BHP Billiton

Submission to the Uranium Mining, Processing and Nuclear Power Review

September 2006

Contents

Executive Summary

This document has been prepared as BHP Billiton's submission to the Prime Minister's Taskforce undertaking the current Uranium Mining, Processing and Nuclear Energy Review (UMPNER).

The global market for uranium

As global gas and oil prices have risen and the security of supply of these fuels has become more tenuous, and as greater interest has emerged in restricting future emissions of greenhouse gases (including carbon dioxide produced from the combustion of fossil fuels), interest in nuclear power as a more significant option for generating electricity has increased.

In 2003, nuclear power constituted approximately 17 per cent of the world's electricity. At 30 June 2005, more than 440 nuclear power reactors were in operation in thirty countries (plus Taiwan, China), with a total electrical generating capacity of almost 370 GW. During 2004-05, power reactors produced an electrical output of around 2,600 TWh. By 2015, the total world nuclear generating capacity is expected to be approximately 403 GW, with total energy production at approximately 2,900 TWh.

Countries using Australian uranium to generate electricity avoid carbon dioxide emissions roughly equivalent to Australia's total annual carbon dioxide emissions from all sources.

Demand for new uranium is growing for a number of reasons, the three main ones being:

- New nuclear power plants are being built to meet the rapidly growing needs of large expanding economies. Industry experts predict a 60 per cent increase in global demand for primary uranium over the next 15 years.

- New nuclear technologies and capital cost reductions associated with large generation fleet expansions in Asia are expected to increase the competitiveness and environmental attractiveness of nuclear power generation in some locations, especially where a carbon price has been established.

- Secondary sources of uranium—such as that recovered from decommissioned nuclear weapons—are expected to decline after 2015, and the demand for primary uranium will increase as a result.

Australia has substantial uranium resources and is the world's second largest uranium exporter. As at 1 January 2005, Australia held about 43 per cent of the world's reasonably assured uranium resources recoverable at less than US$40 per kg—by far the highest proportion in the world—and 31 per cent of resources recoverable at less than US$80 per kg. Australia's Ranger and Olympic Dam mines are respectively the world's second largest (11.6 per cent of world uranium production in 2004) and third largest (9.2 per cent) uranium producers. In 2004, Australia exported 11,215 tonnes of uranium ore concentrates valued at A$475 million. This quantity of uranium is sufficient for the annual fuel requirements of approximately 50 reactors (each of 1,000 MW), producing around 380 TWh of electricity in total—some 1.3 times Australia's total electricity production.

However, Australia does not hold a dominant position in the market for primary uranium, which is highly competitive. Canada is the world's largest uranium producer, producing 29 per cent of the world's primary uranium in 2004. The country that promises to become the next major competitor to Australia is Kazakhstan. Kazakhstan has the world's second largest recoverable reserves and the Kazakh government is in full support of the uranium industry and its embrace of foreign direct investment by Asian, Russian and European utilities will give it access to the finance necessary to exploit these reserves. Other countries with major uranium reserves recoverable at less than US$40 per kg include Namibia, South Africa, Uzbekistan, Jordan and Russia, although South Africa and Jordan are not yet significant producers.

To maintain our competitive position, Australia's uranium industry must be responsive to the needs of our customers. In particular, its customers value:

- certainty that they will receive the quantity of uranium they require—secured by long term supply agreements;

- diversification of their risk of non-supply by purchasing uranium from a number of producers; and

- control over their engagement with the fuel cycle to take direct advantage of the competition at each stage of the fuel cycle, to further diversify their supply risks and to satisfy domestic regulatory requirements.

The geopolitical landscape for the global nuclear market is complex and changing as policy makers seek to balance the perceived risks associated with this power source and the energy security and greenhouse benefits it can provide, especially in the light of new and better technologies.

On the long term (2030+) horizon, Generation IV technologies aim to remove the possibility of severe accidents, minimize high level waste, and improve the proliferation resistance of the fuel cycle as well as reducing the demand for raw fuel. Such a prospect has given rise to proposals by the United Kingdom, Russia and the United States, such as the Global Nuclear Energy Partnership (GNEP), that seek to expand the use of nuclear power in developing countries in a manner that promotes non-proliferation, including through fuel leasing.

While policy development should be sensitive to the potential for these developments, and preserve Australia's options, it would be unwise to base domestic or international policy on an assumption that there will be a necessary, or early, radical departure from the status quo. In short, it is important to seize current and foreseeable opportunities and to work hard to maintain and carefully implement existing non-proliferation safeguards, for three main reasons:

- The Australian Government already has a uranium export policy in place, a fundamental tenet of which is that Australia exports uranium only to countries covered by its network of effective bilateral safeguards agreements and the multi-lateral arrangements administered by the International Atomic Energy Agency. These arrangements ensure that Australian uranium is used only for peaceful purposes.

- Export to utilities from these countries does not constitute a proliferation risk and their demand is sufficient to underpin proposed expansions of uranium mining in Australia.

- The successful development of commercially viable fast neutron reactors that can reuse fuel from the current generation of reactors and the negotiation of revisions to global non-proliferation arrangements is critical to the success of the GNEP and like initiatives. The active deployment of these technologies and a revised international system for managing the fuel cycle will take some decades from the current date, and there is a risk that it might fail to occur.

The emergence of climate change as another major public policy issues on a global scale has done an enormous amount to change attitudes towards the use of nuclear power generation. Australia's greenhouse policies need to be developed in a national and global context. The greenhouse gas debate is bigger than the nuclear debate. Policies need to recognise that greenhouse reductions will occur in the countries where the fuel is used, not where it is mined and milled, and that any national greenhouse gas emissions trading scheme that is introduced in advance of more comprehensive international greenhouse frameworks runs a serious risk of merely driving trade exposed energy intensive activity to countries that do not have the same obligations if it fails to deal effectively, efficiently, speedily and in a manner that is clearly World Trade Organisation compliant with the competitive disadvantage it would place on export industries.

Given the scale of the investment in power generation necessary to underpin the nationally important Olympic Dam expansion project, it is vital that the prevailing uncertainty in greenhouse policies be resolved as soon as possible so that this project can proceed in a timely manner to provide a net global greenhouse benefit through the export of uranium.

Olympic Dam and its proposed expansion

Olympic Dam became part of the BHP Billiton Base Metals business in 2005 when BHP Billiton acquired Western Mining Corporation.

Copper is currently the primary business at Olympic Dam. Uranium, gold and silver are valuable associated products. As at 31 December 2004, proved and provable ore reserves totalled 761 million tonnes, at 1.5 per cent copper, 0.6 kg per tonne of U_3O_8, and 0.5 grams per tonne of gold. The grades of uranium in the ground at Olympic Dam would not support a uranium mine in its own right.

The performance of Olympic Dam as a mine and as a focus of social and environmental responsibility has been very good. Major achievements have included:

- establishment of Australia's largest underground mine currently employing 3,000 people;

- development and continuous expansion of a very complex mining and minerals processing operation;

- a reputation with international customers for quality and reliability of product supply;

- rigorous safety standards and a safety record better than the industry average;

- average radiation exposures to employees well under half of the international limit;

- maintaining a strong commitment to environmental management including demonstrating that mining and effective land management can coexist through the pioneering Arid Recovery Program; and

- agreements with Aboriginal groups to protect heritage and support their community development aspirations.

Olympic Dam has been a great success for Australia economically and environmentally, and BHP Billiton is considering a major opportunity to substantially increase its benefits.

The Olympic Dam expansion project is now being subjected to pre-feasibility study, which in itself is a major 2-year commitment by this company. The pre-feasibility study is expected to be complete in 2007 and the feasibility study in 2008. The construction phase of the expansion would take about 4 years with operation at the expanded capacity beginning in 2013; ramping up to full production in 2014.

If it goes ahead, the Olympic Dam expansion project would involve a new open pit located adjacent to the existing Olympic Dam operation, and BHP Billiton expects that it would more than double the mine's output (double copper and treble uranium output) and substantially increase its demand for energy, water, transportation and labour. An important feature of the expansion is that the increased production of copper and uranium would become of equal importance in value terms.

The Olympic Dam expansion would bring major new economic benefits to the State of South Australia in terms of employment, population and gross state product as shown in Table E.1.

Table E.1

BENEFITS TO SOUTH AUSTRALIA

		Current		**Proposed (draft estimates)**
Permanent jobs	BHP Billiton	3.000	BHP Billiton	~4,000
	State-wide	15,000	State-wide	~20,000
Roxby Downs population		4,200		8,000 – 10,000
Location of workforce	Roxby Downs	80%	Roxby Downs	85%
	FIFO/DIDO	20%	FIFO/DIDO	15%
Construction jobs	Minor works		On site average	5,000
			State-wide	~7,300
Gross State Product (per year)		A$1 billion		~A$2.5 billion

BHP Billiton is preparing an Environmental Impact Statement (EIS) in accordance with guidelines set down by the Commonwealth Department of Environment and Heritage and

Planning SA as part of its pre-feasibility study, and is carefully working through the environment, infrastructure and social impact of the project with the community and government agencies.

The Olympic Dam expansion is a major economic opportunity for Australia and South Australia. While primarily a copper mine, it will also make a contribution important on a global scale to the production of U_3O_8 with a concomitant opportunity to treble the export of uranium from Olympic Dam to 15,000 tonnes and thus reduce the global growth in greenhouse gas emissions. However, the project is not inevitable. The Olympic Dam expansion faces significant potential competition from alternative suppliers of each of the principal product streams, and BHP Billiton will need to consider carefully the outtakes of the EIS process.

Accordingly, while it is important that Australia has an informed debate about future options in relation to its fuller participation in the nuclear cycle, any significant delay in securing planning, environmental and export approvals could put the Olympic Dam expansion project at risk. The Olympic Dam expansion is an export driven project. It is in no way dependent on or planned to facilitate domestic nuclear conversion, enrichment, power generation or spent fuel disposal.

Involvement in front-end and back-end processing

Proposals are being brought forward for Australia to move beyond mining and milling to participate in fuel leasing schemes that involve an integrated offering of front-end (conversion, enrichment and fuel fabrication) and back-end (high level waste processing and disposal) processing. These proposals are argued by their proponents to offer security (non-proliferation) advantages, to be consistent with the United States' GNEP proposals and to be highly attractive on a commercial basis**.**

> **BHP Billiton believes that there is neither a commercial nor a non-proliferation case for it to become involved in front-end processing or the development of fuel leasing services in Australia.**

The global market is currently well supplied by services providers with strong customer relationships, economies of scale and scope, the necessary deep technological expertise and experience, solid reputations for delivery, and expansion plans in place. BHP Billiton has deliberately focused its skills and energies on its core global role in mining and concentration of minerals.

> **Consequently, BHP Billiton's strategy is not to enter the front-end processing market—nor indeed does it have the depth of technological skills and precision engineering manufacturing experience to do so. BHP Billiton's uranium strategy focuses on its strengths as a miner and mineral exporter.**

Some commercial interests have also suggested that GNEP provides an opportunity and almost an obligation for Australia—and hence BHP Billiton and the other miners operating in Australia—to *immediately* adopt a policy of providing a bundled service of conversion, enrichment, fabrication, fuel leasing and waste disposal in preference to the current customer driven preference for the export of U_3O_8 subject to rigorous safeguards agreements. In response to these suggestions, BHP Billiton makes the following observations:

- GNEP (or alternative Russian and British proposals) and the technology on which it depends is decades away from practical implementation and faces very significant technical, commercial and diplomatic hurdles and risks. On the other hand Olympic Dam offers the prospect of enhanced supplies of a low greenhouse emission fuel source to proliferation safe markets within 10 years with key decisions required over the next twelve to twenty four months.

- Any development of a conversion and enrichment capability in Australia will need to clear significant regulatory, diplomatic, and public perception hurdles as well provide a commercial return. We do not believe that conversion and enrichment would be commercially viable in Australia for the foreseeable future. Fuel leasing would face still higher commercial barriers.

- We strongly doubt the acceptability of any government or commercially imposed requirement to lease fuel, as distinct from acquiring uranium, to our major customers, all of whom are highly respected utilities in countries with which Australia has rigorous safeguards agreements, and who have choices about where to acquire their U_3O_8. These utilities generally regard their spent fuel as an asset—a resource for future reprocessing to produce more fuel input. Long term supply arrangements with these utilities are necessary to underpin a commercial decision to proceed with the Olympic Dam expansion.

- Since BHP Billiton does not and will not sell uranium to nations whose activities motivated proposals such as GNEP in the first place, the adoption of such proposals is not a prerequisite for the continuation of Australia's successful track record of non-proliferation safeguards.

- Current and proposed U_3O_8 exports under bilateral safeguards arrangements insisted on by the Australian government are not a source of proliferation risk—nor are the utilities whose energy needs underpin the financial viability of BHP Billiton's current and proposed mining operations.

- In short, insistence in the foreseeable future on a mandatory Australian fuel leasing program in the interests of non-proliferation is an attempt to solve a problem that Australia has had no role in creating and to do it in a way that raises considerable commercial (and national economic) risks.

We believe that any requirement to use Australian fuel leasing and spent fuel disposal services as a condition of access to Olympic Dam concentrates would be unacceptable to BHP Billiton's core customers—both because of customers' need to control their engagement with the fuel cycle for commercial and regulatory reasons and because they regard their spent fuel as an important asset. They have many possible alternative sources of supply of concentrates.

Thus any proposal for current or future mandatory fuel leasing as condition of access to Olympic Dam uranium concentrates could put the expansion project at risk.

Domestic nuclear power generation

Although whether Australia wishes to embrace a domestic nuclear power sector is a matter for governments, the following observations might , be of interest to the Taskforce.

Australia has a diverse and competitive electricity generation market underpinned by transparent market rules and industry regulation. Its most outstanding characteristic is that it produces some of the cheapest and most reliable power available anywhere in the world. Together with resource endowments this has led the Australian economy to become a globally significant supplier of many energy intensive products.

The electricity markets in Australia are renowned for their effective market operation and their clear market signals to encourage efficient investment. The Australian market structure helps ensure that only cost-competitive generators are profitable. Under current circumstances, nuclear generation would not be cost-competitive with existing or anticipated new generation assets.

Based upon a review of the literature, and on recent political and regulatory development, nuclear power is not likely to be cheaper than electricity from coal or gas fired plants, in the absence of significant carbon taxes in markets like Australia unless capital costs can be driven down. Many papers suggesting that nuclear power is now economical rely heavily upon some form of carbon tax or subsidy to offset the cost disadvantage of nuclear relative to fossil fuels.

At a sufficiently high carbon tax, nuclear can become more attractive than electricity from either coal or gas, and, depending on market characteristics, it can be more attractive particularly for base load power than other options including “clean coal” and renewable technologies.

However in Australia, nuclear power plants would face higher competitive barriers than in major North American, European and Asian markets including:

- significantly lower costs for electricity and lower non-greenhouse air pollution impacts (particles, SO_2 and NOX) from competing coal-fired power plants than in the United States, Europe and Asia where nuclear generation has greater comparative advantages (nuclear power has considerable attractions in markets which suffer severe air pollution contributed to by old or inefficient coal fired plant);

- a relatively small overall electricity market that would naturally limit the ultimate number of nuclear plants to a handful and would introduce additional challenges in integrating even a single conventionally-sized plant—that is 1,000+ MW—into the system;

- the lack of an existing regulatory structure for nuclear power, leading to significant regulatory (and political) establishment costs that would be spread over a very small number of plants for quite some time; and

- a lack of skilled personnel with experience building and operating nuclear power plants.

While nuclear power can offer greenhouse benefits (at a cost) and new technologies offer high levels of safety, any decision to develop nuclear power generation in Australia is a matter for governments. The efficiency of the Australian energy market is impressive - if this is to be maintained, it is important that future additions to the generator stock are based on competitive commercial considerations. BHP Billiton has no intention of entering the nuclear power generation market and its potential investment in the expansion of the Olympic Dam project is not dependent in any sense on the establishment of a domestic nuclear power industry.

Product stewardship

BHP Billiton takes corporate responsibility very seriously. It underpins our social licence to operate and upholds the company's global reputation. Our product stewardship program is a key component of the company's activities in this area, as evidenced by our actions to expand product stewardship across all our products, and in leading moves to develop an internationally endorsed product stewardship model for uranium.

Maintaining public acceptance of a vibrant uranium concentrates export industry is vital to underpin the economic and greenhouse contribution that the uranium mining industry can make. Any significant accident or failure in any uranium mine that damages the environment or public health—or any failure to deal fairly with indigenous and other communities—will impact on the public's attitude to all mines.

> **BHP Billiton therefore underlines the importance of world's best health, safety, environmental, indigenous, community and safeguards arrangements for all Australian uranium mines and exports– an obligation on all governments and all uranium miners.**

On an international level, BHP Billiton has taken a leading role as part of the World Nuclear Association and Australia's Uranium Industry Framework. BHP Billiton strongly supports the Minerals Council of Australia's current recommendation to the UMPNER that the Australian uranium mining industry establish uranium stewardship approaches through the World Nuclear Association and other relevant international forums, and applies the outcomes to its operations, recognising that those operations are limited to the mining of uranium, production and transport of uranium oxide concentrate and management of radioactive waste in the form of tailings produced from those operations.

There is a core responsibility on all governments involved in the approval and regulatory oversight of each step in the chain to ensure that the relevant parties exercise their responsibilities to avoid proliferation, to protect the environment and human health, and to avoid accident. BHP Billiton is confident that arrangements put in place by the Australian Government and the relevant State and Territory governments do that successfully and provide an important part of the critical governance framework within which the industry stewardship initiative can make a contribution.

Chapter 1

The global market for uranium

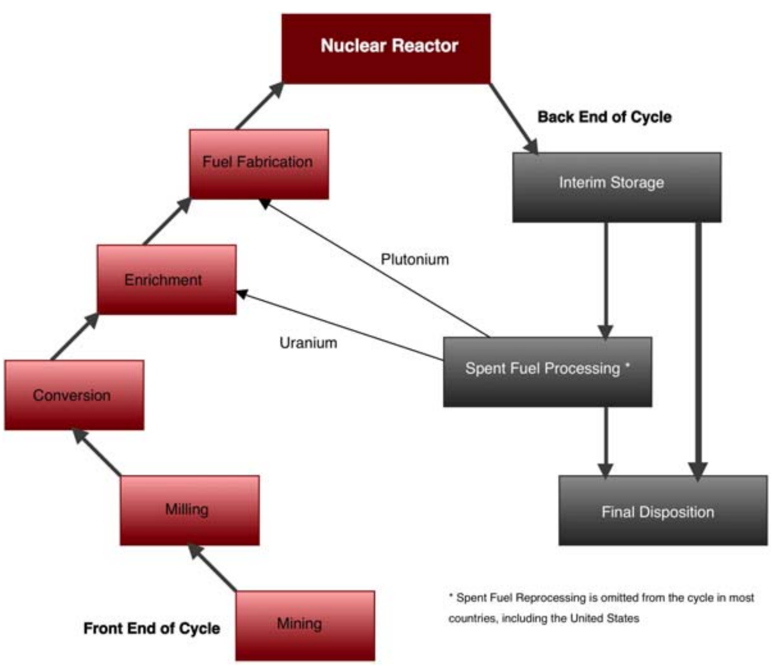
1.1 The nuclear fuel cycle

The nuclear fuel cycle (illustrated below in Figure 1.1) is comprised of the following steps:

- Uranium mining and milling, leading to the production of uranium oxide (U_3O_8);
- Conversion of U_3O_8 to uranium hexafluoride (UF_6);
- Enrichment of the levels of the isotope uranium 235 (U235) to approximately 3-5 per cent from the naturally occurring levels of 0.71 per cent;
- Fabrication of nuclear fuel assemblies for delivery to nuclear power stations;
- Generation of electricity at the nuclear power station that uses nuclear fuel for heat; and
- Treatment and ultimate disposal of the spent nuclear fuel (either through reprocessing or direct disposal of the spent fuel).

Figure 1.1

NUCLEAR FUEL CYCLE



Source: http://www.eia.doe.gov/cneaf/nuclear/page/intro.html.

1.2 Nuclear power industry globally

As global gas and oil prices have risen and the security of supply of these fuels has become more tenuous, and as greater interest has emerged in restricting future emissions of greenhouse gases (including carbon dioxide produced from the combustion of fossil fuels), interest in nuclear power as an option for generating electricity has increased.

In 2003, nuclear power constituted approximately 17 per cent of the world's electricity.[1] At 30 June 2005, more than 440 nuclear power reactors were in operation in thirty countries (plus Taiwan, China), with a total electrical generating capacity of almost 370 GW. During 2004-05, power reactors produced an electrical output of around 2,600 TWh. By 2015, the total world nuclear generating capacity is expected to be approximately 403 GW,[2] with total energy production at approximately 2,900 TWh.[3] Around the world, seven new reactors started up during 2003 and 2004, and eleven retired.

While the proportion of the world's electricity provided by nuclear power is expected to fall marginally over time, particularly in the West, the absolute amount of nuclear power generation is projected to increase, particularly in the East. This reflects the strong growth in overall energy demand, mostly in the emerging mega economies of Asia.

Strong nuclear construction programs are underway in China, Japan and Korea, and India is also expected to add to its fleet of nuclear plants.

In the United States and internationally, several initiatives to evaluate and promote expanded use of nuclear power are underway. These initiatives range (in terms of time horizons) from the US Nuclear Regulatory Commission's current efforts to provide an opportunity for streamlined licensing and permitting for nuclear plant that might be licensed within the next few years to the Generation IV International Form[4], which is focused on nuclear power technologies with target commercialisation dates of "before 2030". In time, these initiatives might arrest the forecast decline in the proportion of global power provided from nuclear sources, particularly if greenhouse and fuel security concerns continue to increase.

The commercial viability of nuclear power is dependent on the cost of alternative power sources and the capital cost of the construction of nuclear generation sets. In economies with high power costs arising from poor access to cheap fossil fuels, large scale hydro or geothermal power, nuclear power can provide a commercially attractive form of base load generation as part of an energy portfolio. It is possible that this competitiveness could be further enhanced in countries like China with large scale build programs which could result in lower capital costs for generation sets. In economies such as Australia and North America, which have access to plentiful low cost coal based power generation, nuclear options are not, and are less likely to be, commercial—that is, without a subsidy—unless some form of carbon price is placed on competing fossil fuels. Of course, as we discuss later in section 4.3, any such carbon price would increase the attractiveness of energy conservation and other low

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[1] Energy Information Administration 2006, *International Energy Outlook: 2006*, June, Tables A9 (14,781 TWh total global electricity consumption) and F11 (2,523 TWh of nuclear electricity production).

[2] ibid., Table F5.

[3] ibid., Table F11.

[4] http://gif.inel.gov/

emission power generation technologies (including carbon capture and storage for fossil fuels, and power sourced from "renewable" sources such as wind, biomass and geothermal). The best current estimates suggest that nuclear power could be competitive with many of these other low emission sources but that will be influenced by the rate of technological development in each of the sectors as well as locational factors. The unavoidable effect of a carbon price would be to increase the cost of electricity with particular implications for the energy intensive, trade exposed sectors of the economy.

1.3 Demand for uranium

Uranium is used in more than 440 nuclear reactors around the world. Demand is heavily concentrated along the east coast of the United States, Western Europe, South Korea and Japan. Producers of U_3O_8 deliver the product to conversion facilities in Canada, the US or Europe where the buyer takes ownership. The United States is the world's largest market and France is, with 78 per cent share of nuclear for their power production, the most reliant on supplies.

Countries using Australian uranium to generate electricity avoid carbon dioxide emissions roughly equivalent to all Australia's annual carbon dioxide emissions from all sources.[5]

Demand for new uranium is growing for a number of reasons, the three main ones being:

- Increasing demand for electricity – New nuclear power plants are being built to meet the rapidly growing needs of large expanding economies. There are 26 new reactors already under construction. The expected growth in the reactor fleet is mainly concentrated in Asia especially in Japan, South Korea, China and India. Industry experts predict a 60 per cent increase in global demand for primary uranium over the next 15 years.[6]

- Lower cost nuclear technologies – New nuclear technologies and capital cost reductions associated with large generation fleet expansions in Asia are expected to increase the competitiveness and environmental attractiveness of nuclear power generation in some locations, especially where a carbon price has been established (see section 4.2 for more discussion on this).

- Declining secondary sources – Secondary sources of uranium—such as that recovered from decommissioned nuclear weapons—are expected to decline after 2015, and the demand for primary uranium will increase as a result. Most significantly, under an agreement between Russia and the United States in 1993, highly enriched uranium (HEU) from nuclear weapons is being blended down to low-enriched uranium that can be sold to commercial nuclear power producers. In September 2005, the governments of the United States and Russia issued a joint statement acknowledging that the implementation of the HEU purchase agreement had achieved its halfway point with 250 tonnes of HEU having been down-blended.

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[5] Australian Safeguards and Non Proliferation Office 2004, *ASNO Annual Report 2004-2005*, p. 23.

[6] World Nuclear Association 2005, *The Global Nuclear Fuel Market, supply and demand 2005-2030*.

The Minerals Council of Australia's (MCA's) submission[7] to UMPNER presents more detail of the about the growing use of nuclear power and the global demand for uranium. BHP Billiton endorses the figures presented by the MCA and refers the taskforce to this submission for additional detail.

1.4 Sources of primary uranium

(a) Australia

As at 1 January 2005, Australia held about 43 per cent of the world's reasonably assured uranium resources recoverable at less than US$40 per kg—by far the highest proportion in the world—and 31 per cent of resources recoverable at less than US$80 per kg. Australia's Ranger and Olympic Dam mines are respectively the world's second largest (11.6 per cent of world uranium production in 2004) and third largest (9.2 per cent) uranium producers.

Australia is the world's second largest uranium exporter. In 2004, it exported 11,215 tonnes of uranium ore concentrates valued at A$475 million.[8] This quantity of uranium is sufficient for the annual fuel requirements of approximately 50 reactors (each of 1,000 MW), producing around 380 TWh of electricity in total—some 1.3 times Australia's total electricity production[9]. Australia's uranium supplied nuclear power stations which generated about 2 per cent of total world electricity production.

A significant share of the increased demand for primary uranium could be sourced from an expanded Olympic Dam (see section 2.2), especially after the ratification of the bilateral agreement between China and Australia that will allow the export of uranium to China. This agreement is currently before the Joint Standing Committee on Treaties of the Commonwealth Parliament.

(b) Other sources of primary uranium

Canada is the world's largest uranium producer, producing 29 per cent of the world's primary uranium in 2004. Its reserves are lower than Australia: as at 1 January 2005, Canada held about 10 per cent of the world's reasonably assured uranium resources recoverable at less than US$40 per kg.

The country that promises to become the next major competitor to Australia is Kazakhstan. Kazakhstan has the world's second largest recoverable reserves and the Kazakh government is in full support of the uranium industry. Its licensing and permitting process is relatively short when compared with the Canadian and Australian approval process. Kazakhstan already produces 9 per cent of the world's uranium and its production could reach 15,000 tonnes per year of U_3O_8 by 2025. Much of that expansion will be financed by direct equity investments by customers from Russia and Asia which is encouraged by the Kazakh government.

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[7] Minerals Council of Australia 2006, *Submission: Review of Uranium Mining, processing and nuclear energy in Australia*, August, pp. 1-4.

[8] Australian Safeguards and Non Proliferation Office 2004, *ASNO Annual Report 2004-2005*, p. 23.

[9] Australia's national electricity generation was 284.37 TWh in 2004-05: IEA 2006, *Electricity information*, July, p. I.32-3.

Other countries with major uranium reserves recoverable at less than US$40 per kg include Namibia, South Africa, Uzbekistan, Jordan and Russia, although South Africa and Jordan not yet significant producers.

1.5 The needs of uranium customers

Our customers are typically large utilities with an integrated electricity generation portfolio consisting of coal, gas nuclear and renewables. They have made (or plan to make) major capital investments in long-lived and large scale power generation plants, and they have an intense interest in long term security of uranium supply and price to underpin both their financing and their system stability and reliability requirements. They achieve these objectives by using the following arrangements:

- Long term supply agreements with uranium producers – Customers need certainty that they will receive the quantity of uranium they require so they seek long term supply agreements. Some uranium is traded on a spot market, but this is a small proportion of overall trade.

- Diversity of the supply base – Customers diversify their risk of non-supply by purchasing uranium from a number of producers. The majority of our customers have indicated that the maximum volume of uranium that they would purchase from one source is 25-30 per cent of their total requirement.

- Control over their engagement with the fuel cycle – Our utility customers purchase uranium directly from uranium producers and make their own arrangements to toll the material through conversion and enrichment facilities. This enables them to take direct advantage of the competition at each stage of the fuel cycle: among uranium producers, among suppliers of conversion services, and among enrichment plants. It also enables them to further diversify their supply risks. Each customer has close long term relationships with particular fabrication facilities that create fuel rods strictly in accordance with its precise specifications (which can be plant specific) and the requirements of its domestic safety regulator. There are high technical and regulatory costs in establishing these relationships and most fuel fabricators will have supply agreements with a limited number of utilities. In many cases customers regard spent fuel as an asset to be held for re-processing as economic technologies become available.

These arrangements also align with BHP Billiton's objectives. We have a strong need for long term price and quantity certainty, underpinned by long term supply agreements and concomitant export approvals to underpin major investments such as the Olympic Dam expansion.

The implication of these arrangements is that it is difficult to use control over even a significant proportion of uranium resources to extract rents from later stages in the nuclear fuel cycle. Utilities, the ultimate customers, will be very alert to any exposure to loss of spent fuel assets and risk—commercial, security of supply, and regulatory—arising from loss of control over, and narrowing of their choices with respect to conversion, enrichment, fabrication and eventually reprocessing services. While Australia and the Olympic Dam project are important suppliers of uranium on the global scale, they are not without significant and potentially growing competition that will limit the ability of any entity to extract rents from any stage of the nuclear fuel cycle.

1.6 Geopolitical context

The nuclear fuel cycle has always attracted close attention at the national and international scale because of the perceived risks associated with this power source. These risks include:

- risks associated with diversion of nuclear fuels to weapons manufacture (including current concerns regarding “rogue states”, or through the use of waste in “dirty bombs” by terrorist groups);

- major accidents with resulting human health and environmental impacts potentially over a broad area; and

- containment and safe storage and disposal of long lived radioactive waste.

These risks must be balanced against the potential greenhouse and air pollution benefits arising from the contribution of nuclear power, particularly in the growing mega-economies of Asia and Latin America.

The balance of these risks and benefits will be influenced by the prospective technology developments on the horizon.

(a) Technological drivers

Due to the high capital cost of constructing nuclear power plants, the existing fleet of plants is expected to operate through to the end of their useful lives. Thus, most of the demand for nuclear fuel for a long period of time will be driven by technology that is already in place. Improvements in reactor designs will be realized, but only as and to the extent which new nuclear plants are placed into service.

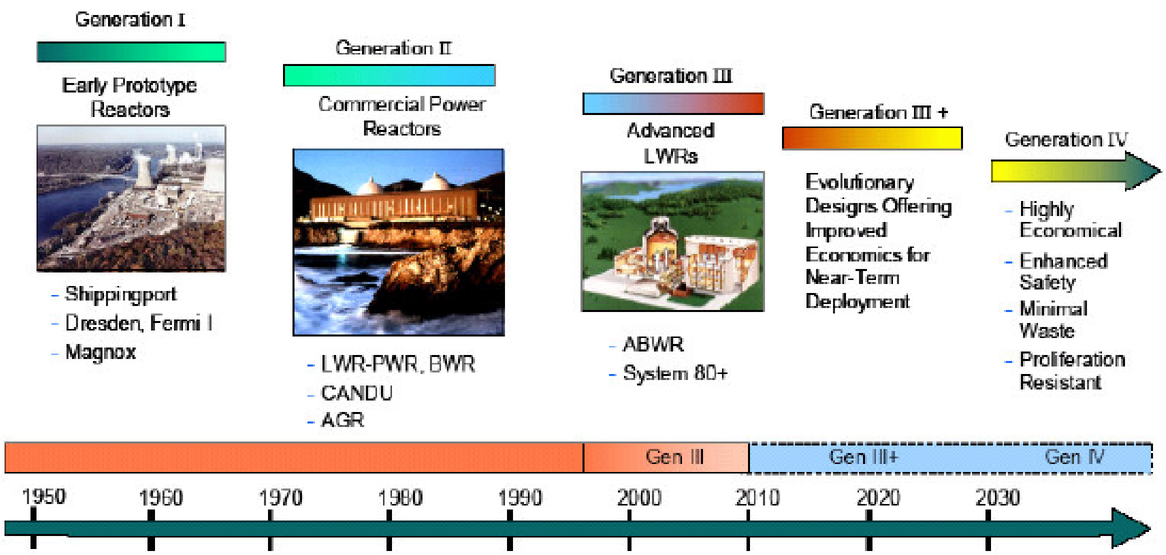
Regarding expected design improvements, current (Generation I to III) reactors are likely to be supplemented and in time ultimately replaced by plants with improved economics, more fail safe and simpler safety systems, and a capacity to limit the impact of even severe failures to the immediate neighbourhood of the plant. The first of these—Generation III+ advanced reactors—are likely to begin to be deployed over the period 2010–2020.[10]

Figure 1.2 illustrates the evolution of nuclear power systems from Generation I commercial reactors in 1950s up to the future Generation IV systems which could begin to be placed into service after about 2030.

[10] US Department of Energy Research Advisory Committee and the Generation-IV International Forum, 2002, *A Technology Roadmap for Generation IV Nuclear Energy Systems*, December. p. 5.

Figure 1.2

EVOLUTION OF NUCLEAR POWER SYSTEMS



Source: US Department of Energy Research Advisory Committee and the Generation-IV International Forum 2002, *A Technology Roadmap for Generation IV Nuclear Energy Systems*, December, p. 5.

Notes: LWR = light-water reactor; PWR = Pressurized water reactor; BWR = boiling-water reactor; ABWR = advanced boiling-water reactor; CANDU = Canada Deuterium Uranium.

The next generation of designs are being developed in substantial part through the Generation-IV International Forum (GIF, a group of ten nations plus the European Union and co-ordinated by Unite States Department of Energy) and the International Atomic Energy Agency (IAEA) coordinated International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO). Generation IV technologies aim to remove the possibility of severe accidents, minimize high level waste (HLW), and improve the proliferation resistance of the fuel cycle as well as reducing the demand for raw fuel.

The successful development of commercially viable fast neutron reactors that can reuse fuel from the current generation of reactors is critical to the success of the Generation IV initiatives. New international protocols to reduce the proliferation risk of the nuclear fuel cycle through mechanisms that strengthen constraints over the global deployment of enrichment and reprocessing capabilities are also needed. The scientific and technical risks in developing the entire suite of required technologies, and the diplomatic and economic complexities that would underpin their eventual deployment within a more proliferation resistant fuel cycle, are considerable. There is little commercial incentive to invest in their development and the track record of governments in maintaining support for research and development on the scale required is not good. The active deployment of these technologies and a revised international system for managing the fuel cycle will take some decades from the current date, and there is a risk that it might fail to occur.

While policy development should be sensitive to the potential for these developments, and preserve Australia's options, it would be unwise to base domestic or international policy on an assumption that there will be a necessary, or early, radical departure from the status quo. In short, it is important to seize current and foreseeable opportunities and to work hard to maintain and carefully implement existing non-proliferation safeguards. We elaborate on this point in subsequent sections of this submission.

(b) Energy security

For countries with a high dependence on oil and gas for power generation recent resource and geopolitical trends have raised the interest in broadening their energy base to underpin energy security. In particular growing global demand for liquid fuels and gas, intersecting with constraints on supply (arising from natural disasters, instability in the Middle East and Russian influence on supply of gas to much of Europe) has led to sharp price spikes and the risk of actual disruption to supplies. In these markets nuclear energy for base load power generation provides a highly secure and reliable energy source and acts as a competitive foil to higher priced fossil fuels. In the longer term there is considerable interest in the development of hydrogen powered fuel cells as a means of dealing with energy and greenhouse risks in transport, and nuclear power offers a low greenhouse emissions energy source for the creation of hydrogen on the scale required.

(c) Safeguards and stewardship

The global community, stakeholders and governments in Australia, and BHP Billiton are all concerned at ensuring that uranium mined in Australia is transported and stored safely, and used solely for peaceful purposes. Maintaining public acceptance of a vibrant uranium concentrates export industry is vital to underpin the economic and greenhouse contribution that the uranium mining industry can make. Any significant accident or failure in any uranium mine that damages the environment or public health—or any failure to deal fairly with indigenous and other communities—will impact on the public's attitude to all mines. BHP Billiton therefore underlines the importance of world's best health, safety, environmental, indigenous, community and safeguards arrangements for all Australian uranium mines and exports—an obligation on all governments and all uranium miners.

On an international scale, substantial non-proliferation safeguards are already in place.

All U_3O_8 sold by Australian uranium mines is subject to comprehensive international nuclear non-proliferation safeguards administered by the IAEA and the Australian Safeguards and Non-Proliferation Office (ASNO). The IAEA was established by the United Nations in 1957 and is responsible for the safeguards programs associated with the Nuclear Non-Proliferation Treaty (NPT).

A fundamental tenet of the Australian Government's uranium policy is that Australia exports uranium only to countries covered by its network of bilateral safeguards agreements.[11] These agreements place obligations on the bilateral partner relating to nuclear material which is subject to the provisions of the particular bilateral agreement, known as Australian obligated nuclear material (AONM). Moreover, these obligations apply to uranium as it moves through

[11] Australian Safeguards and Non Proliferation Office 2004, *ASNO Annual Report 2004-2005*, p. 24.

the different stages of the nuclear fuel cycle as well as to material generated through the use of that uranium.

Australia carefully selects the countries with which it will conclude a bilateral safeguards agreement. In the case of non-nuclear weapon states (NNWS), it is a minimum requirement that IAEA safeguards apply to all existing and future nuclear activities in that country. In the case of nuclear weapon states (NWS), there must be a treaty-level assurance that AONM will be used only for peaceful purposes and AONM must be covered by safeguards arrangements under that country's safeguards agreement with the IAEA.

Australia currently has 19 nuclear cooperation agreements covering 36 countries. These bilateral safeguards agreements serve as a mechanism for applying IAEA safeguards and various supplementary conditions. These requirements ensure that AONM is appropriately accounted for as it moves through the nuclear fuel cycle, is used only for peaceful purposes in accordance with the applicable agreements, and in no way enhances or contributes to any military process. In the context of Australia's bilateral safeguards agreements, military purpose means: nuclear weapons; any nuclear explosive device; military nuclear reactors; military propulsion; and depleted uranium munitions. A summary of Australia's uranium export policy in given in Box 1.1.

Box 1.1

SUMMARY OF AUSTRALIA'S URANIUM EXPORT POLICY

- Australian uranium may only be exported for peaceful non-explosive purposes under Australia's network of bilateral safeguards Agreements, which provide for:
  - coverage of uranium exports by 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 to a third party, for any enrichment beyond 20 per cent of uranium-235 and for reprocessing of AONM, and
  - physical security requirements;
- Australia retains the right to be selective as to the countries with which it is prepared to conclude safeguards arrangements;
- non-nuclear weapon state customer countries must at a minimum be a party to the NPT and have concluded a full-scope safeguards Agreement with the IAEA;
- nuclear weapon state customer countries must provide an assurance that AONM will not be diverted to non-peaceful or explosive uses and accept coverage of AONM by IAEA safeguards; and
- commercial contracts for export of Australian uranium should include a clause noting that the contract is subject to the relevant bilateral safeguards arrangement.
- as announced by the Minister for Foreign Affairs on 4 May 2005, Australia is further tightening its export policy by making an additional protocol with the IAEA (providing for strengthened safeguards) a pre-condition for the supply of Australian obligated uranium to non-nuclear weapon states.

Source: http://www.dfat.gov.au/security/aus_uran_exp_policy.html

Thus, while BHP Billiton's formal involvement with any particular uranium product ends with the delivery of that product to our customers, the bilateral arrangements provide strong mechanisms to ensure that uranium we supply will be used in accordance with those obligations.

BHP Billiton strongly supports this stance. In particular, it notes the bi-partisan support for the negotiation of the most recent bilateral safeguards agreements—the Australia-China Nuclear Material Transfer Agreement and Nuclear Cooperation Agreement—which are currently before the Joint Standing Committee on Treaties of the Australian Parliament for public hearings, consideration and advice to the Australian Government in relation to their ratification. These agreements comply fully with Australian safeguard conditions ensuring that AONM is used exclusively for peaceful purposes as it is under the same type of agreements with the United States, the United Kingdom, France and Russia.[12] When ratified by both countries, BHP Billiton is confident that these agreements, together with the existing agreements with other countries (in a number of cases proposed enhancements are also before Joint Standing Committee on Treaties) will provide a sound, proliferation proof basis for the export of uranium from its Australian operations.

While BHP Billiton believes that the current Australian approach is sound it notes that there is some international discussion around the prospects of improving safeguards through controlling the nuclear fuel cycle more tightly through restricting access to enrichment capacity.

These proposals have arisen in the context of concern about the potential development of nuclear weapons by states which may be signatories of the NPT or other "rogue" states. Proposals have been floated by the United Kingdom, Russia and the United States. Of these proposals, the best known is the Global Nuclear Energy Partnership (GNEP) advanced by the United States. It aims to provide a basis for much greater use of nuclear energy in the longer term while improving proliferation resistance through the containment of enrichment capabilities to a small group of countries.

Box 1.2

GLOBAL NUCLEAR ENERGY PARTNERSHIP

As part of President Bush's Advanced Energy Initiative, the Global Nuclear Energy Partnership (GNEP) seeks to develop worldwide consensus on enabling expanded use of economical, carbon-free nuclear energy to meet growing electricity demand. This will use a nuclear fuel cycle that enhances energy security, while promoting non-proliferation. It would achieve its goal by having nations with secure, advanced nuclear capabilities provide fuel services — fresh fuel and recovery of used fuel — to other nations who agree to employ nuclear energy for power generation purposes only. The closed fuel cycle model envisioned by this partnership requires development and deployment of technologies that enable recycling and consumption of long-lived radioactive waste.

The Partnership would demonstrate the critical technologies needed to change the way used nuclear fuel is managed – to build recycling technologies that enhance energy security in a safe and environmentally responsible manner, while simultaneously promoting non-proliferation.

Source: http://www.gnep.energy.gov/

[12] Minister for Foreign Affairs 2005, *Submission to the House of Representatives Standing Committee on Industry and Resources*, 3 May,

In Chapter 3, we discuss Australia's greater involvement in the nuclear fuel cycle and underline BHP Billiton's position that it wishes to remain involved as a mining company but not to be further involved in the cycle.

BHP Billiton has developed a comprehensive stewardship model through which it communicates how it manages its responsibility for its uranium product and its concerns for the whole fuel cycle. The model is described in Chapter 5.

(d) Greenhouse – International contribution

The emergence of climate change as a major public policy issues on a global scale has done an enormous amount to change attitudes towards the use of nuclear power generation.

Australia's principal current and probable future contribution is likely to be through the export of uranium which is converted, enriched, fabricated and used overseas. As we mentioned earlier, Australian uranium supplies about 2 per cent of total world electricity production. Countries using Australian uranium thus avoid direct carbon dioxide emissions from power production roughly equivalent to Australia's entire annual carbon dioxide emissions from all sources. The Olympic Dam expansion will provide an opportunity for Australia to make an even greater contribution in coming years by approximately doubling total uranium production in Australia, thus essentially offsetting all of Australia's CO_2 production once again.

Policies that permit the deployment of nuclear power (subject to stringent safety and environmental safeguards) as part of a portfolio[13] of energy options, particularly in countries which are large and growing contributors to global greenhouse emissions, could make a significant contribution to the efficient reduction of global greenhouse gas emissions. Policies that could encourage an efficient deployment of a mix of low greenhouse emission power sources include carbon pricing, subsidies and regulation. However, willingness to use policies of this character in economies with large and growing emissions is likely to depend on a significant degree of international cooperation, incentives for technology transfer and facilitative arrangements to allow resource access such as Australia's bilateral safeguards agreements.

Australia's greenhouse policies need to be developed in a national and global context. The greenhouse gas debate is bigger than the nuclear debate. Furthermore, greenhouse reductions will occur in the countries where the fuel is used, not where it is mined and milled. This situation is analogous to the export of relatively low emission fuels such as liquefied natural gas.

Hence, BHP Billiton supports the emphasis in the submission to the Review by the Minerals Council of Australia on the importance of government support in Australia for technology development across a portfolio of technologies.[14] The objective of those technologies would be to achieve consistent, large-scale emission reductions without imposing inefficiently high costs in the near term. Deployment of these technologies as they progressively become available is likely to require some form of market incentive. In the interim, there will be a need

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[13] Including fossil fuels with carbon capture and storage when feasible, renewable energy sources and efficient use of energy through appropriate price signals that may include a carbon component.

[14] Minerals Council of Australia 2006, *Submission: Review of Uranium Mining, processing and nuclear energy in Australia*, August, p. 17.

for investment in a range of long lived stationary energy generation assets employing currently available technologies (including for example new generation to support the proposed expansion of the Olympic Dam). Existing technologies and fuel alternatives have different greenhouse signatures and costs of power generation. It is important that investors in these power generation assets have a clear understanding of governments' (Commonwealth and State) greenhouse strategies long beyond the 2008-12 Kyoto Protocol commitment period – the alternative is to risk stalling critical investment or stranding assets at great economic cost in the future.

BHP Billiton has noted the release by the National Emissions Trading Taskforce for State and Territory Governments of a discussion paper, *Possible Design for a National Greenhouse Gas Emissions Trading Scheme*.[15] The discussion paper sets out a possible design for an emissions trading scheme applying to the stationary energy sector.

Any national greenhouse gas emissions trading scheme that is introduced in advance of more comprehensive international greenhouse frameworks runs a serious risk of merely driving trade exposed energy intensive activity to countries that do not have the same restrictions. Olympic Dam is an example of a major export investment which offers the prospect of significantly reducing greenhouse emissions on a global scale but which will require a significant upgrade to South Australia's electricity generation capacity with an inevitable attendant increase in local greenhouse emissions. Besides Canada, Australia's principal future competitors are in countries—particularly Kazakhstan and Uzbekistan—which are not now, nor likely to be in the foreseeable future, subject to any significant emissions limitations. Any national emissions trading scheme introduced in advance of more comprehensive international agreements must not fail to deal effectively, efficiently, speedily and in a manner that is clearly World Trade Organisation compliant with the competitive disadvantage it would place on export industries. Otherwise, such a trading scheme would be deeply flawed.

Given the scale of the investment in power generation necessary to underpin the nationally important Olympic Dam expansion project it is vital that the prevailing uncertainty in greenhouse policies be resolved as soon as possible so that this project can proceed in a timely manner to provide a net global greenhouse benefit through the export of uranium.

[15] National Emissions Trading Taskforce 2006, *Possible design for a National greenhouse gas emissions trading scheme, Discussion paper*, 16 August.

Chapter 2

Olympic Dam and its proposed expansion

Olympic Dam has been a great success for Australia economically and environmentally, and BHP Billiton currently has a major opportunity to substantially increase its benefits. The Olympic Dam expansion project is being subjected to pre-feasibility study, which in itself is a major 2-year commitment by this company. This section describes the current activities at Olympic Dam, the emergence of the current market opportunity to expand it, and the type of expansion that could come about and the challenges its faces.

2.1 The current operations at Olympic Dam

(a) Overview

Located 560 km north of Adelaide, South Australia, Olympic Dam is a multi-mineral ore body. It is the world's fourth-largest remaining copper deposit and the largest uranium deposit. It also contains significant quantities of gold and silver. Olympic Dam is Australia's largest underground mine. Most of Olympic Dam's employees live in Roxby Downs township, about 16 km south of the operations. The township has a population of about 4,000.

Olympic Dam became part of the BHP Billiton Base Metals business in 2005 after BHP Billiton acquired WMC Resources Limited in August 2005.

Copper is currently the primary business at Olympic Dam. Uranium, gold and silver are valuable associated products. As at 31 December 2004, proved and provable ore reserves totalled 761 million tonnes, at 1.5 per cent copper, 0.6 kg per tonne of U_3O_8, and 0.5 grams per tonne of gold. The grades of uranium in the ground at Olympic Dam would not support a uranium mine in its own right.

BHP Billiton has long term contracts for the sale of uranium oxide concentrates to customers in the United Kingdom, France, Sweden, Finland, Belgium, Japan, South Korea, Taiwan, Canada and the United States.

A mining venture of the scale and long life of Olympic Dam has required detailed consideration of Governments. In 1982 the Parliament of South Australia enacted the *Roxby Downs (Indenture Ratification) Act 1982* that:

- levies a royalty fee of 3.5 per cent on the value of the products dispatched from the mine;
- confers continuing mining rights (via a Special Mining Lease) at Olympic Dam Operations for the deposit's expected mine life;
- confers the right to draw water;
- provides Government infrastructure and services; and

- permits production of up to 350,000 tonnes of copper per year.

The Special Mining Lease relating to the Olympic Dam Operation has been granted for a period of 50 years with rights of extension for further periods of 50 years. While Olympic Dam is subject to extensive regulation, the regulatory regime also reflects the need for certainty in the light of the very significant and long term nature of the investment necessary to maintain the operation.

(b) Mine performance

The performance of Olympic Dam as a mine and as a focus of social and environmental responsibility has been very good. Major achievements have included:

- establishment of Australia's largest underground mine currently employing 3,000 people;

- development and continuous expansion of a very complex mining and minerals processing operation;

- a reputation with international customers for quality and reliability of product supply;

- rigorous safety standards and a safety record better than the industry average;

- average radiation exposures to employees well under half of the international limit;

- maintaining a strong commitment to environmental management including demonstrating that mining and effective land management can coexist through the pioneering Arid Recovery Program; and

- agreements with Aboriginal groups to protect heritage and support their community development aspirations.

(c) Background and briefing documents

BHP Billiton has been pleased to provide the UMPNER Taskforce with a range of background documents in relation to our operations at Olympic Dam:

- Interim environment management and monitoring report, 1 July 2004 – 30 June 2005;

- Interim Great Artesian Basin wellfields report, 1 July 2004 – 30 June 2005;

- Material presented to a media tour of Olympic Dam on 5 April 2006 and to an analysts' briefing on 4 May 2006; and

- Some of our recent press releases on Olympic Dam.

BHP Billiton was also pleased to host a tour by the UMPNER of the Olympic Dam site and would welcome the opportunity to provide any further explanation should the Taskforce deem it necessary.

2.2 The Olympic Dam proposed expansion

In this section, we describe how plans for the Olympic Dam proposed expansion started, the details of the expansion, the status of the expansion plans, the substantial benefits of the project, and the challenges we face to make it a reality.

(a) Preliminary investigations

In 2004, WMC Resources Limited commenced a preliminary study to investigate the feasibility of a major expansion of the Olympic Dam operations. The study included:

- a major drilling programme to better define the resources in the southern part of the deposit;
- assessing the alternative mining, treatment and recovery methods for the southern part of the deposit.

Initial drilling identified significant additional resources in the south-eastern portion of the deposit. The resources as at December 2004 were almost a 30 per cent increase over the resources to December 2003.

(b) Pre-feasibility study

Since acquiring WMC Resources Limited, BHP Billiton has committed to prepare a very comprehensive pre-feasibility study to rigorously examine development alternatives and analytically select a preferred development plan. A feasibility study will follow to refine and optimise a single go-forward case. The pre-feasibility study is expected to be complete by the in 2007 and the feasibility study in 2008. The construction phase of the expansion would take about 4 years with operation at the expanded capacity being in 2013; ramping up to full production in 2014.

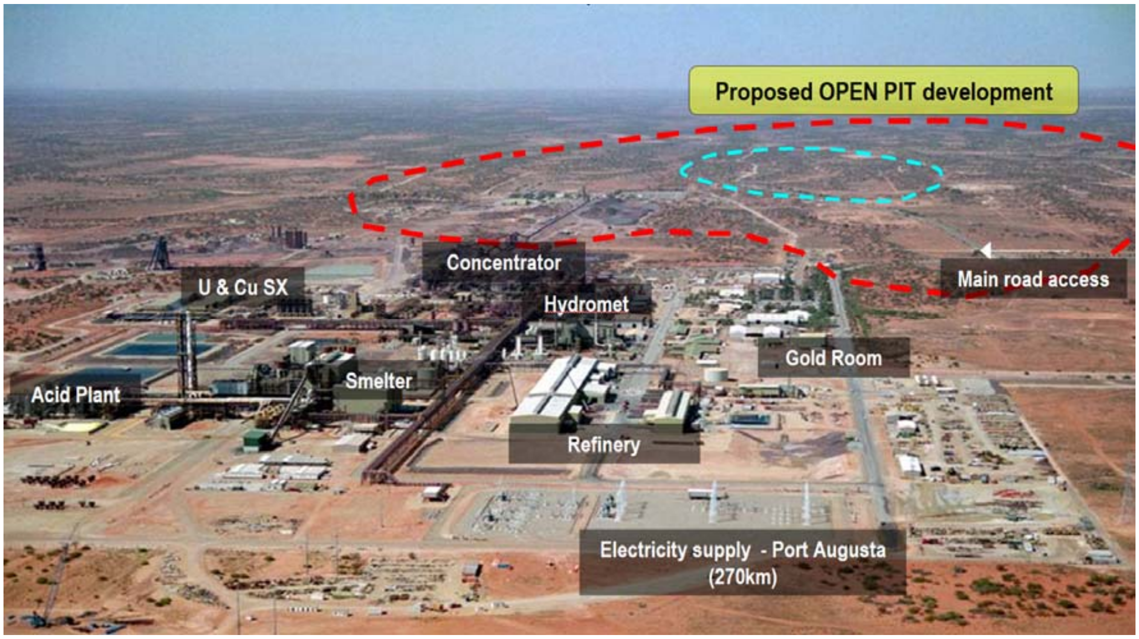
(c) Nature of the expansion

From the results of its preliminary investigations, WMC Resources Limited selected open pit as the preferred method over underground mining (sub-level caving or block caving). BHP Billiton's plans are based on the same approach.

The new open pit would be located adjacent to the existing Olympic Dam operation as shown in Figure 1.1.

Figure 1.1

LOCATION OF OPEN PIT



Subject to the outcomes of the pre-feasibility study, the expansion could include:

- a new ore processing plant with about four times the capacity of the existing facilities;
- 90 km of new rail line (Olympic Dam to Pimba) and associated terminals;
- new electricity transmission lines about 270 km long;
- a new airport with capacity for Boeing 737 jets and night flying;
- a new coastal desalination plant and a pipeline about 320 km long;
- a new construction camp for up to 5,000 people;
- new accommodation and services, with an expected doubling of the population of Roxby Downs.

BHP Billiton expects that the Olympic Dam expansion project would more than double the mine's output (double copper and treble uranium output) and substantially increase its demand for energy, water, transportation and labour to the extent set out in Table 2.1.

An important feature of the expansion is that the increased production of copper and uranium would become of equal importance in value terms.

Table 2.1

PROPOSED OUTPUTS AND INPUTS OF OLYMPIC DAM EXPANSION

	Current		Proposed (draft estimates)	
Mine production (per year)	Ore (underground)	9 million tonnes	Ore (open pit)	40 million tonnes
	Copper	220,000 tonnes	Copper	500,000 tonnes
	Uranium	4,000 tonnes	Uranium	15,000 tonnes
	Gold	80,000 ounces	Gold	500,000 ounces
	Silver	800,000 ounces	Silver	2,900,000 ounces
Electricity		120 MW Electricity source: the SA regional grid with the National Electricity Market		420 MW to 520 MW Electricity source: SA grid, on-site gas, or combination plus a percentage of renewable
Water		12,000 megalitres per year (32 megalitres/day or 374 litres/second) Water source: Great Artesian Basin		48,000 megalitres per year (132 megalitres/day or 1,534 litres/second) Water source: Existing GAB + coastal desalination
Transport in/out		1 million tonnes per year Transport mode: road 12,000 trucks per year (33 per day)		2.2 million tonnes per year Transport mode: road or direct rail 26,500 trucks (73 per day)
Exports		Via Port Adelaide		Via Port Adelaide and/or Darwin

(d) Benefits to South Australia

The Olympic Dam expansion will bring major new economic benefits to the State of South Australia in terms of employment, population and gross state product as shown in Table 2.2.

Table 2.2

BENEFITS TO SOUTH AUSTRALIA

	Current		Proposed (draft estimates)	
Permanent jobs	BHP Billiton	3,000	BHP Billiton	~4,000
	State-wide	15,000	State-wide	~20,000
Roxby Downs population		4,200		8,000 – 10,000
Location of workforce	Roxby Downs	80%	Roxby Downs	85%
	FIFO/DIDO[16]	20%	FIFO/DIDO	15%
Construction jobs	Minor works		On site average	5,000
			State-wide	~7,300
Gross State Product (per year)		A$1 billion		~A$2.5 billion

(e) Environmental Impact Statement

To gain environment and planning approval for the expansion of Olympic Dam, BHP Billiton is preparing an Environmental Impact Statement (EIS) in accordance with guidelines set down by the Commonwealth Department of Environment and Heritage and Planning SA[17] as part of its pre-feasibility study.

The scope of the EIS will include:

- a description of the existing operations;
- project justification;
- a description of the proposed expanded project;
- a description of the alternatives investigated, including the no-expansion option;
- a description of the community consultation process undertaken;
- an assessment of the existing environment, potential impacts on that environment and mitigation measures proposed to ameliorate impacts;
- a Draft Environmental Management Plan;

[16] FIFO/DIDO refers to the staff that fly in, fly out / drive in, drive out; that is, staff that don't live near Olympic Dam.

[17] Department of Environment and Heritage and Planning SA 2006, *Guidelines for an environment impact statement on the proposed expansion of the Olympic Dam operations at Roxby Downs*, January.

- a means of cross-referencing the relevant sections of the EIS with the corresponding sections of the final guidelines; and

- appendices that include:

  - the final guidelines;

  - the key personnel of the study team;

  - a list of the stakeholders consulted; and

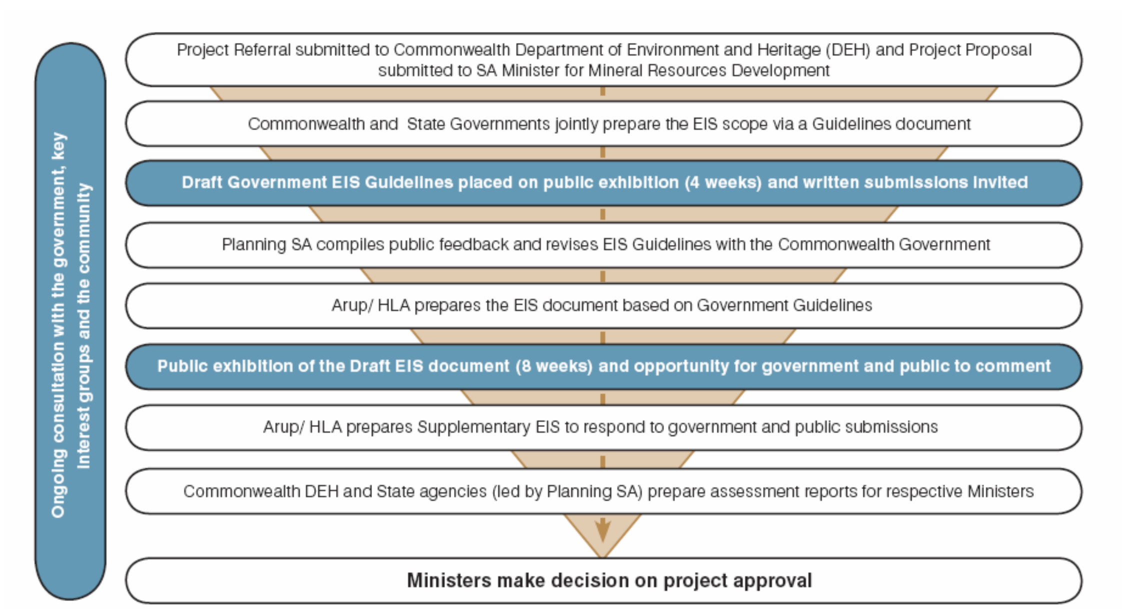
  - technical reports that supplement the EIS (including the source, currency, reliability and any uncertainties in relation to the information).

Among a large range of matters that BHP Billiton will explain in the EIS will be its efforts to consult with the whole community, particularly indigenous groups, and its preferred approach to the establishment of the water, electricity and transport infrastructure required for the Olympic Dam expansion.

BHP Billiton intends to publish its draft EIS in 2007. The EIS will be assessed under a joint Commonwealth and State Government process, as illustrated in Figure 2.3 below. BHP Billiton anticipates constructively addressing, in the EIS, all material issues of environmental impact.

Figure 2.3

STEPS IN THE OLYMIC DAM EXPANSION EIS ASSESSMENT



Source: BHP Billiton http://www.olympicdameis.com/assets/EIS_InfoSheet01.pdf

(f) Indigenous engagement

BHP Billiton is has commenced discussions with the Kokatha, the Kuyani, and the Barngala people, native title claimants, for the purpose of striking an Indigenous land use agreement for the Olympic Dam expansion. We have met on site with representatives of each group and their legal advisors, and we believe that discussions are proceeding on a cooperative basis. We anticipate that agreement with them will be finalised by the end of 2006. During this period, BHP Billiton is providing funding to each group for administration support to ensure that they can participate fully in the negotiations.

We are keen to ensure that local indigenous people share in the benefits of the Olympic Dam expansion. BHP Billiton operates a job readiness scheme that trains local indigenous people to a level that enables them to apply for employment at Olympic Dam or elsewhere in the region.

The next sections discuss some of the key challenges to realising this massive project, and obtaining its regional, national and global benefits. The most important of these challenges include infrastructure (water, electricity and transport), domestic skills shortages, securing appropriate export licences and environmental oversight.

(g) Water

Our existing operation at Olympic Dam takes water from the Great Artesian Basin (GAB), which is then desalinated before use. BHP Billiton more than off-sets its use of artesian water with water savings from our program to fund the capping of bores on pastoral properties in the region. WMC Resources Limited and BHP Billiton have together spent more than A$2 million dollars to cap pastoral bores in South Australia.

An expanded Olympic Dam will need more good quality water and BHP Billiton is searching for the most economically and environmentally sound source of this additional demand. It has explored several options, including the option of talking more water from the GAB. At this stage, we believe the best source is a coastal desalination plant on the upper Spencer Gulf. A desalination plant will treat the water after which it would be pumped to the mine.

(h) Electricity

Operations at Olympic Dam currently require 120 MW of power, and the expansion would require around another 400 MW. Transmission lines into Olympic Dam have a transfer capability of up to 280 MW.

BHP Billiton is investigating a number of options to satisfy this increased demand of the Olympic Dam expansion. While gas fired power generation on site has been evaluated, the option currently preferred on economic grounds is purchasing power from the National Electricity Market (with a long term wholesale or retail contract) and building a second 275 kV transmission line from Port Augusta. BHP Billiton expects that this option would facilitate the development of new generation capacity in South Australia.

(i) Transport

Expansion of Olympic Dam will need BHP Billiton to increase the capacity of air and surface transport links, including constructing a new airport.

Currently, most of Olympic Dam's product, including its uranium oxide, is trucked to Adelaide and exported from Port Adelaide. In the pre-feasibility stage, BHP Billiton is investigating its options to move freight in and out of the expanded Olympic Dam mine site. Total surface freight will increase from 1 million to 2.2 million tonnes per year.

At this stage, we see a good opportunity to build a 90 km rail branch line from the mine site to an intermodal connection at Pimba, and use this rail line to transport a substantial proportion of the mine's inputs and outputs. This would also enable us to use the Adelaide to Darwin rail line and to export some of our product from Darwin. We believe this option could provide substantial cost, safety and reliability advantages, particularly by removing a significant amount of truck traffic from South Australian roads.

(j) Domestic skills shortages

The labour market in Australia is already tight, especially for companies such as BHP Billiton who are seeking recruit for positions in rural and remote areas. In particular, as identified in a recent study published at the Department of Education, Science and Training (DEST), the availability of people skilled in science, engineering and technology is are already low and demand will increasingly outstrip supply.[18]

BHP Billiton has a number of initiatives in place to address these challenges and notes the Government's strategy set out in the DEST report. As well as developing its own recruitment program, BHP Billiton is supporting the establishment in the northern region of South Australia of a technical college proposed by the Australian Government, which would have an emphasis on the resources sector in its course offerings. We are also establishing a mining and heavy engineering skills training centre planned by the South Australian Government.

(k) Extension of export licence

In due course, BHP Billiton will be applying to the Australian Government for an extension to its uranium export licence. As stated in section 1.6, we are cognisant of the Government's uranium export policy and will seek our licence extension well within that policy.

2.3 Implications for policy

The Olympic Dam expansion is a major economic opportunity for Australia and South Australia. While primarily a copper mine, it would also make a contribution important on a global scale to the production of U_3O_8 with a concomitant opportunity to treble the export of uranium from Olympic Dam and thus reduce the global growth in greenhouse gas emissions.

[18] Department of Education and Training 2006, *Audit of science, engineering and technology skills*, July, p. 49.

Determining the feasibility of the expansion is a large undertaking in itself. It is subject to a complex web of State and Commonwealth approvals as well as the need in parallel to negotiate commercial arrangements that can underpin the huge capital investment required. The peak financing requirement for the expansion will depend on the outcome of this work and, at this stage, it is too early to provide a reliable estimate.

The size and quality of the resource on a global scale could lead to a complacency on the part of regulators at State and Commonwealth level that the project will proceed no matter how long approvals are delayed or what conditions are placed on those approvals. However, the project is not inevitable. The Olympic Dam expansion faces significant potential competition from alternative suppliers of each of the principal product streams. With respect to U_3O_8, projects in Kazakhstan, Uzbekistan and in the longer term South Africa and Namibia could provide significant competition.

High quality and timely regulatory approvals are important to the feasibility of this nationally significant project. These approvals, and the confidence they provide to customers for the product lines, are critical to project financing and commitment. The principal approvals required are:

- environmental and planning approvals from the State and Commonwealth governments;
- ratification of the Australia-China Nuclear Material Transfer Agreement and Nuclear Cooperation Agreement; and
- export licence approvals from the Commonwealth Government of sufficient length and certainty to underpin long term supply agreements for the export of U_3O_8.

Accordingly, while it is important that Australia has an informed debate about future options in relation to its fuller participation in the nuclear cycle (including under the United States proposed Global Nuclear Energy Partnership and parallel British and Russian proposals) it is equally important that this debate is not seen as relevant to, or a reason for slowing, the granting of regulatory approvals for the Olympic Dam expansion, for the following reasons:

- The Olympic Dam expansion is based on the continuation of the existing proliferation policies that have served Australia very well for multiple decades.
- BHP Billiton will meet world’s best practice health, safety, environmental, indigenous, community and safeguards arrangements, and believes this practice should apply for all Australian uranium mines and exports.
- BHP Billiton has no intention to use the mine as a basis to begin providing fuel leasing, conversion, enrichment, nuclear power or national or international waste disposal/storage services.
- BHP Billiton would expect to enter into long term supply arrangements for the export of a large proportion of the total uranium concentrate production to facilitate the expansion, and its customers will only enter into those agreements if they are confident that the terms of the supply agreements will be honoured over their entire lives.

- Any government requirement to use fuel leasing services as a condition of our customers access to Olympic Dam product would seriously jeopardise BHP Billiton's ability to enter into the long term supply arrangements which underpin the Olympic Dam expansion.

- GNEP and its associated support for fuel leasing while an important option for safely expanding the range of countries in which nuclear power might be economically deployed is reliant on Generation IV technologies, and as yet undeveloped international agreements. It is likely to be decades rather than years in the future—on the other hand Olympic Dam offers the prospect of enhanced supplies of a low greenhouse emission fuel source to proliferation safe markets within 10 years with key decisions required over the next twelve to eighteen months.

- Recognising the scale of the Olympic Dam resource, and other uranium resources in Australia, granting of environmental and export approvals necessary for the Olympic Dam expansion project to proceed would not inhibit or constrain policy options over the long term.

In addition to formal regulatory approvals, Governments can play an important facilitative and policy role. While as a global hard rock miner BHP Billiton is well placed to source (subject to a supportive visa framework) critical professional skills to underpin projects of this scale, domestic skills development in the context of a labour market already under pressure from the scale of resource development requires attention from all levels of government. Similarly, BHP Billiton must, as it approaches critical decisions with major implications for the expansion of South Australia's power generation capacity, have a clear understanding of the long term policy frameworks, both Commonwealth and State, for handling domestic greenhouse emissions, and how those policies will both (a) mitigate any impact on the global competitiveness of the project and (b) recognize the project's very significant capacity to reduce global greenhouse emissions through the use of the U_3O_8 product stream in other countries.

If this nationally significant project is to proceed and provide its potential global environmental benefits from 2013 onwards, then it is important that all the regulatory approvals, and essential facilitative policy decisions are made through the course of 2007, with the key environmental and export licence approvals being made by April 2007 if possible, so that BHP Billiton may make the decisions necessary to commit to the expansion project at a time that can ensure its commercial feasibility.

Chapter 3

Involvement in front-end and back-end processing

It has been suggested that Australian industry should establish facilities and services to add value to uranium and to participate in other levels of the nuclear fuel cycle.

Proposals are now also being brought forward for Australia to move beyond mining and milling to participate in fuel leasing schemes that involve an integrated offering of front-end (conversion, enrichment and fuel fabrication) and back-end (high level waste processing and disposal) processing. These proposals are argued by their proponents to offer security (non-proliferation) advantages, to be consistent with the United States' GNEP proposals and to be highly attractive on a commercial basis.

BHP Billiton believes that there is neither a commercial nor a non-proliferation case for it to become involved in front-end processing or for mandating the development of fuel leasing services in Australia. BHP Billiton's uranium strategy focuses on its strengths as a miner and mineral exporter.

BHP Billiton also notes that these services are currently proscribed under Australian legislation (the *Environmental Protection and Biodiversity Conservation Act*).

This chapter first examines the nature of the market for front-end processing and the challenges for Australia to enter it. Later sections examine Australia's potential involvement in fuel leasing schemes.

3.1 Markets for front-end processing

(a) Conversion services

U_3O_8 conversion into UF_6 is a simple and easily replicable chemical process. Technical barriers to entry are low, however, in many jurisdictions there are high regulatory barriers.

The market for conversion services is dominated by 5 large players: Converdyn, Cameco, Areva and British Nuclear Fuels and Tenex – located in the United States, Canada, the United Kingdom, France and Russia respectively. Under current bilateral agreements, both Australian and Canadian uranium can be converted in any of these countries.

While the market is concentrated, there is significant overcapacity. This is likely to continue in future and new commercial entrants are unlikely. BHP Billiton understands that both Converdyn and Areva are launching studies to investigate expansion options, and Areva is likely to proceed with expansion to feed its planned George Besse II enrichment facility. UF_6 is a more volatile substance than U_3O_8 and, its transport, while it is not an insurmountable barrier, is accordingly more complex.

(b) Enrichment services

There are two technological processes—gaseous diffusion or centrifuge—for enriching uranium from 0.71 per cent U235 (the naturally occurring fraction of the U235 isotope in all U_3O_8) to 3-5 per cent U235 (the fraction needed in nuclear fuel). Both processes use UF_6, and hence both require conversion services.

Enrichment has massive barriers to entry—including access to technology and approvals under international protocols—and is concentrated with 4 large players: USEC, Areva, Urenco and Tenex, located within the nuclear weapon states of the United States, the United Kingdom, France and Russia respectively. There are high levels of government involvement both directly and in close regulatory oversight.

Even mature power generation markets with strong technology bases like Japan and South Korea have not developed enrichment sectors.

There is an oversupply of enrichment services and existing expansion plans suggest that there is unlikely to be ready room for a new entrant for decades.[19]

Over the next decade, all of the gaseous diffusion plants will be phased out of production and replaced by new planned centrifuge capacity, both in France and in the United States. Urenco is also committed to build an additional enrichment facility in New Mexico, commissioning due 2015. Utilities often acquire enrichment services from a number of enrichment providers to maintain price competition and spread technical and supply risks.

To date no country without a substantial domestic nuclear energy sector (or direct access to one through cross border trading in the case of prospective developments in Mexico) has developed a major commercial conversion and enrichment sector.

(c) Fuel fabrication services

Fuel fabrication is a highly specialised service, strongly linked with end use customers and closely supervised by the regulatory agencies in end user country. Together with the technical requirements, the high cost of establishing compliance with a range of regulatory frameworks is a major barrier to entry. All fuel fabricators are organisations like General Electric with deep skills and experience in high technology manufacture.

Fabricating nuclear fuel assemblies for any nuclear reactor design is technically challenging, and requires the greatest coordination with nuclear safety regulators. Unlike uranium extraction, conversion and enrichment, the output of the nuclear fuel fabrication step must reflect the specific reactor design (or even the specific reactor) for which the fuel is intended. Furthermore, the performance of the nuclear fuel assemblies is at the heart of the safety analysis for nuclear power plants. If the assemblies maintain their mechanical and chemical integrity while providing the expected nuclear physics performance, then the reactor will operate as expected. If the nuclear assemblies do not meet those performance specifications,

[19] Confirmed in Supplementary Submission No 33-2 to the House of Representatives Standing Committee on Industry and Resources Inquiry into the development of the non-fossil fuel energy industry in Australia, *Supplementary questions to ASNO, following public hearings in November 2005, Responses by Mr John Carlson, Director General, ASNO*, 31 January, p. 4.

then radioactive materials are more likely to be released from the assemblies in amounts beyond the licensing requirements.

The highly technical nature of the nuclear fuel fabrication step produces high technical barriers to entry. While the basic mechanical steps of fuel fabrication (conversion of UF_6 to UO_2, sintering and grinding of the UO_2 to produce fuel pellets, and loading the fuel pellets and other materials into the metal tubular assemblies) are relatively straightforward, the design and licensing of the nuclear fuel assemblies themselves is a complex task, and must be tailored to specific reactors designs and/or reactors.

Due to the close link between nuclear safety and the performance of the nuclear fuel assemblies, nuclear fuel fabrication facilities are closely regulated by nuclear safety authorities, with a specific focus on the appropriateness of the fuel for specific reactors. Hence, the market for nuclear fuel fabrication services should probably be considered as multiple national or regional markets, or, at best, markets serving specific lines of nuclear reactor design, rather than a single international market. The largest such "sub-market" would be nuclear fuel for light water reactors (3-5 per cent enriched UO_2, enclosed within zirconium alloy tubes). It is unlikely that a nuclear fuel fabrication facility could be developed at a great distance (either geographically or politically) from the nuclear plant operators who are its customers and their regulators.

3.2 Challenges for any Australian conversion, enrichment and fabrication industry

(a) Regulatory oversight

Adding any steps of the nuclear fuel cycle within Australia would require additional oversight and regulation at both the national and international levels. For example, the construction and operation of an enrichment facility within Australia would require negotiation of international agreements and IAEA oversight regarding proliferation safeguards, as well as domestic legislative change and appropriate safety, proliferation and environmental regulation regarding the long-term management of the depleted uranium that would be generated. These costs would be considerable and virtually independent of the size of the operation.

(b) Technology issues

As noted already enrichment has massive barriers to entry—including access to technology and approvals under international protocols. The technology licences are closely held and any profits associated with enrichment investments are likely to accrue to the technology provider.

Nuclear fuel fabrication is a step that would require a long lead time and high levels of technology transfer. Nuclear fuel assemblies are highly engineered products, with requirements specific to each nuclear power plant (and potentially varying during the plant's lifetime). Moreover, nuclear power regulatory authorities view the fuel assemblies as an integral part of the overall plant and its safety systems, and the specific fuel designs and specifications often require approval by those regulators. Without a domestic nuclear power industry as a platform for developing fuel fabrication expertise, we suspect that breaking into this market would be very difficult for an Australian enterprise. Fuel fabrication and power generation are often located nearby one another, or at least in the same country, as both enterprises must answer to the same regulatory authorities. Fuel fabrication services are universally provided by organisations with deep technology, engineering and precision manufacturing experience.

(c) The economics of domestic conversion, enrichment and fabrication

The economics of any Australian conversion, enrichment or fabrication do not look positive, either individually or collectively. The global market is currently well supplied by services providers with strong customer relationships, economies of scale and scope, the necessary deep technological expertise and experience, solid reputations for delivery, and expansion plans in place. Some regulatory authorities—for example the Euratom Supply Agency[20]—place limits on the proportion of enrichment services that can be secured "out of country", while there has been ongoing legal action by the United States enrichment service providers to attempt to prevent the provision of enrichment services to the United States by Tenex. Utilities often spread their enrichment service contracts to maintain price tension and reduce security risks—to the extent that they are able to do so under their domestic regulatory requirements.

BHP Billiton has no intention of entering this market, nor indeed does it have the depth of technological skills and precision engineering manufacturing experience to do so. We do not see a strong commercial case for suggesting that a new entrant Australian firm would have a competitive advantage over the existing service providers. In fact, given the challenges of establishing a new industry of this type in Australia, the opposite is likely. Our view is consistent with that expressed in a Submission to the Prosser Committee by representatives of the Australian Government with respect to the economics of enrichment and reprocessing:

> Under current circumstances, with established global enrichment and reprocessing capacities exceeding demand, the development of indigenous enrichment/reprocessing is not economic, except possibly in the case of very large power programs. An example of the latter is Japan, which operates some *55* power reactors. Even Japan buys most of its enrichment from others, and the very substantial investment in reprocessing has been influenced not by current economics but by future fuel cycle plans (i.e. the development of fast neutron reactors). By comparison, the example of South Korea (currently operating some 20 reactors) shows that a large and expanding nuclear power program can proceed with great success on the basis of external enrichment services. The majority of the world's nuclear power programs are based on external fuel cycle service suppliers.[21]

As previously noted, no country without a substantial domestic nuclear energy sector has, to date, developed a major commercial enrichment or fabrication sector.

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[20] The Euratom Supply Agency is an independent body supervised by the European Commission. It ensures equal access to resources and a common nuclear material supply policy throughout the European Union.

[21] Supplementary Submission No 33-2 to the House of Representatives Standing Committee on Industry and Resources Inquiry into the development of the non-fossil fuel energy industry in Australia, *Supplementary questions to ASNO, following public hearings in November 2005, Responses by Mr John Carlson, Director General, ASNO*, 31 January, p. 4.

(d) Customer needs

As described in section 1.5 of this submission, utilities typically acquire U_3O_8 and then contract directly with established conversion, enrichment and fuel fabrication service suppliers to meet their specific technical specifications for long periods and often spread supply agreements across a number of suppliers. Customers value this flexibility and choice.

Many users of nuclear fuel procure the materials and services of these steps at different geographic locations, for example, purchasing U_3O_8 from one location, conversion and enrichment services elsewhere, and fuel fabrication services and material from yet another location. There is little evidence of a preference for purchasing a "bundled" supply of U_3O_8, conversion, enrichment and fuel fabrication services and no established market for fuel leasing.

The customers that underpin BHP Billiton's proposed expansion plans at Olympic Dam all come from countries that meet Australia's strict bilateral safeguards requirements as well as being parties to the NPT. Domestic conversion, enrichment, fuel fabrication and leasing services are neither necessary to ensure against proliferation risks nor do we have any evidence that such services could be made attractive to these customers.

(e) BHP Billiton's business strategy

BHP Billiton is focused on being a customer-responsive mining business of global importance: a business that excels as a result of concentrating on its core skills across a range of mineral and energy extraction activities.

It would not be consistent with its core corporate strategy for BHP Billiton to enter into the downstream processing of uranium, where it has no established competence, no clear advantage in a highly competitive market, and little chance of making a reasonable return on its investment,

3.3 Nuclear fuel leasing and spent fuel disposal – basis and nature of current proposals

From the 1960s until recently, the NPT has been remarkably successful in slowing the spread of nuclear weapons while facilitating the use of peaceful nuclear power. In the 1960s it was widely anticipated that the number of nuclear weapons states would number in the tens if not twenties by the current date. In fact the spread, although worrying, has been modest—Israel, India, Pakistan and possibly North Korea. However "recent and ongoing violations" of the NPT, particularly the cases of North Korea and Iran, as well as the failure of the 2005 NPT Review Conference to agree to any final declaration, have led some to question whether the NPT may be reaching the end of its useful life[22].

Substantially in response to these concerns, a number of proposals have been made for the introduction of new regimes based on more proliferation resistant options. These responses

[22] Carlson J 2005, *Safeguards and Non-Proliferation: Current Challenges and the Implications for Australia*, Presented to the 2005 Conference of the Australian Nuclear Association, Sydney, 10 November, p. 2.

aim to limit the spread of proliferation-sensitive technologies through the development of a closed fuel cycle which can allow access to nuclear energy without the risk of the separate production of fissile material. Dr John Carlson, Director General of the Australian Safeguards and Non-proliferation Office puts it like this:

> “The need for proliferation-resistant technologies is highlighted by the likelihood that plutonium recycle will become widely established in the future. Plutonium recycle using fast neutron reactors can improve the efficiency of uranium utilisation by a factor of some 50-60%. Fast neutron reactors also offer substantial waste management advantages, through transmutation of actinides and long lived fission products. However, plutonium recycle based on the traditional “fast breeder” reactor concept, in which high-fissile plutonium is produced in a “blanket” and separated through reprocessing, would present major proliferation risks.
>
> Attention is now being given to fast neutron reactor concepts, such as the Russian BREST reactor, in which plutonium with isotopics suited for weapons use is never produced, and spent fuel undergoes simplified reprocessing in which plutonium is never separated from uranium, actinides and most fission products. If fuel cycle concepts of this kind are established, uranium enrichment and current reprocessing technology will be phased out. So the challenge to contain the spread of enrichment and reprocessing, while acute, may also be finite. Meanwhile, development of criteria for assessing the acceptability of new enrichment and reprocessing projects might include an assessment of how much additional enrichment/reprocessing capacity is actually required globally over next 20-30 years. This is likely to show that the justification for new projects is limited.”[23]

Alongside the Russian proposals are those by the United States under the GNEP. These would envisage the provision and recycling of fuel through the use of fast neutron reactors, with the fuel being provided on a “cradle to grave” basis through a leasing program which requires the provider to not only provide the fuel but to manage the eventual safe disposal of the resulting high level wastes (in limited volumes). While the original US concept was based on these services being provided by only existing nuclear weapons states recent press comments have suggested that as major suppliers of uranium with strong and stable traditions of good governance and high non-proliferation standing Canada and Australia could be included in the group of countries to provide these services.[24]

Some commercial interests have suggested that GNEP provides an opportunity and almost an obligation for Australia—and hence BHP Billiton and the other miners operating in Australia—to *immediately* adopt a policy of providing a bundled service of conversion, enrichment, fabrication, fuel leasing and waste disposal in preference to the current customer driven preference for the export of U_3O_8 subject to rigorous safeguards agreements. In response to these suggestions, BHP Billiton makes the following observations:

- GNEP (or alternative Russian and British proposals) and the technology on which it depends is decades away from practical implementation and faces very significant technical, commercial and diplomatic hurdles and risks – on the other hand Olympic Dam

[23] ibid., pp. 6-7.
[24] Elliot G 2006, ‘US backs PM’s nuclear vision’, *The Australian*, 17 August.

offers the prospect of enhanced supplies of a low greenhouse emission fuel source to proliferation safe markets within 10 years with key decisions required over the next twelve to 18 months

- We do not believe that conversion and enrichment would be commercially viable in Australia. Nor do we believe any government imposed requirement to lease fuel, as distinct from acquiring uranium would be acceptable to its major customers, all of whom have alternative choices about where to acquire their U_3O_8, and all are highly respected utilities in countries with which Australia has rigorous safeguards agreements. These utilities generally regard their spent fuel as an asset—a resource for future reprocessing to produce more fuel input. Long term uranium supply arrangements with these utilities are necessary to underpin a commercial decision to proceed with the Olympic Dam expansion.

- Since BHP Billiton does not and will not sell uranium to nations whose activities motivated proposals such as GNEP in the first place,[25] the adoption of such proposals is not a prerequisite for the continuation of Australia's successful track record of non-proliferation safeguards.

- Current and proposed U_3O_8 exports under bilateral safeguards arrangements insisted on by the Australian government are not a source of proliferation risk—nor are the utilities whose energy needs underpin the financial viability of BHP Billiton's current and proposed mining operations. "The risk of proliferation does not come from nuclear power – and it is notable that those countries pursuing proliferation programs have not had nuclear power. It is simply not true … that Australian uranium has been diverted or gone missing."[26]

- In short, insistence in the foreseeable future on a mandatory Australian fuel leasing program in the interests of non-proliferation is an attempt to solve a problem that Australia has no role in creating and to do it in a way that raises considerable commercial (and national economic) risks.

Any requirement to use Australian fuel leasing and spent fuel disposal services as a condition of access to Olympic Dam concentrates would be unacceptable to BHP Billiton's core customers—both because of the customers need to control over their engagement with the fuel cycle for commercial and regulatory reasons and because they regard their spent fuel as an important asset. They have many possible alternative sources of supply of concentrates.

3.4 Implications for policy

The Australian debate on the issue of fuel leasing—encompassing enrichment and high level waste disposal—has attracted a great deal of attention. BHP Billiton believes that it is important to keep market fundamentals and the high quality safeguards offered by Australia's

[25] With respect to India, BHP Billiton notes that it is not a signatory to the NPT and accordingly has no bilateral safeguards treaty with Australia. Neither is it subject to a framework that has the support of either the IAEA or the Nuclear Suppliers Group. In these circumstances BHP Billiton does not regard India as a prospective customer for Olympic Dam product.

[26] Carlson J 2005, *Safeguards and Non-Proliferation: Current Challenges and the Implications for Australia*, Presented to the 2005 Conference of the Australian Nuclear Association, Sydney, 10 November, p. 8

current and proposed bilateral agreements in mind. There is no evidence that a change to current Australian Government policies to facilitate domestic enrichment, fuel leasing and high level waste disposal would lead to significant economic opportunities or reduce proliferation risks in the foreseeable future.

To the contrary, moving too quickly could erode the public's acceptance of an expanded uranium export industry—an industry which will make a significant contribution to both national and state economic growth as well as to the limitation of global greenhouse emissions. It would also put at risk our reputation with customers of being a reliable supplier of uranium concentrates and our ability to enter into the long term supply arrangements that underpin expansion of uranium mining.

Noting that a nuclear fuel leasing industry—if permitted by the regulatory framework—is most unlikely to be commercially viable, BHP Billiton would strongly oppose any policies to artificially support the premature development of such an industry by requiring BHP Billiton's customers to use Australian conversion, enrichment or fabrication services—or to quarantine reserves to underpin such a domestic capacity in the future. It would put customer relations and the investments those underpin at risk. We note that artificial constraints on export capacity are not part of the Australian Government's approach. The Australian Government has resolutely opposed proposals to quarantine North West Shelf gas reserves for future domestic use and those same arguments apply in this case.[27]

There are real risks that any regulatory interventions of such a nature would entail significant economic costs. Such interventions would be very unattractive to our established and prospective power utility customers, who place a premium on their ability to manage the cost, location and technical characteristics of the conversion, enrichment and fuel fabrication services that are critical to them. It is important to remember that although Australia is blessed with significant economically attractive uranium resources, it is not without competitors and that this competition is likely to increase.

BHP Billiton notes that it is important for the Australian Government to continue to play an active role in international negotiations designed to reduce the risks associated with nuclear fuels reprocessing at a time when global expansion of the use of nuclear power may be an important element in the portfolio of responses to greenhouse risks. It notes that many of the technologies and protocols being discussed in this context are unlikely to come to fruition in less than 20+ years. In participating in these negotiations, the Australian Government would appropriately have regard to the preservation of long term options for the development of Australia's energy industries, including those associated with the nuclear fuel cycle,

[27] As articulated by Minister for Industry, Tourism and Resources in his speech to the Australian Petroleum Production & Exploration Association conference at the Gold Coast on 16 May 2006.

Chapter 4

Domestic nuclear power generation

Although whether Australia wishes to embrace a domestic nuclear power sector is a matter for governments, the following observations might be of interest to the Taskforce.

4.1 Nature of Australia's electricity market

Australia has a diverse and competitive electricity generation market underpinned by transparent market rules and industry regulation. Its most outstanding characteristic is that it produces some of the cheapest and most reliable power available anywhere in the world. Together with resource endowments this has led the Australian economy to become a globally significant supplier of many energy intensive products.

Table 4.1

PROFILE OF THE AUSTRALIA ELECTRICITY GENERATION MARKET AS AT 30 JUNE 2005

Installed grid-connected capacity	45,000 MW	
Further embedded capacity	3,800 MW	
	Energy generated (TWh)	
Black coal	138.20	55.6%
Brown coal	55.80	22.5%
Coal gases	3.00	1.2%
Oil	1.86	0.7%
Hydro	15.61	6.3%
Natural gas	32.00	12.9%
Solar/wind	0.78	0.3%
Combustible renewables & waste	1.12	0.5%
Nuclear	0.00	0.0%
Total	248.37	

Source: Energy Supply Association of Australia 2005, *Annual Review 2004-2005*, November, p. 7, and IEA 2006, *Electricity information*, July, p. I.32-3.

By European or North American standards, Australia's electricity market is not a large one but it has been singled out as best practice in terms of electricity sector liberalisation.[28] An important characteristic in the market is the availability of abundant indigenous fuels: coal, hydro, gas and the new opportunities to exploit renewable technologies on a commercial basis, albeit facilitated by the Commonwealth Mandatory Renewable Energy Target and some State schemes. Since the major reforms during the later 1990s, public and private sector companies have made significant commercial investments in new generation capacity. Because of its reliance on fossil fuels, and in particular coal, it is relatively greenhouse intensive and emissions from the sector are increasing steadily.

4.2 Why consider nuclear electricity generation?

(a) Technological advances

Nuclear powered electricity generators reactors being built today are of third-generation designs that build upon prior experience, and are expected to be safer and more economical. Key features of these "Generation III" or "Generation III+" technologies typically include:

- Greater reliance on natural processes (for example, natural circulation and convection) and inherent system characteristics (larger thermal inertias) to increase safety without adding active safety systems;
- Implementation of "lessons learned" in nuclear operations and maintenance to simplify operations and maintenance, and to reduce occupational exposure to radiation;
- Significant standardisation of, and simplification to, reactor design (for example, the EPR concept developed by Areva would use 47 per cent fewer valves, 16 per cent fewer pumps and 50 per cent fewer tanks, per MW, than prior designs)[29]; and
- Capital cost reductions achieved through such simplifications and standardisations.

As noted earlier, these reactors designs are unlikely to be commercially competitive with coal or wind energy in many areas of the world—including Australia and the United States—even if the forecasted costs savings are achieved. However, these designs will be commercially attractive in other regions of the world. This economic attractiveness is in addition to the supply security benefits of nuclear power.

(b) Response to the value of carbon

As a generation technology that has no greenhouse gas emissions during operations, nuclear power can play a useful role in mitigating global climate change associated with increased concentrations of greenhouse gases. A 1,000 MW nuclear plant that displaced a similarly sized coal plant would, over a 40 year period, avoid the substantial CO_2 emissions that otherwise occur. Hence, interest in nuclear power has increased significantly as concerns about greenhouse gas emissions have risen.

[28] IEA 2005, *Lessons from liberalised electricity markets*, December, p. 41.
[29] http://www.unistarnuclear.com/UniStarBroch.pdf, p. 4.

Some commentators have noted that the mining and milling, conversion and enrichment stages of the nuclear fuel cycle consume energy and that if these steps are sufficiently energy intensive—for example, if the ore concentrations at the mines are sufficiently low—the net energy gain (and carbon emissions avoided) could be negative. While theoretically possible, current mining and milling operations use ore concentrations that provide for significant net energy/carbon gains.

Nuclear power has a significant net carbon/energy gain when considering the uranium mining, milling, conversion and enrichment, and fuel fabrication (and the associated transport steps). For example, the total electricity required to produce nuclear electricity is about 3 per cent of the total output. The fossil energy required is less than 2 per cent of the output electricity, even with no allowance for the higher quality of the output (electricity) than the inputs (thermal fossil energy)[30]. Furthermore, significant improvements in enrichment technologies—namely, the on-going shift to gas centrifuge technology—further decreases the required energy inputs and thus increase the energy/carbon gain from nuclear technology.

4.3 Challenges for domestic nuclear energy

The electricity markets in Australia are renowned for their effective market operation and their clear market signals to encourage efficient investment. The Australian market structure helps ensure that only cost-competitive generators are profitable. Under current circumstances, nuclear generation would not be cost-competitive with existing or anticipated new generation.

Based upon a review of the literature, and on recent political and regulatory development, nuclear power is not likely to be cheaper than electricity from coal fuelled plants, in the absence of significant carbon taxes in markets like Australia unless capital costs can be driven down.

Table 4.2 below presents one estimate of electricity costs for various technologies and indicates that nuclear is 13 per cent more expensive than gas, and (significantly) 6 per cent more expensive than wind (which is also a carbon-free resource in its power production phase)—noting that the extent of these cost differences in any give application will depend on location and timing.

Table 4.2

FORECAST ELECTRICITY COSTS FOR VARIOUS TECHNOLOGIES (2004 US$ PER MWh)

Cost type	Coal	Natural Gas	Wind	Nuclear
Capital	30.4	11.4	40.7	42.7
O&M	4.7	1.4	8.3	7.8
Fuel	14.5	36.9	0.0	6.6
Total	53.1	52.5	55.8	59.3

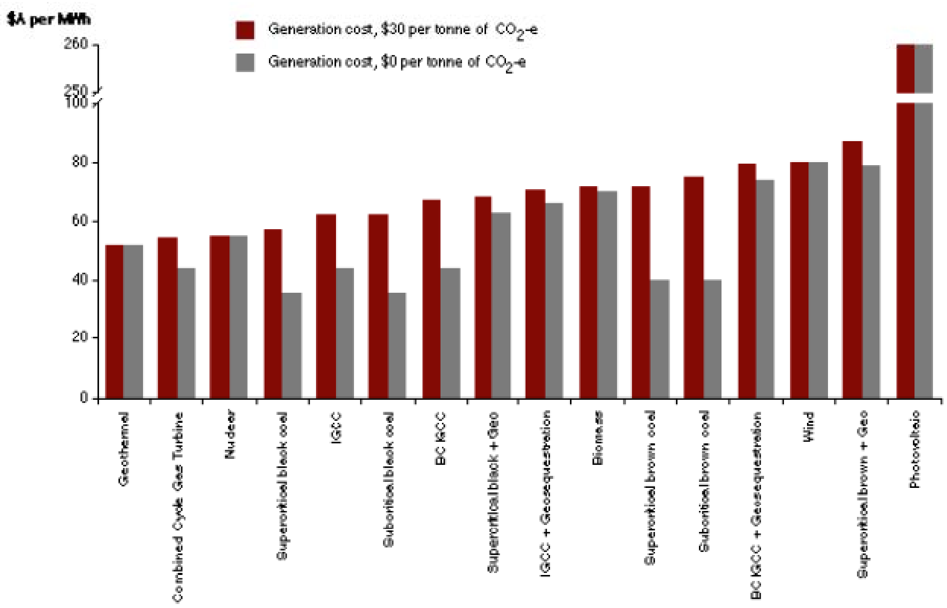
Source: Energy Information Administration, *International Energy Outlook 2006*, June.

[30] Jan Willem Storm van Leeuwen and Philip Smith at www.stormsmith.nl.

Many papers suggesting that nuclear power is now economical rely heavily upon some form of carbon tax or subsidy to offset the cost disadvantage of nuclear relative to fossil fuels.[31] At a sufficiently high carbon tax, nuclear can become more attractive than electricity from either coal or gas, and, depending on market characteristics, it can be more attractive particularly for base load power than other options including "clean coal" and renewable technologies.

The following figure provides material based on the estimates of Australian costs of electricity production under different carbon price assumptions.

COMPARING INDICATIVE GENERATION COSTS (LRAC) UNDER A $30 PER TONNE CO_2–E PRICE AND A ZERO CARBON PRICE



Source: MMA; The Allen Consulting Group; and The Australian Government 2004, *Securing Australia's Energy Future* (White Paper).

Note: based on assumed cost of geosequestration of $50 per tonne of CO2–e. Key: BCIGCC = Brown Coal Integrated Gasified Combined Cycle; IGCC = Integrated Gasified Combined Cycle.

While nuclear looks attractive as a possibility on these assumptions, many other technologies (wind, solar, clean coal, carbon geosequestration, carbon offsets, energy efficiency, etc.) could also become more competitive in a world of carbon prices. Actual costs will reflect whether the prices of emerging technologies (for example, coal with carbon capture and sequestration) can be brought down and whether the capital costs of nuclear power can be reduced with large scale installation of generating capacity in markets like China driving down the cost of key components.

[31] For example, Gittus JH 2006, *Introducing nuclear power in Australia: an economic comparison*, prepared for the Australian Nuclear Science and Technology Organisation, March, Canberra.

However in Australia, nuclear power plants would face higher competitive barriers than in major North American, European and Asian markets including:

- significantly lower costs for electricity and lower non-greenhouse air pollution impacts (particles, SO_2 and NOX) from competing coal-fired power plants than in the United States, Europe and Asia where nuclear generation has greater comparative advantages (nuclear power has considerable attractions in markets which suffer severe air pollution contributed to by old or inefficient coal fired plant);

- a relatively small overall electricity market that would naturally limit the ultimate number of nuclear plants to a handful and would introduce additional challenges in integrating even a single conventionally-sized plant—that is 1,000+ MW —into the system;

- the lack of an existing regulatory structure for nuclear power, leading to significant regulatory (and political) establishment costs that would be spread over a very small number of plants for quite some time; and

- a lack of skilled personnel with the experience of building and operating nuclear power plants.

Tackling greenhouse emissions and underpinning energy security requires investment in research covering a portfolio of technology alternatives. BHP Billiton is a participant in the COAL21 partnership between the coal and electricity industry, unions, federal and state government and research bodies that to identify and help realise a reduction or elimination of greenhouse gas emissions from coal based electricity generation in Australia. We also participate in two cooperative research centres (CRCs): the CRC for coal for sustainable development, and the CRC for greenhouse gas technologies.

In a carbon-constrained world, the availability of nuclear power offers another option in the portfolio of potential technological responses. It is possible that the capital costs (the key cost factor for nuclear power) for generation II technologies can be reduced with large scale installation of generating capacity in markets like China driving down the cost of key components. For generation III and III+ technologies, the technical and commercial risks are better understood than those for new carbon capture and sequestration technologies associated with fossil fuels or those for advanced renewable energies. Even so, the current estimate is that only few new nuclear plants are expected to be built in the United States over the next few years, and then only as a direct result of the US$15 per MWh subsidy (and other incentives) available under the *Energy Policy Act 2005* to the next few plants built. Generation IV technologies which will not likely be available before 2030 might offer a more competitive price but they are subject to substantial economic and technical uncertainties.

BHP Billiton supports the emphasis in the submission to the Review by the Minerals Council of Australia on the importance of government support in Australia for technology development across a portfolio of technologies.[32] The objective of those technologies would be to achieve consistent, large-scale emission reductions without imposing inefficiently high costs in the

[32] Minerals Council of Australia 2006, *Submission: Review of Uranium Mining, processing and nuclear energy in Australia*, August, p. 17.

near term. Deployment of these technologies as they progressively become available is likely to require some form of market incentive.

As with other aspects of the nuclear fuel cycle, BHP Billiton reiterates that it does not wish to advocate the merits of nuclear power generation in Australia and has no intention of entering that market. Its investment in the expansion of the Olympic Dam is not dependent in any sense on the establishment of a domestic nuclear power industry.

4.4 Implications for policy

Current and prospective nuclear technologies are not price competitive with fossil fuel power in Australia. At the carbon price (or subsidy) necessary to make nuclear power generation more commercially attractive, other technologies, including wind, geothermal, biomass, as well as energy conservation, would also become more attractive. The relative attractiveness of each technology would be dependent on locational characteristics and the characteristics of the power supply sought (base load, peaking etc.). In these circumstances, it would be consistent with Australia's highly efficient market based approach to the power sector to provide the appropriate incentives—which would involve credible mechanisms to allow markets to make judgements about forward carbon prices or subsidies—and allow the market to make the appropriate technology and investment choices.

However, as has been noted earlier in section 1.6, any national greenhouse gas emissions trading scheme that is introduced in advance of more comprehensive international greenhouse frameworks runs a serious risk of merely driving trade exposed energy intensive activity to countries that do not have the same obligations unless it can deal with the competitive disadvantage it imposes.

Chapter 5

Product stewardship

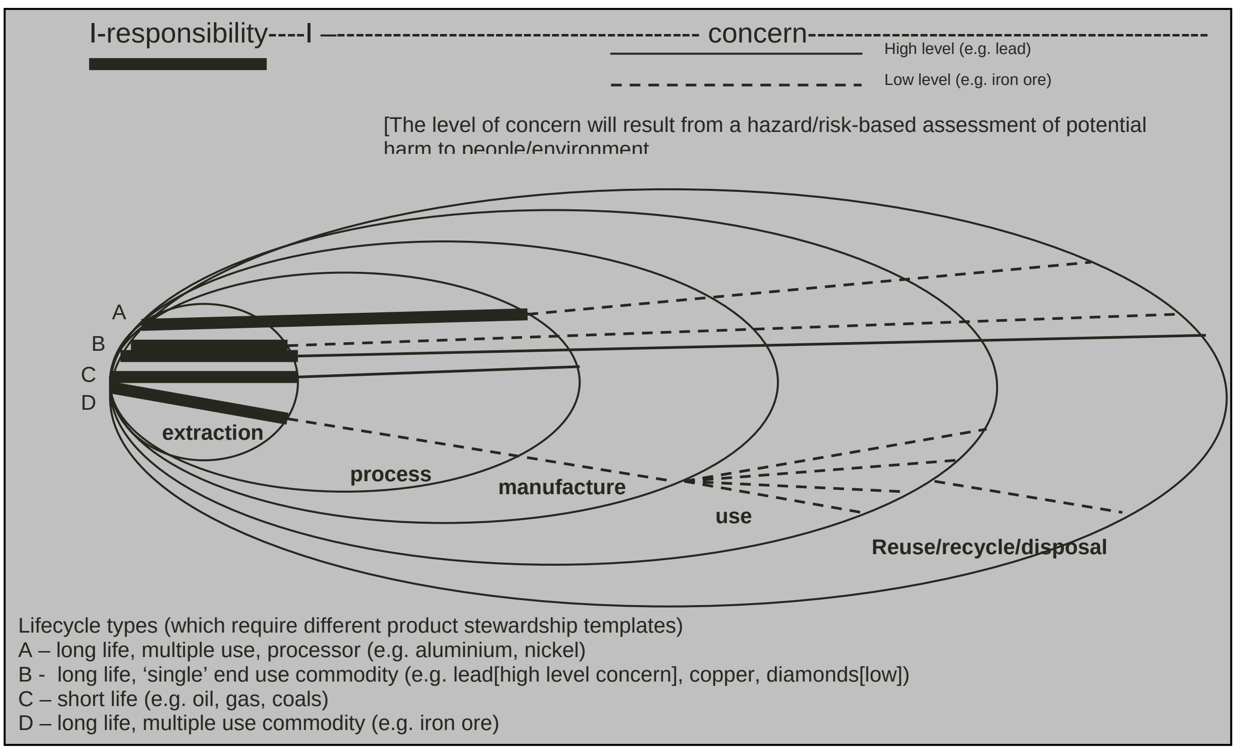
BHP Billiton takes corporate responsibility very seriously. It underpins our social licence to operate and upholds the company's global reputation. Our product stewardship program is a key component of the company's activities in this area, as evidenced by our actions to expand product stewardship across all our products, and in leading moves to develop an internationally endorsed product stewardship model for uranium.

5.1 Our stewardship model

A product stewardship model was developed by BHP Billiton in 1999, beginning with a project for lead. Following its acquisition of WMC Resources Limited in 2005, BHP Billiton expanded the stewardship project and developed a model that which clearly differentiates between areas of product responsibility and areas of concern for a product, for different life cycles and commodities.

Figure 5.4

BHP BILLITON'S CONCEPTUAL MODEL OF RESPONSIBILITY AND CONCERN RELATIONSHIP FOR DIFFERENT LIFE CYCLES AND COMMODITIES



A cornerstone of an effective stewardship model is that those who are best placed to manage a risk (health, environmental or proliferation) should be responsible for doing so. In relation to uranium, the focus of the stewardship model (see Figure 5.4) is on those phases of the cycle for which BHP Billiton has a direct responsibility: from extraction of the ore and until ownership of U_3O_8 is transferred at the converter.

Our concern is to minimise potential harm to people and the environment. Any stewardship plan developed by the commercial players in the nuclear fuel cycle should be located within an appropriate framework of government regulation—in Australia this is provided by State and Commonwealth governments—covering health, environmental and proliferation risks.

5.2 Engagement of WNA and UIF

Maintaining public acceptance of a vibrant uranium concentrates export industry is vital to underpin the economic and greenhouse contribution that the uranium mining industry can make. Any significant accident or failure in any uranium mine that damages the environment or public health—or any failure to deal fairly with indigenous and other communities—will impact on the public's attitude to all mines.

For this reason BHP Billiton has been concerned to play a leadership role in engaging both governments and other participants in mining and milling in Australia, and reaching out to others in the broader nuclear fuel cycle.

BHP Billiton strongly supports the Minerals Council of Australia's current recommendation that the Australian uranium mining industry establish uranium stewardship approaches through the World Nuclear Association (WNA) and other relevant international forums, and applies the outcomes to its operations, recognising that those operations are limited to the mining of uranium, production and transport of uranium oxide concentrate and management of radioactive waste in the form of tailings produced from those operations.[33]

During 2005, we held extensive discussions on uranium stewardship, internally, and externally with stakeholders such as the WNA to establish its Uranium Stewardship Working Group—whose members include all sectors of the fuel cycle—and within the Uranium Industry Framework where we again took the initiative to establish another Uranium Stewardship Working Group.

To date these working groups have developed the following outcomes.

For the UIF working group meeting in July 2006, there was acknowledgement that:

- Uranium stewardship is the management of uranium throughout its life cycle to maximise value and minimise the safety, environmental and social impacts of its production, use, recycling and/or disposal.

[33] Minerals Council of Australia 2006, *Submission: Review of Uranium Mining, processing and nuclear energy in Australia*, August, p. 35.

- Ongoing community concerns and associated political restrictions remain key impediments to the sustainable growth of the uranium mining industry in Australia, and its ability to respond to expected growth in world energy demand.

- Uranium stewardship provides a useful means of addressing current impediments to the sustainable development of the uranium industry by shaping public perceptions and building community confidence through better demonstration of how uranium is managed by operators in each step of the uranium fuel cycle.

- The Australian minerals industry's primary focus is on its direct responsibilities for continually improving the environmental and social performance of its mining operations—this includes current operations and any new operations that may be proposed and approved in the future.

- A uranium stewardship platform provides the industry a capacity to engage in the global life cycle of uranium use and management, through influencing the actions of other stakeholders.

- The UIF uranium stewardship working group recommends that the Australian uranium industry establishes a uranium stewardship platform as the basis for engagement with the global uranium stewardship programs currently being developed by the World Nuclear Association.

Outcomes from the WNA working group:

- There will be a uranium stewardship programme of action to enable and demonstrate that uranium is produced, used and disposed of in a safe and acceptable manner. The programme will take a life cycle approach and encourages use of leading practices for health, safety, environment, and social aspects along the value chain and emphasises waste minimisation and encourages recycling.

- This is the first time that all sectors of the uranium life cycle sat around the same table to discuss stewardship.

- The ongoing plan is to identify 'best practice' in each sector of the life cycle and to get the participants in the uranium stewardship program to ensure that best practise becomes standard globally, across the life cycle; several examples of best practise in other sectors of the uranium life cycle have be observed by BHP Billiton personnel as part of our education in understanding how other sectors of the life cycle minimise potential harm to people and the environment in their sector of responsibility.

- The Uranium Stewardship Working Group provides an opportunity for all sectors of the life cycle to understand, appreciate and potentially learn from each other.

- Uranium stewardship is a shared responsibility by all sectors in the uranium life cycle.

- The next meeting of WNA Uranium Stewardship Working Group will be held in September 2006.

BHP Billiton will take an active role in work by the nuclear industry to address stewardship concerns for the entire Uranium life cycle. The UIF Steering Group is suited to taking a lead role and to coordinating development of the stewardship model through its Uranium Stewardship Working Group. BHP Billiton will seek to include customers and other participants in the value chain in the development of the UIF stewardship model.

BHP Billiton would like to see the UIF Uranium Stewardship Working Group brief broadened to ensure that no non-profitable uranium mines are left in a poor state of rehabilitation.

Through engagement with the WNA and UIF, BHP Billiton is seeking to extend its model of responsible product stewardship to the global marketplace.

5.3 Implications for policy

The nuclear fuel cycle is so complex and subject to potential risk that stewardship cannot be the responsibility of any one commercial player. BHP Billiton's direct responsibility is for the mining, milling and transport of its product to the point that control and ownership passes to the user. That said, each player in the chain is obliged to exercise proper care and concern—even in areas beyond their responsibility and capacity to directly manage risk. This requires cooperation among the partners in the industry, and BHP Billiton has been an active participant, and moving force, in the development of an industry wide stewardship framework through the Uranium Industry Framework and World Nuclear Association forums.

However, there is a core responsibility on all governments involved in the approval and regulatory oversight of each step in the chain to ensure that the relevant parties exercise their responsibilities to avoid proliferation, to protect the environment and human health, and to avoid accident. BHP Billiton is confident that arrangements put in place by the Australian Government do that successfully and provide an important part of the critical governance framework within which the industry stewardship initiative can make a contribution.

BHP Billiton therefore underlines the importance of world's best practice in health, safety, environmental, indigenous, community and safeguards arrangements for all Australian uranium mines and exports—an obligation on all governments and all uranium miners.

Appendix A

Abbreviations

ANSTO	Australian Nuclear Science and Technology Organisation
AONM	Australian obligated nuclear material
ASNO	Australian Safeguards and Non-Proliferation Office
BHPB	BHP Billiton
DEH	Department of Environment and Heritage
DFAT	Department of Foreign Affairs and Trade
DITR	Department of Industry Tourism and Resources
FIFO/DIDO	fly in, fly out / drive in, drive out
EIS	Environmental Impact Statement
GIF	Generation-IV International Forum
GNEP	Global Nuclear Energy Partnership
GW	gigawatt
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
HLW	high level waste
HEU	highly enriched uranium
JSCOT	Joint Standing Committee on Treaties
MCA	Minerals Council of Australia
MW	megawatt
NNWS	non-nuclear weapon states
NWS	nuclear weapon states
NPT	Non-Proliferation Treaty
OSS	Office of the Supervising Scientist
TWh	terawatt-hour (10^9 kWh, kilowatt-hours)
U	uranium
U-235	uranium isotope 235
UF_6	uranium hexafluoride
U_3O_8	uranium oxide
UIF	Uranium Industry Framework
UMPNER	Uranium Mining Processing and Nuclear Energy Review
USWG	Uranium Stewardship Working Group
WNA	World Nuclear Association

Appendix B

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