Adelaide, UOC producers forced to charter a vessel to take two months stock out of Port Adelaide.

2004 – In June the shipping company reduced the number of slots available for UOC containers by six due to seasonal commodities and over-booking.

2004 – In October 2004 the rail operator between Canada and USA put out an embargo refusing to transport any further 'Class 7' due to lengthy delays experienced. Additional costs forced onto UOC producers to truck UOC shipments instead of using the rail. Some shipments were re-routed to avoid delays.

2004 – In December the shipping company agreed to take the extra six UOC containers back on every four week sailing, however charges were increased by 40 percent.

2005 – In January the shipping company announced their vessel required unscheduled maintenance and needed to go back into dry dock. The replacement vessel could not take 'Class 7' for the February sailing.

2005 – January – March, trials of shipments of 'Class 7' using the services of the Adelaide to Darwin railway over a three-month period began. Forty-eight 'Class 7' containers were transported to and shipped out of Port Darwin.

2005 – In March the (Adelaide - Singapore - Europe) vessel returned from dry dock and services are currently taking 24 'Class 7' 20-foot containers per sailing.

URANIUM INFORMATION CENTRE Ltd.

A.B.N. 30 005 503 828

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To increase Australian public understanding of uranium mining and nuclear electricity generation.

The principal aims of the Centre are:

- To provide information about the development of the Australian uranium industry, the contribution it can make to world energy supplies and the benefits it can bring Australia,
- To be a broker of information on all aspects of the mining and processing of uranium, the nuclear fuel cycle, and the role of nuclear energy in helping to meet world electricity demand,
- To promote an understanding of the role of nuclear energy in relation to other sources of energy, and especially the environmental implications of each..

Activities

The Centre produces and distributes a variety of publications including a weekly news summary (e-mail & web), a bimonthly newsletter, a continually-updated range of Nuclear Issues Briefing papers, and colour information brochures for schools. It also provides material to the news media. Its site on the World Wide Web - **http://www.uic.com.au** is heavily used and widely cited. Since 2001 it has been closely working with the World Nuclear Association, based in London.

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