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Australian Uranium Association

Outlook for the Uranium Industry

Evaluating the economic impact of the Australian uranium industry to 2030

April 2008

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Contents

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This report was prepared for the Australian Uranium Association solely for the purpose of providing an economic analysis of the potential expansion of the Australian uranium industry.

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Summary and conclusions

Summary

After decades in the doldrums, with demand stagnant and contract prices at a low level, the world's uranium industry is experiencing a period of what looks likely to be sustained growth. Contract prices have risen to around US$90/lb (up from less than US$20 a few years ago), existing mines are expanding production and exploration expenditure has increased substantially. In Australia's Northern Territory alone, where there were only four exploration permits earlier this century, now there are over one hundred.

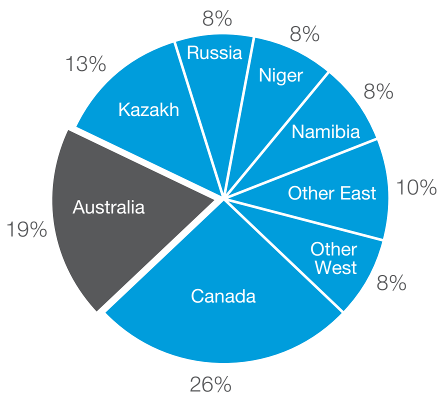
Two major factors, concerns about energy security and climate change, are driving the renaissance of nuclear power around the world and, hence, the fortunes of the uranium industry.

Australia's opportunity

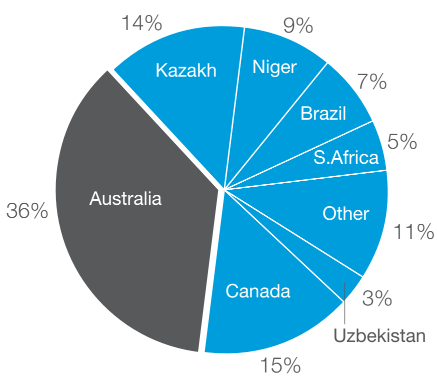
The growth of the global uranium market offers major opportunities for Australia. As shown in the chart below, Australia has by far the largest share of estimated uranium resources with over a third of the world's resources[1] at a price of US$40/kg. Yet currently Australia's share of the world market for uranium remains below 20 per cent.

Figure ES.1: Resources[2] compared with production (2006)

Primary supply 2006
(46,530 tonnes U_3O_8, 65%)



Reasonable Assured Resources
(< US$40/kg, 1.9 Mt U)



Source: Salisbury, C., 2007, *Energy Resources of Australia: Providing Energy for the Future*, Energy Resources Australia, presentation to the Melbourne Mining Club 17 December, Darwin, p 9.

The failure to convert a strong resources position into a comparable share of the world's uranium market does not reflect badly on Australian industry. Rather it reflects a political situation where Australians have been divided in terms of their attitude to the industry. Opposition to the uranium industry developed in the late 1970s and then in the early-1980s manifested itself in a policy adopted by the Australian Labor Party that limited the industry to three existing mines. Until this policy was overturned by the ALP in April 2007, it discouraged exploration and prevented the development of new uranium mines in Australia for nearly a quarter of a century.

Although the ALP's change in policy in 2007 should have removed the main regulatory barrier to industry development, there has been a delay in the implementation of the policy at the State level. None of the governments in the four States that ban uranium mining have yet moved to implement the new ALP policy.

Uranium market dynamics

The state of the world's uranium market is almost wholly dependent on the global fortunes of the nuclear power generation industry. All of Australia's uranium finds its way to the end use of electricity generation.

The nuclear energy sector is currently enjoying a renaissance. There are two major strategic reasons for this and a number of tactical or technical factors. Among the latter is the fact that a new generation of reactor designs promise even greater safety margins as well as significantly cheaper electricity. In addition, ideological issues from the 1970s and 1980s have less resonance with a generation that has grown up since the end of the Cold War.

The two strategic issues are energy security and climate change.

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1 As per the definitions applied by GeoScience Australia in regards to uranium deposits, the term 'resources', instead of 'reserves', is used to refer generically to describe a uranium deposit. Where JORC specific statistics are provided throughout this report, the term 'reserves', within the JORC definition of reserves, will be used to describe the uranium deposit. Where OECD Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA) specific statistics are provided throughout this report, the term 'resources' within the OECD/IEA definition of resources will be used. Where OECD Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA) specific statistics are provided throughout this report, the term resources within the OECD/IEA definition of resources will be used.

2 The term 'resources' refers to the OECD/NEA definition of uranium resources.

Continuing tension in the Middle East in the wake of the Iraq war and the subsequent insurgency, together with interrupted supplies from other regions, raises doubts about the security of gas and oil supplies to the west. When this uncertainty occurred previously, in the 1970s, it brought about the first major boom in the nuclear industry. The same effect can be seen now and is cited in both the US and UK, for example, as a reason for turning back to nuclear power.

Australia, with its political stability, low sovereign risk and reputation as an efficient and reliable supplier of natural resources, is very well placed to benefit from these concerns about energy security. Not only does Australia have the largest share of the world's coal trade, but our trade in liquefied natural gas (LNG) is also growing rapidly, underpinned by very substantial gas resources offshore in the north-west. Add to this the future opportunities in uranium, where Australia's share of global resources exceeds Saudi Arabia's share of the world's oil resources, and an aspiration for Australia to become a so-called 'energy superpower' does not look misplaced.

The impact on the uranium industry of global policy measures to address anthropogenic climate change may be even more substantial and long lasting. Following the fourth report of the Intergovernmental Panel on Climate Change (IPCC), completed in 2007, the world appears to be ready to take substantial action to reduce emissions of greenhouse gases (GHGs). Developed nations will negotiate an interim reduction to 2020, with cuts of between 25 and 40 per cent from 1990 levels being on the table.

The dilemma here is that at the same time as there is a requirement to reduce emissions of GHGs, projections of global energy demand to 2030 suggest that electricity generation capacity will need to double in a little over twenty years.

Emissions reductions of the magnitude that are being discussed would have a very considerable impact on the electricity generation sector, which globally is dominated by current technology coal plants with a high carbon footprint.
In the medium term, the response of the stationary energy sector to climate change will involve a portfolio of technologies. Renewables and gas will make an important contribution, mainly in providing intermediate and peaking power although geothermal energy shows promise as a source of base load electricity. Since it is difficult to see how the world's demand for electricity to 2050 could be met without a major contribution from coal, it also seems essential that the development of commercially viable carbon capture and storage (CCS) technologies proceeds successfully.

Investment in nuclear power

While low carbon alternatives to nuclear power are under development, not all of these technologies are available now while those that are may not yet be commercially attractive. Nuclear energy is "carbon free" and can provide reliable base load power at a cost not significantly greater than current coal generation.

The Executive Secretary of the IPCC stated at Bali that:

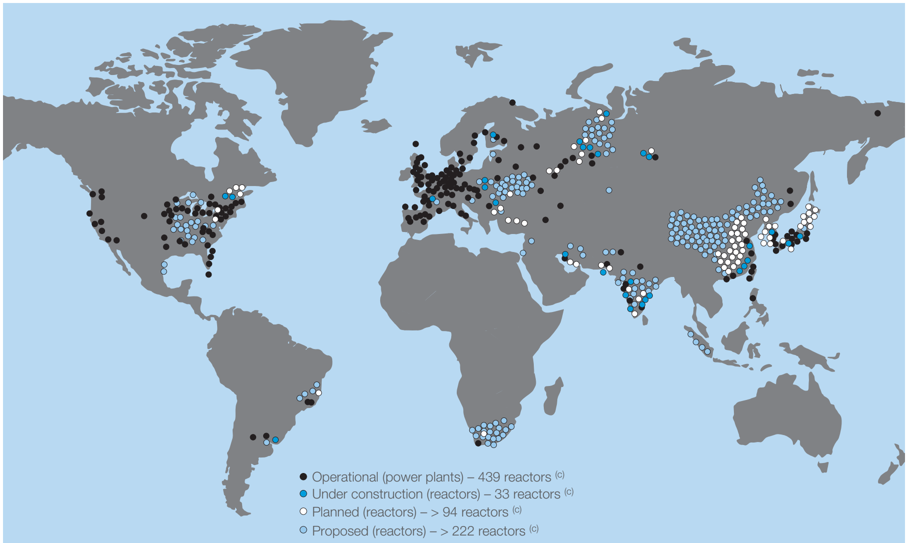
I have never seen a credible scenario for reducing emissions that did not include nuclear energy.[3]

The recent British White Paper on nuclear power concluded that:

Nuclear power is the most cost effective low-carbon generation technology. It has an estimated abatement cost of £0.3/t CO_2 compared to onshore wind power, the next nearest currently available low-carbon electricity generation technology, which has an estimated abatement cost of £50/t CO_2.[4]

As a result of these various factors, an increasing number of new nuclear generators are being built and planned. According to BHP Billiton, 33 reactors are currently under construction globally, another 94 are estimated to be either on order or in the advanced planning stage while there are proposals for a further 222 generators (Figure ES.2)

Figure ES.2: Existing and planned nuclear power reactors



Source: (c) World Nuclear Association information as at 17 October 2007, reproduced in BHP Billiton, 2007, *BHP Billiton and Rio Tinto: A Matter of Value*, BHP Billiton, Melbourne, p 29.

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3 Quoted in Angus Grigg, 'Nuclear test for Rudd,' *Australian Financial Review*, 8-9 December 2007, Sydney, page 22

4 Department for Business, Enterprise and Regulatory Reform, 2008, *Meeting the Energy Challenge: A White Paper on Nuclear Power*, http://www.berr.gov.uk/files/file43006.pdf [January 2008], London, page 66. While not stated explicitly, it appears that the high relative cost of wind power is boosted by the need to provide back-up generation for base load power.

Three examples of this shift in favour of nuclear power are provided by:

- The United States, where, after twenty years of no activity, the Nuclear Power 2010 program has been developed to provide government facilitation and some financial support to the private sector to construct a new generation of nuclear power plants. In addition, the Bush administration has developed the Global Nuclear Energy Program (GNEP) to assist countries around the world to install safe nuclear power generators and reduce the risk of proliferation.
- The UK, where the Labour government has performed an about face from its previously announced policy of phasing out existing nuclear plants and not building any new ones. Its White Paper, published in January 2008, states that the government will support the construction of a number of new nuclear generators on the basis that this will both provide greater energy security and allow Britain to meet its emissions reduction targets more reliably and at a lesser cost.
- South Africa, which as a major coal exporter with considerable uranium resources has some similarities to Australia. Electricity generation in South Africa is currently dominated by coal, but a new nuclear power program will provide 30 per cent of electricity supplies by 2030. South African scientists and engineers have built on German research to develop the Pebble Bed Modular Reactor (PBMR), which potentially offers considerable advantages in terms of flexibility, safety and economics. PBMR reactors can be built in modules each providing 165MW of power. Cooled by helium gas, they do not need to be located next to a large body of water.

These are only three examples of the many countries that are taking up the nuclear generation option. In particular China, which is also working on pebble bed designs, may be gearing up to invest heavily in nuclear power in the next few years.

Another important consideration regarding nuclear power is that technological developments are occurring at a rapid pace. Generation III and IV reactors offer substantial improvements over earlier models, in terms of flexibility, efficiency, costs and safety. These developments are often the result of over half a century of research.

Australia's supply potential

Australia currently has three operating mines, Ranger in the Northern Territory and Olympic Dam and Beverley in South Australia. A fourth mine, Honeymoon in South Australia, has also recently been approved. In 2007, Australia exported 10,232 tonnes of uranium oxide (yellowcake) valued at $881 million.

Australia is well placed to expand its supplies of uranium to world markets. Future supply scenarios are substantially influenced by Olympic Dam, where BHP Billiton is examining the feasibility of expanding annual production of U_3O_8 from around 4,000 tonnes currently to 19,000 tonnes. Although the full extent of the resources at Olympic Dam is still uncertain, currently around 230,000 tonnes of U_3O_8 have been discovered, making it the largest uranium resource in the world.

A number of other important discoveries were made in the 1970s and 1980s but never developed. This owed much to the three mines policy as well as the slump in global demand for uranium. Many of these prospects are now set to be developed. Two other potential mines in South Australia have reserves totalling around 35,000 tonnes of U_3O_8. In the Northern Territory the Ranger mine still has reserves estimated at over 80,000 tonnes, while other as yet undeveloped prospects in the Territory add around 130,000 tonnes to total resources.

Importantly, there are also major prospects in Western Australia and Queensland, where uranium mining remains prohibited. Located in Western Australia are two very substantial deposits, Yeelirrie and Kintyre. Total reserves in these two and in five other prospects in Western Australia are estimated at around 172,000 tonnes.

In Queensland, six important prospects are noted in this report, including Valhalla and Westmoreland, with possible resources of U_3O_8 amounting to over 46,000 tonnes in that State.

These projections of resources almost certainly underestimate the true situation substantially. Since the 1980s and until relatively recently, exploration activity has been at a very low level in Australia, while exploration for uranium is still prohibited in NSW and Victoria.

Two scenarios for uranium industry development to 2030

In order to estimate the economic impact of the growth of the Australian uranium industry out to 2030, it is necessary to take a view about how the world's energy policy will develop in the future. In this report, two scenarios are developed, based to a large degree on reasonable expectations of the future global response to the threat of climate change. Climate Action represents the minimum expected rate of change in key economic variables in response to climate change. This is a highly likely global demand scenario. The second scenario is less certain; the realisation of this scenario will depend on the rate of climate change realised and the extent to which potentially more aggressive emissions cuts are pursued globally. Our analysis of these issues is set out at length in Chapter 4 of this report in order to justify the assumptions that underlie the scenarios.

The first of the scenarios – Climate Action – represents a moderately conservative approach to reducing greenhouse gas emissions, while the other – Climate Crisis – is less certain to eventuate and paints a picture of a world in which accelerating climate change induces governments to take strong action to reduce emissions. The two scenarios reflect, to a large degree, the alternative stabilisation pathways contained in the work of the IPCC: that is, limiting average global temperature rises to three and two degrees Celsius respectively.

In order to provide a yardstick against which to measure the economic effects of these scenarios, a 'base case', or business-as-usual projection is also developed.

These three views of the future are summarised below.

- *Base case* – a projection of the global uranium market based on government action to reduce greenhouse gas emissions remaining at around its current low level. In this instance, the business as usual case is based on the IEA Reference scenario forecasts for 519 GWe (519 reactors each with an installed capacity of 1,000 MWe) by 2030. This was considered to be the level of demand that would occur globally if no significant action on climate change were to occur. While this may seem a modest increase in the light of the current planned expansion of the industry worldwide, it needs to be considered in the context of the fact that many of the older reactors around the world will need to be decommissioned by 2030. In order that the base case can provide a yardstick against which the impact of industry growth may be assessed, the assumption is made that Australia's uranium production remains at around current levels.
- *Climate Action scenario* – the world takes relatively moderate action to address climate change, with a longer term aim of stabilising carbon concentrations in the atmosphere at 550 parts per million. Globally, emissions will be reduced by significantly less than the target of 25-40 per cent from 1990 levels that remains on the table for developed countries following the Bali conference in December 2007. As a consequence, around 960 nuclear reactors are operating world wide by 2030. This projection is consistent with the IPCC's projections for the uptake of nuclear power generation under a global US$50 carbon price. The global demand estimates also accord with ABARE and UMPNER projections. Critically, the IPCC is the only body that has explicitly considered the impact of a carbon price on demand for nuclear power. Under this scenario, the uranium contract price is US$100/lb compared with around US$90 today. Since the scenario involves an increase in market demand of about 85 per cent, this price appears entirely plausible.
- *Climate Crisis future* – an increased rate of climate change drives substantial global policy action, with a goal of stabilising carbon concentrations at around 450 parts per million. While this may seem an extreme outcome, requiring cuts in GHG emissions of 60 per cent or more by 2050, it reflects exactly what the IPCC (and Garnaut) is advising needs to be done. Scientists are concerned that an increase in average global temperatures of over two degrees might drive the world to a tipping point, particularly, for example, in terms of slowing or shutting down the thermohaline ocean circulations. The US$100 CO_2-e price factored into the scenario is, if anything, conservative in this context. As a consequence, 1,634 nuclear reactors are operating world wide by 2030. The projected contract price for uranium of US$150/lb in 2030 reflects a situation where nuclear energy becomes so competitive, thanks to the carbon price, that its use is limited only by the supply of uranium. The incentive would be there for Australian uranium production to expand very substantially.

Contained within each scenario are two alternative Australian uranium supply futures: Regulation Reform, where South Australia, the Northern Territory, Queensland and Western Australia all allow the mining and export of uranium oxide, and Constrained Supply, where only South Australia and the Northern Territory are included. Within the Climate Action scenario, Australia would supply 25 per cent of the world market under Regulation Reform, otherwise market share would remain at the present level of 19 per cent. Within Climate Crisis, Australia's market share is projected to be 30 per cent and 24 per cent under Regulation Reform and Constrained Supply respectively. The scenarios are summarised in Figure ES.3.

Economic impact of an expanded Australian uranium industry

The modelling results show that the expansion of Australia's uranium mining industry would have a major beneficial impact on the Australian economy. The results are presented in the form of NPVs to 2030, with a seven per cent discount rate.

It should be emphasised that these figures compare the economic impact of increased uranium mining against a base case, or business-as-usual scenario, under which the level of uranium mining in Australia remains as it is today. In addition, no negative impacts on other industries (such as coal) resulting from policy action on climate change have been factored in.

Finally, it should also be noted that because the MMRF model incorporates resource constraints, any economic shock, such as the growth of uranium mining, has a negligible impact on the overall level of employment. While employment will generally increase in the States where the increased activity occurs, this will tend to 'crowd out' employment growth in other jurisdictions.

Figure ES.3: Key assumptions by scenario

REGULATION REFORM: Uranium mining allowed in South Australia, the Northern Territory, Western Australia and Queensland

REGULATION REFORM IN A CLIMATE ACTION WORLD 960 (1,000MWe) nuclear power reactors Australia accounts for 25% global demand by 2030 (37,000t U_3O_8 from SA, NT, Qld and WA)	REGULATION REFORM IN A CLIMATE CRISIS WORLD 1,634 (1,000MWe) nuclear power reactors Australia accounts for 30% global demand by 2030 76,000t U_3O_8 from SA, NT, Qld and WA)
Climate Action world: US$50 CO_2 price CONSTRAINED SUPPLY IN A CLIMATE ACTION WORLD 960 (1,000MWe) nuclear power reactors Australia accounts for 19% global demand by 2030 (28,500t U_3O_8 from SA and NT only)	Climate Crisis world: US$100 CO_2 price CONSTRAINED SUPPLY IN A CLIMATE CRISIS WORLD 1,634 (1,000MWe) nuclear power reactors Australia accounts for 24% global demand by 2030 (61,250t U_3O_8 from SA and NT only)

CONSTRAINED SUPPLY: Uranium mining allowed in South Australia and the Northern Territory only

Source: Deloitte Economics

In terms of NPVs to 2030, in net terms:

- Under the *Climate Action* scenario, Australia's GDP would be $14.2 billion higher than otherwise and Consumption $12.3 billion higher if mining continued only in South Australia and the Northern Territory.
- Under the *Climate Action* scenario, Australia's GDP would be $17.4 billion higher than otherwise and Consumption $15.3 billion higher if mining were also allowed in Western Australia and Queensland.
- Under the *Climate Crisis* scenario, Australia's GDP would be $26.8 billion higher than otherwise and Consumption $23.6 billion higher if mining continued only in South Australia and the Northern Territory.
- Under the *Climate Crisis* scenario, Australia's GDP would be $32.3 billion higher than otherwise and Consumption $28.5 billion higher if mining were also allowed in Western Australia and Queensland.

Another benefit of the industry's development for Australia as a whole lies in the potential impact on global greenhouse gas emissions. Under the Climate Crisis scenario, for example, with Western Australia and Queensland allowing mining, the supply of Australian uranium to nuclear generators would potentially remove around 2.5 billion tonnes of GHG emissions globally compared with the supply of a similar quantity of electricity from current technology coal plant. This reduction is equivalent to around 5 per cent of current global emissions.

The results of the modelling for South Australia and the Northern Territory under these scenarios are shown below in Table ES.1 above. These impacts, particularly for South Australia, are extremely high, with Gross State Product being between $21 billion and $37 billion higher in NPV terms to 2030 than otherwise would be the case. The increase in consumption, a measure of the economic welfare of the community, is also very substantial. In the context of South Australia's population, currently well under 1.5 million people, these economic impacts are massive. They are due mainly to the impact of the expansion of Olympic Dam.

Table ES.1: Economic outcomes for South Australia and The Northern Territory

	Climate Action Scenario		Climate Crisis Scenario	
	Constrained Supply ($NPV_{7\%}$, 2008-2030)	Regulation Reform ($NPV_{7\%}$, 2008-2030)	Constrained Supply ($NPV_{7\%}$, 2008-2030)	Regulation Reform ($NPV_{7\%}$, 2008-2030)
South Australia				
GSP	$21,034m	$20,929m	$37,244m	$37,044m
Consumption	$9,276m	$9,346m	$16,489m	$16,572m
Investment	$6,383m	$6,374m	$11,498m	$11,474m
Government Revenues	$2,510m	$2,510m	$4,484m	$4,476m
Northern Territory				
GSP	$2,409m	$2,301m	$5,982m	$5,811m
Consumption	$852m	$844m	$2,104m	$2,064m
Investment	$444m	$405m	$1,183m	$1,114m
Government Revenues	$337m	$330m	$820m	$808m
Greenhouse Gases Avoided Globally (2008-2030)	**11,379Mt**	**14,917Mt**	**18,918Mt**	**23,431Mt**

Source: MMRF and Deloitte Economics

Given that the Northern Territory's population is a little over one-tenth of that of South Australia, the impacts on the Territory's economy are comparable in their magnitude.

This extremely high positive impact on the economies of South Australia and the Northern Territory would inevitably have some crowding out effects in other jurisdictions, including Queensland, where growth in GSP is slightly lower than it otherwise would have been.

The results for Western Australia and Queensland, presented in Table ES.2 on the following page, are shown not relative to the Base Case but compared to the scenarios where Australia's uranium production expands only in South Australia and the Northern Territory.

In interpreting these results it must be remembered that any evaluation of Australia's uranium futures will be dominated by Olympic Dam. This means that the massive impact projected for South Australia's economy as a result of uranium industry expansion makes everything else appear to be relatively modest. Yet in any other circumstances and in their own right in this case, these impacts on Western Australia and Queensland would be regarded as highly positive.

If Western Australia changed its policy on uranium mining, for example, the NPV of the projected impact on its Gross State Product to 2030 ranges up to $5.2 billion. The equivalent figure for Queensland is over $2.5 billion, a very significant increase in itself.

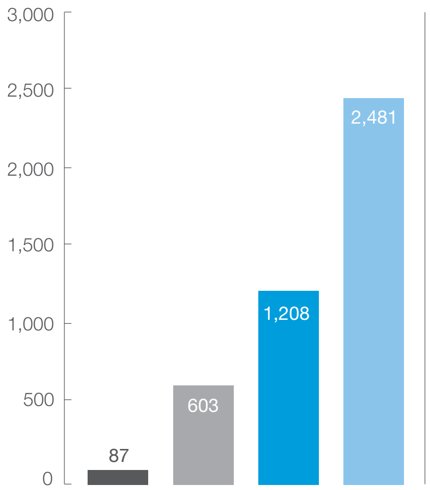
Table ES.2: Economic outcomes for Western Australia and Queensland

	Climate Action Scenario Regulation Reform	Climate Crisis Scenario Regulation Reform
Western Australia		
GSP	$3,248m	$5,186m
Consumption	$1,362m	$2,161m
Investment	$838m	$1,236m
Government Revenues	$462m	$744m
Queensland		
GSP	$1,478m	$2,529m
Consumption	$931m	$1,582m
Investment	$508m	$830m
Government Revenues	$204m	$346m
Greenhouse Gases Avoided Globally (2008-2030)	14,917Mt	23,431Mt

Source: MMRF and Deloitte Economics

Implications for the global greenhouse challenge

Figure ES.4: Greenhouse gas emissions reductions



Australia's CO_2 emissions reduction requirement by 2010 to meet Kyoto target

Australia's average annual CO_2 emissions from 2008-2012

Mt of CO_2 avoided globally based on Australia's exports of uranium in 2030 in the Climate Action scenario (Reg Reform)

Mt of CO_2 avoided globally based on Australia's exports of uranium in 2030 in the Climate Crisis scenario (Reg Reform)

Source: Deloitte Economics and Australian Greenhouse Office, 2006, Tracking to the Kyoto Target: Australia's Greenhouse Emissions Trends 1990 to 2008–2012 and 2020, Department of Environment and Heritage, Australian Government, Canberra.

The increase in the global use of nuclear power in the future will have a very substantial beneficial impact on greenhouse gas emissions.

This is illustrated in Figure ES.4. Under the Climate Action/regulatory reform assumption, for example, and compared with coal-fired electricity generation, Australia's exports of uranium will bring about the avoidance of more than 1.2 billion tonnes/CO_2-e emissions in 2030 alone. The equivalent figure for the Climate Crisis/regulatory reform scenario is nearly 2.5 billion tonnes. These are clearly very significant numbers.

Conclusions

Two important global strategic considerations, energy security and the response to climate change, have combined to provide highly favourable circumstances for the future development of the world's uranium industry.

These two issues, combined with the development of a new generation of atomic reactors, have led to a renaissance of nuclear generation worldwide. Over 350 new reactors are currently at the proposal, planning or construction phase.

Several developed economies, faced with the prospect of being required to make substantial cuts in GHG emissions, are already turning to nuclear power as the most economic and efficient currently available technology for generating significant quantities of base load power.

With around 36 per cent of global uranium resources, Australia's reputation as a politically stable, reliable energy supplier offers a great opportunity to take advantage of this very favourable market situation. On the other hand, there are regulatory issues that compromise the industry's ability to respond fully to this challenge. First, despite a change in the ALP's policy at the federal level, most Australian States maintain bans on uranium mining. Secondly, there are overlaps and inconsistencies in the general regulatory framework for the industry that could prejudice the rate of development.

Australian governments will recognise that the removal of these regulatory barriers would bring about a considerable prize. The modelling presented in this report suggests that the economic rewards to the Australian community from the growth of the Australian uranium industry would be very substantial, with a highly positive impact on living standards. The impact on the South Australian and Northern Territory economies will be highly positive. Were Western Australia and Queensland to change their policies in favour of uranium mining, their communities would also derive significant economic benefits while making an important contribution to reducing greenhouse gas emissions worldwide.

1 Prospects for Australian Uranium

This chapter analyses the environmental, economic and political drivers of demand for nuclear power globally and in turn, demand for uranium from Australia.

1.1 Uranium mining in Australia

After decades of poor performance, the uranium industry is booming again. In 2006-07, the uranium price increased, in real terms, to levels not seen since the oil shocks of the 1970s. Uranium miners are now enjoying good returns and looking forward to even better results in the future. Resources previously considered marginal have become economic, so that mine lives are being extended significantly. After years of very low exploration activity, activity in the industry is at a high level – for example, where less than ten exploration permits for uranium were current in the Northern Territory a few years ago, now there are over one hundred.

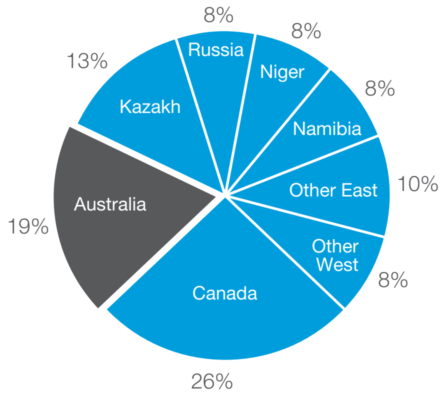
This is good news for Australia. Of the world's reasonably assured resources[5] of uranium, Australia is estimated to have the greatest share at 36 per cent – Canada comes next with 15 per cent (see Figure 1.1). While Australia has the largest economic resources[6] of uranium, however, we are only the second largest producer and command less than 20 per cent of the global market. In 2006, Canada's production exceeded Australia's by 30 per cent. This suggests that the Australian industry has a considerable potential to perform much better, both in terms of increasing uranium exports in absolute terms and growing market share.

The main end use for Australia's uranium, after it has been enriched, is as a fuel for nuclear power generation. The future demand for uranium will therefore be directly linked to the number of nuclear reactors installed globally in the coming decades. As discussed in this Chapter, after several decades of stagnation, the future outlook for nuclear power generation is probably more positive then ever before. The threat of climate change has radically altered the energy landscape across the globe. One particular impact of this is that, with carbon beginning to have a price, the economics of nuclear power will change significantly in the next few years. In addition, the current uncertainty regarding energy security in a number of major economies is also driving a desire in many western countries to diversify energy supplies away from oil and gas.

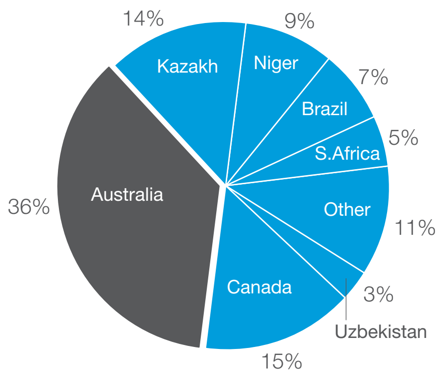
Any analysis of the uranium industry cannot be decoupled from issues surrounding its end use, in fuelling the nuclear energy industry. Nuclear power has become a political issue in many developed economies, mainly among the generations who lived through the Cold War. The changed competitive position of nuclear power over the coming decades, however, means that there will be some tension in some countries between the industry's increasingly positive economic benefits and the politics of allowing the industry to grow.

Figure 1.1: Resources compared with production (2006)

Primary supply 2006
(46,530 tonnes U_3O_8, 65%)



Reasonable Assured Resources
(< US$40/kg, 1.9 Mt U)



Source: Salisbury, C., 2007, *Energy Resources of Australia: Providing Energy for the Future*, Energy Resources Australia, presentation to the Melbourne Mining Club 17 December, p 9.

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6 As per the definitions applied by GeoScience Australia in regards to uranium deposits, the term resources, instead of reserves, is used to refer generically to describe a uranium deposit.

1.2 Politics and economics

1.2.1 Australia's three mines policy

The fact that the Australian uranium industry has performed below its potential reflects past government decisions rather than any obvious failure on the industry's part. Concerns regarding nuclear issues have long been held in sections of the Australian Labor Party (ALP) and, as with other left of centre parties around the world, these reached their peak in the late Cold War period of the 1970s and 1980s. This culminated in the Hawke government policy, announced in 1984, to limit the uranium industry in Australia to three mines – the existing Ranger and Nabarlek operations in the Northern Territory, and a new mine, Olympic Dam, to be developed in South Australia. The three mines policy was replaced by a 'no new mines' commitment when the ALP went into opposition in 1996, meaning that if the party returned to government it would not revoke the licence of any uranium mine that had been approved in the interim but it would not approve any new licences.

The effect of this policy was to remove almost all incentives for exploration or new mine development in Australia for over two decades. Exploration seemed pointless, while none of the highly prospective deposits discovered in the 1970s or early 1980s could be developed. Even when a non-ALP government was in office in Canberra, the length of time required for the approvals process for a new uranium mine meant that there could be no certainty that it would be completed in the three year period before another election.

In April 2007, however, the ALP overturned its 'no new mines' policy, thereby apparently giving the green light to rapid industry development. The difficulty is, however, that in practical terms the lights have remained stuck on amber.

While new mines can be developed in South Australia and the Northern Territory, those State governments that had previously imposed bans on uranium mining within their jurisdictions have as yet made no moves to lift them. These bans do not just apply to Western Australia and Queensland, both of which play host to several prospective mines, but to New South Wales and Victoria as well. Despite the very important change in policy at the federal level, therefore, uranium mining effectively remains confined to the Northern Territory and South Australia.

1.2.2 Nuclear power post-Chernobyl

While the political ban on new mine development has undoubtedly suppressed growth in the Australian uranium industry, to some extent the prohibition has mattered less than it might have done. This is because it coincided with a period where the industry was in the doldrums, when there had been, if anything, a decline in demand and future prospects were generally seen as poor.

This reflects the fact that after a surge of activity in the 1970s, largely in response to the two oil shocks, the world generally turned against nuclear power.[7] There were several reasons for this:

- political or ideological opposition to nuclear fission following years of Cold War tension;
- the accident at Three Mile Island (1979) and the meltdown and associated leakage of radioactive material at Chernobyl (1986);
- as coal- and gas-fired generators became more efficient, the cost of electricity produced by nuclear reactors became uncompetitive;
- in the US particularly, reactor designs became increasingly customised, resulting in a significant blow-out in capital costs; and
- following the accidents at Three Mile Island and Chernobyl, the regulatory framework for the industry was generally made more restrictive while insurance became difficult to obtain and much more expensive.

The situation now, however, is radically different. A new generation of reactor designs has become available, with increased flexibility, lower capital costs through standardisation and even higher safety standards. Many countries around the world are planning new nuclear power stations. After a thirty-year lay-off, for example, US regulators received applications for seven new nuclear plants in 2007, with applications for 22 further plants expected this year.[8]

Those State governments that continue to impose bans on mining may well consider their position in the future. One highly relevant issue will clearly be the effects on the local economy in their States if the ban were to be lifted.

1.3 Global drivers

Two important factors are driving the world's renewed interest in nuclear power and hence the global uranium market. These are energy security and climate change. In 2006, these two concerns prompted the US Administration to establish the Global Nuclear Energy Partnership (GNEP):

As part of President Bush's Advanced Energy Initiative, …. 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.[9]

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7 An exception was France, where nuclear power provides nearly 80 per cent of electricity supplies.

8 *The Age*, 11 February 2008.

9 Office of Nuclear Energy, 2008, GNP Program, http://www.gnep.energy.gov/gnepProgram.html [January 2008], US Department of Energy, Washington D.C.

1.3.1 Energy security

In terms of energy security, one obvious concern is the reliability of future oil and gas supplies from the Middle East. In some ways this is an echo of the period 1973-80, which witnessed both conflict in the Middle East and two major oil price shocks resulting from the development of the OPEC cartel. The current concerns reflect continuing conflict and uncertainty in the Middle East following the Iraq war and subsequent insurgency and little hope for an early resolution of the Palestinian issue.

A related issue is the high price of oil, currently touching US$100/barrel, with several authorities now suggesting that global oil supplies may be at or near their peak. This view was endorsed by the Chairman and CEO of General Motors, Rick Wagoner, at the 2008 Detroit motor show when he announced a push for the development of electric cars:

"There is no doubt demand for oil is outpacing supply at a rapid pace, and has been for some time now. As a business necessity and an obligation to society we need to develop alternative sources of propulsion."[10]

In addition to the security issues attached to oil, similar concerns relate to natural gas. Some countries in Europe together with the USA are becoming significant importers of gas, much of which comes from Russia and the Middle East. The price of gas is linked to the oil price and, in addition, disruption of these supplies in the future cannot altogether be ruled out.

Clearly this suggests the desirability of alternative energy sources, including nuclear power, hopefully derived from countries that are not among the world's political hot spots. As we have seen, the two largest uranium suppliers are Canada and Australia, two politically stable nations with a democratic tradition.

Some may argue that oil and nuclear energy are not close substitutes, and in transport applications this is currently true. If we are to move towards motor vehicles powered by electric battery or hydrogen fuel cells, however, nuclear energy can play a critical role in both facilitating the carbon-free re-charging of plug-in batteries and the production of hydrogen.

Nuclear power is certainly a substitute for gas and oil in stationary energy, with three per cent of the US electricity supplies, for example, still being generated by oil combustion and both Europe and the US being major users of gas for electricity generation. In a carbon constrained world the price of natural gas is expected to rise appreciably, not merely as a result of a carbon price and rising oil prices but as a consequence of increased demand. While the same argument may be applied to uranium, fuel costs account for a much higher proportion of operating costs for a gas-fired generator than a nuclear plant.

In any case, it is certainly true that the previous boom in the nuclear power industry, and consequently in the uranium price and associated exploration activity, coincided with the oil shocks of the 1970s.

1.3.2 Climate change

Many people in business, even in the uranium industry, have not yet understood the radical changes in our economic system that will occur as a result of the policy response to the threat of climate change. Our analysis suggests that climate change is likely to be a significantly stronger driver of growth in the uranium industry than security of supply issues, although both factors will interact with one another.

The fourth report of the Intergovernmental Panel on Climate Change (IPCC), published in stages during 2007, has confirmed that the world is getting warmer, that the climate is changing and that human actions are almost certainly responsible for this.[11] Depending on a number of assumptions, the IPCC estimates that average global temperatures could be several degrees higher by the end of this century.

Increasing global temperatures of this magnitude threaten not only to cause considerable environmental damage but also pose significant challenges to economic growth and, in some cases, national security. Sir Nicholas Stern's report on the economics of climate change, published in late 2006, put a strong case that the costs of climate change to the world economy are likely to be significantly higher than the cost of taking early action to arrest it.[12]

Although it is now over fifteen years since the Earth Summit in Brazil and a decade since the Kyoto protocol was signed, climate change has only become a mainstream concern relatively recently. This is the result of a combination of factors, including:

- an increase in severe weather events (such as a cyclone destroying much of New Orleans and a particularly long drought in Australia);
- publication of the fourth report of the UN Intergovernmental Panel on Climate Change (IPCC), with an even higher degree of scientific unanimity than before on the causes of climate change and the threat it poses;
- the popular success of Al Gore's Oscar-winning movie, *An Inconvenient Truth*; and
- publication in the UK of the influential report on the economics of climate change by Sir Nicholas Stern.

Irrespective of the causes, it is undeniable that the level of community concern about climate change, certainly in the developed world, increased strongly in 2006 and 2007. The impact on the US and Australia, the only two nations that had refused to ratify the Kyoto protocol, is of particular note. In the US, the Bush Administration moderated its tone on climate change and, while still resisting binding targets, accepted at the APEC meeting in Sydney in September 2007 that nations would need to reduce their greenhouse gas emissions.

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10 Dowling, J., 2008, 'Time's up for petrol cars,' Sydney Morning Herald, 15 January 2008, Sydney

11 Intergovernmental Panel on Climate Change, 2007, *Fourth Assessment Report (AR4)*, Working Group I, The Physical Basis of Climate Change, Summary for Policy Makers, available at http://ipcc-wg1.ucar.edu/wg1/wg1-report.html, [October 2007]

12 HM Treasury, 2006, The Stern Review Final Report, http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm, [October 2007], London

Currently, the leading candidates for President, including Senators McCain, Clinton and Obama, are all committed to making deep cuts in US emissions.

In Australia, in 2007 the Howard government accepted the need for reductions in emissions after 2012 and announced that an emissions trading scheme would begin in 2011. At the subsequent election where climate change was an important issue, the government changed and then Australia ratified the Kyoto protocol. The present government has committed to reducing Australia's emissions by 60 per cent from 2000 levels by 2050 and has also stated that it will propose an interim target some time during 2008. The report by Professor Ross Garnaut, now expected in its final version in September this year, will provide input into this. In his first interim report, Garnaut has suggested that Australia may need to consider deeper cuts, of up to 90 per cent by 2050.[13]

The countries of the European Union have been leaders in pursuing international action on climate change. They have now committed to reducing emissions by 20 per cent from 1990 levels by 2020, and will raise this to 30 per cent if a significant number of other nations participate in deep emissions reductions.

The issue of major emitters among developing countries remains difficult to address, but nations such as China and India are becoming increasingly concerned about the potential effect of climate change on their own communities. This may help to drive an agreement between developed economies and the developing world. Any agreement is likely to revolve around significant transfers of technology to developing countries in return for action on emissions reductions, involving, perhaps, a ramping up of the Kyoto Clean Development Mechanism (CDM).

The conclusion is that the world is moving to ramp up efforts to combat climate change. Following the Bali conference of the parties to the UNFCCC in December 2007, a proposal that developed economies reduce emissions by between 25 and 40 per cent from 1990 levels by 2020 remains on the table. Targets will be negotiated intensively over the next two years.

These are the circumstances facing governments of all levels as they formulate their climate change policies in 2008. The expectation must be that the world will begin to take significant action to reduce emissions in the post-Kyoto period after 2012. It needs to be remembered that the already substantial proposed emission reductions are relative to 1990 levels. They represent a much larger reduction from business as usual emissions projections and, if adopted, would require enormous changes in the way we supply and use energy. The implications for the stationary energy sector, particularly electricity generation, are explored below.

The implications for some Australian export industries are also highly favourable. Already the world's leading coal exporter, Australia's large resources of uranium and natural gas have the potential to make us an 'energy superpower' in a post-Kyoto world. As Professor Ross Garnaut has stated in his interim report on the effect of climate change on Australia:

Australia is a major exporter of minerals that will receive advantages from a strong international [greenhouse gas] mitigation effort, notably uranium (by far the world's largest reserves of high quality uranium oxide) and natural gas (exceptionally large resources per capita amongst developed countries).[14]

1.4 Climate change and electricity generation

With the electricity generation sector currently accounting for approximately 40 per cent of greenhouse gas emissions globally, and with economic and population growth projected to result in a doubling in demand for electricity by 2030, there is a strong need for communities to transition to zero or low emitting electricity generation technologies in the near to medium term.[15] In this context, it is likely that global prices for carbon emissions will begin to emerge over the next decade, and indeed, carbon markets are already in operation in a number of regions of the world.

Faced with the probability that significant reductions in emissions will be required by developed nations by 2020, many countries are looking to nuclear energy as the most cost-effective solution. In this context, Yvo de Boer, Executive Secretary of the IPCC, stated at Bali in December 2007 that:

I have never seen a credible scenario for reducing emissions that did not include nuclear energy.[16]

This has substantial implications for the uranium industry.

1.4.1 Alternative generation technologies: how does nuclear stack up?

The introduction of carbon prices will alter traditional price relationships between different fuel technologies in electricity generation, and in particular will erode the historic cost advantages of emissions intense fossil fuels, such as coal. Low emissions generation technologies, such as nuclear power, gas and some renewables, are likely to be in greater demand by consumers, though not all low emissions technologies are appropriate or capable of providing a continuous, reliable supply of power (base load).

13 Garnaut Climate Change Review, *Interim Report*, Canberra, February 2008.

14 Garnaut Climate Change Review, *Interim Report*, Canberra, February 2008, page 56.

15 International Energy Agency, 2006, *World Energy Outlook 2006*, International Energy Agency, Paris

16 Quoted in Angus Grigg, 'Nuclear test for Rudd,' *Australian Financial Review*, 8-9 December 2007, Sydney, page 22

A number of countries, including Australia, are investing significant funds in 'clean coal' technologies, such as carbon capture and storage (CCS). Many of these technologies, however, are still not technically or commercially proven and will require considerable further development if they are to reduce long run average costs to the level of other base load alternatives that are proven and available now.

The truth of this assertion becomes apparent when examining the options for electricity generation, particularly base load generation, in a carbon constrained world. On the basis of currently available technologies, the options presented by the fourth report of the IPCC include:

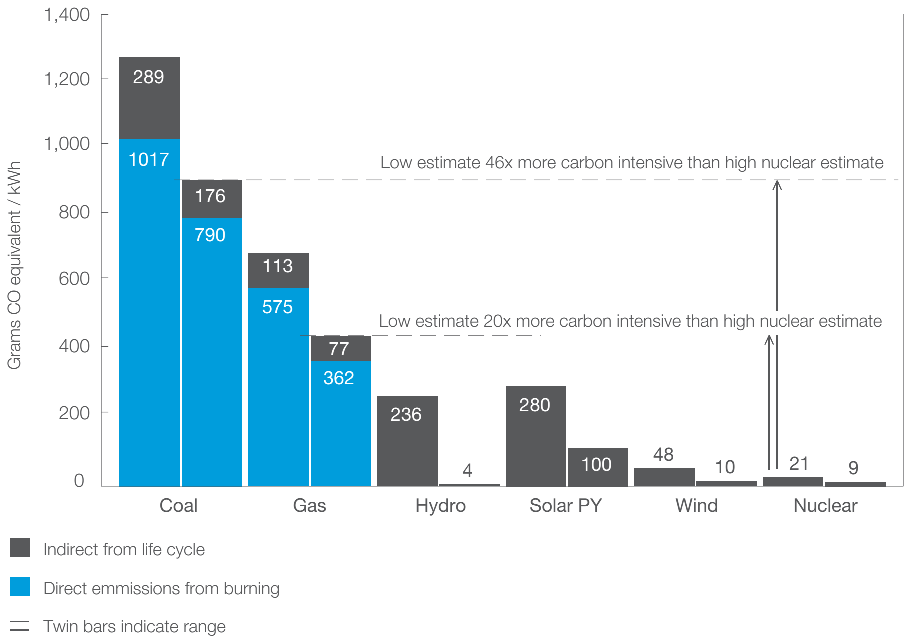
Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of Carbon Capture and Storage (CCS, e.g. storage of removed CO_2 from natural gas.[17]

The non-nuclear options all have problems, particularly with accommodating future requirements for base load power. Of the IPCC's options, for example:

- *Improved supply and distribution efficiency.* Certainly this can be improved, as can the efficiency with which energy is used. There are two limitations, however. First, partly because of a lack of obvious policy levers, such improvements cannot be expected to contribute more than a small fraction of the reductions in emissions likely to be required. Secondly, this contribution is essentially a 'one-off'.
- *Fuel switching from coal to gas*. With a greenhouse gas footprint of around 375kg/MWh compared with black coal at around 900kg/MWh and brown coal at about 1,300kg/MWh, gas is regarded as a valuable interim technology for base load generation. But its emissions are still significant and the demand for gas in other applications in a carbon-constrained world is likely to drive up the gas price. The cost of gas accounts for around 35 per cent of the long run average cost (LRAC) of a combined cycle generator.
- *Renewable heat and power.* Renewables will clearly play a substantial role in supplying carbon-free electricity. But only geothermal power and perhaps biomass are suitable for base load generation and they will never provide more than a relatively modest proportion of the required supply. Solar power is still very costly, while, in Australia at least, wind's LRAC remains about double that of a coal-fired generator and about 50 per cent more than nuclear. If solar or wind power were to be used for base load generation, the experience of Germany in particular suggests that it would require fossil fuel back-up. As well as being somewhat counter-productive, this would be an extremely expensive option.
- *Combined heat and power.* Co-generation will make a contribution, but only in a very limited way given the limited opportunities for the employment of this technology. Co-gen generally is based on fossil fuels, where the usual problems with the GHG footprint apply.
- *Early applications of carbon capture and storage.* Any assessment of the available low carbon generation technologies together with those on the horizon, suggests that fossil fuels with carbon capture and storage (CCS) will need to play a significant role in supplying electricity globally during this century. Yet at present the technology remains untested commercially, while in general it is also unlikely to be commercially feasible to remove all emissions. For a coal plant with CCS, for example, emissions are likely to remain at around 200kg/MWh, while at this point in time the costs of capturing and sequestering the remaining emissions remain substantial.

The relative carbon footprint of some important current generation technologies are shown in Figure 1.2 below. The chart shows both direct emissions and estimates of life cycle emissions, which generally relates to GHGs generated by producing the fuel and the related plant.

Figure 1.2: Generation technologies: relative carbon footprint



Source: International Atomic Energy Agency, 2000, *Climate Change and Nuclear Power*, International Atomic Energy Agency, Paris.

17 Contribution of Working Group III to the Fourth Assessment Report of the IPCC, Summary for Policy Makers, page 10

For some commentators to rule out nuclear power on grounds of cost, while promoting wind and solar power, is particularly puzzling. Nuclear power is significantly cheaper than energy from either of these sources. It currently provides the cheapest electricity in the United States. In any case, this is a matter best left to the market place. The most efficient approach to reducing GHG emissions is to introduce a carbon price into the economy, either via a carbon tax or an emissions trading system. Provided any externalities are appropriately valued, this will allow the market to select the most efficient technologies.

In terms of relative costs of currently available technologies, nuclear power is regarded as one of the cheapest options for 'carbon-free' base load electricity (See Figure 1.2). Geothermal also offers great potential but its capacity to supply substantial quantities of electricity is doubtful because of the limited availability of appropriate locations. In the future the cost of technologies such as fossil fuels with CCS is likely to come down, but we cannot rely on this nor predict with any certainty the longer term cost. In the UK, the recent White Paper on nuclear power concluded from its analysis that:

Nuclear power is the most cost effective low-carbon generation technology. It has an estimated abatement cost of £0.3/t CO_2 compared to onshore wind power, the next nearest currently available low-carbon electricity generation technology, which has an estimated abatement cost of £50/t CO_2.[18]

1.4.2 Technological change

In Australia, the discussion of likely technological changes in power generation to meet the needs of the community under a carbon constraint, generally focuses on the following issues:

- means of storing electricity so that renewable generation technologies such as wind and solar can provide a continuous electricity supply;
- the development of solar power, including the efficiency of individual solar pv;
- development of wave and tidal generation in Australia;
- clean coal technologies, including carbon capture and storage; and
- geothermal ('hot dry rocks') technologies and their potential to provide continuous supplies of electricity in Australia at an economic cost.

Clearly all of these areas are of considerable importance. A portfolio of technologies will be required if we are to address the climate change threat at least cost to the community.

There are, however, also major technological developments taking place in the nuclear power industry. These are the result of very substantial research programs that, in many cases, go back to the 1950s.

The Generation III reactors that are currently being constructed meet new benchmarks in terms of efficiency in fuel use, safety, flexibility and a competitive cost of electricity. One of several examples of these new reactors, although technically a Generation III+, is the Westinghouse AP-1000. This design was certified in the US in 2005, and has also been selected for construction in China (four units to date) and probably Europe. The AP-1000 features lower capital costs, greater built-in safety and a projected life of sixty years. The projected long run average cost of electricity generated by an AP-1000 plant of 1100 MWe is around $US35/MWh, which would be highly competitive with current best practice coal generation. Overnight capital costs, which can be very high for nuclear power plants, are estimated to be a competitive $1,200/kw for a plant of 1100 MWe.[19]

Generation IV plants, however, are currently at the development stage and promise even greater benefits. Following the accident at Three Mile Island in 1979, the US Congress proposed that a major national research effort be made to develop a simpler and safer reactor design than those currently available. The objectives of the Generation IV reactors are passive safety, good economics, proliferation resistance and improved environmental characteristics including reduced waste and better fuel utilisation than current models. Some concepts offer much more efficient use of uranium, including the use of reprocessed fuel, which also reduces the waste disposal task. Some designs involve underground construction for greater security.

As an example of possible Generation IV technologies, high temperature gas cooled reactors (HTGR) have been the subject of a considerable research effort since the 1950s – Australian scientists were experimenting with a unique pebble bed design at Lucas Heights in the early 1960s. There are now several designs coming to fruition in the US, Japan, China and Europe. Some models hold out the promise of addressing climate change on several fronts by producing hydrogen, zero emissions electricity at a highly competitive price as well as a water desalination process. It is expected that HTGR reactors will be operating before 2020.

As another example of gas cooled reactors, for the last 15 years, the South African utility Eskom, in collaboration with local and overseas interests, has been developing the Pebble Bed Modular Reactor (PBMR). The PBMR draws on well-proven German technology and aims for a step change in safety, economics and proliferation resistance. Construction of a demonstration plant commenced in 2007 for completion in 2010 and the government has announced a program to build 24 PBMR generators (see Box 1.1). The cost of electricity from the reactors is projected to be a highly competitive US$30/MWh and the overnight capital cost, when the units are built in clusters of eight 165MW modules, is expected to be of the order of US$1,000/kw.[20]

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18 Department for Business, Enterprise and Regulatory Reform, 2008, *Meeting the Energy Challenge: A White Paper on Nuclear Power*, http://www.berr.gov.uk/files/file43006.pdf [January 2008], London, page 66. While not stated explicitly, it appears that the high relative cost of wind power is boosted by the need to provide back-up generation for base load power.

19 Australian Uranium Association, 2008, *Advanced Nuclear Power Reactors*, Nuclear Issues Briefing Paper 16, February, page 3.

20 Australian Uranium Association, *Ibid*, page 7.

Box 1.1: South African pebble bed modular reactors

"In the early 1990s, South African study teams pondered the nation's electricity supply for the future and came to the conclusion that a significant proportion should be nuclear, and that the nuclear power should not be water dependant. So the concept of a small, compact, water independent, gas-cooled reactor was projected as a potential solution. The concept was named the Pebble Bed Modular Reactor.

"The exit temperature of the helium from the reactor is designed to be 940°C, compared to the operating temperatures of a conventional water cooled PWR of some 200 to 300°C. This high gas temperature has led to the opening up of an entire potential market for the use of the exit gas as process heat directly without having to generate electricity at all. This potential of building a process heat reactor is being examined in some depth.

"The total power of the South African PBMR is 165 MW which is about the power requirement of a moderately sized city, but much smaller than the power output of conventional large PWR nuclear stations.

"One of the South African design criteria was to be able to place smaller reactors near to where the power is required and not to have to site them near large bodies of water, usually the ocean. Another design aspect was to be able to build cheap, affordable power stations that could be built rapidly. A rapid construction cycle would ideally follow rapid decision making by the political and financial authorities.

"Because the reactors are inexpensive, it should not be necessary to have to endure many years of fundamental decision making followed by extended years of construction. PBMRs are designed to be able to be constructed in 24 months. The modest power rating of 165 MW is also the reason why the reactor system was designed as 'modular.' This 'modularity' allows for easier financial decision making and power planning - an additional reactor can be added to an existing system within 24 months after a planning decision has been made.

"The PBMR is inherently safe. It has no water cooling of the core so the much feared LOCA (or Loss of Coolant Accident) that can occur in a conventional PWR if the water coolant runs out of the core, cannot occur in the case of a PBMR. Helium gas cannot become radioactive, so although the coolant gas passes through the reactor core, it does not become radioactive, so even in the extremely unlikely event of a helium coolant leak, the gas would present no hazard.

"South Africa intends not only to build PBMRs for domestic use, but also for export. PBMRs are not only ideal for small countries, but also for large First World countries. In the case of the latter, individual reactors can be placed near specific cities and towns or near industrial areas or harbours. In fact the reactors are small enough and sufficiently inexpensive that they can be purchased by private companies that use large amounts of power such as mines, aluminium smelters and the like."

Source: Kemm, K., 'New nuclear power for South Africa: the stage is set', *Leader*, 30 January 2008, www.leader.co.za/article.aspx?s=1&f=1&a=415.

1.4.3 Implications

A strong conclusion is that, at this point in time, nuclear power is the only proven technology capable of producing a substantial and uninterrupted supply of electricity to a sophisticated economy with very low emissions and at a competitive cost. It is notable that in France, for example, carbon dioxide emissions from electricity generation fell by 80 percent in just seven years after 1980 due to a large scale switch to nuclear power following the 1970s oil shocks.[21]

Clearly nuclear energy cannot do all the 'heavy lifting' required to meet the emissions abatement challenge, but it will represent an increasingly important element in the world's clean energy portfolio over the coming decades.

This conclusion is also relevant in a wider sense. Not only can nuclear power provide a commercial solution now in the stationary energy sector, but until other efficient greenhouse-friendly technologies are developed it is also likely to be one of the cheapest sources of abatement throughout the economy as a whole. In the transport sector, for example, low to zero emission alternatives to the internal combustion engine that are acceptable in the market place are barely on the horizon. Similar problems apply to agriculture. The use of a broad, market-based instrument, such as emissions trading or a carbon tax, will drive abatement from the cheapest available source irrespective of the sector in which it is located. In this sense, nuclear power may have many advantages, particularly in the early stages of emissions reductions, allowing technological breakthroughs in other sectors to take over the running in the longer term.

It is also important to note that while technological progress is being made in clean coal with CCS and renewables, the nuclear industry is by no means standing still. The developments in Gen III and Gen IV reactors are the culmination of many decades of research. They suggest that, within a decade, the international community will be able to select generation technologies that provide zero emissions electricity possibly at a cost no higher than that currently provided by high emissions coal plants. They may also offer efficient means of producing hydrogen and desalinated water. These nuclear plants will also provide very high levels of safety, less waste and a much more efficient use of U_3O_8, suggesting that the world's resources of uranium will last for considerably longer than is currently anticipated.

21 Ferreira, T., 2003, 'South Africa's nuclear program', *Science in Africa*, June.

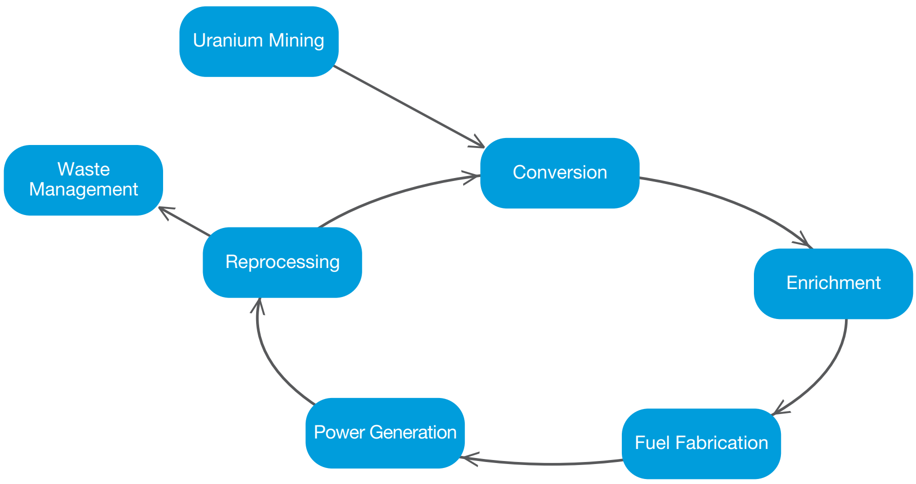
2 Global market for uranium

This chapter briefly summarises uranium's position within the nuclear fuel cycle and describes the global market for uranium.

2.1 Uranium in the nuclear value chain

As stated in Chapter 1, growing demand for nuclear power as a result of new climate change policy action and security of supply considerations will drive an increase in demand for uranium, which is the primary fuel source for nuclear power generation. Uranium is converted into nuclear fuel through a number of important intermediate value adding steps known as the nuclear fuel cycle. The value chain for nuclear energy production, including the nuclear fuel cycle, is presented in Figure 2.1. Key steps in the value chain are described in further detail below.

Figure 2.1: The nuclear energy value chain



Source: Adapted from the World Nuclear Association, 2007, The Nuclear Value Chain, World Nuclear Association, London.

2.1.1 Uranium mining

Uranium mining involves the recovery of uranium ore from the earth. There are two mining techniques used to recover the ore, excavation and in-situ recovery. The choice of technique is governed by the nature of the ore body, as well as safety and economic considerations.

- Excavation typically involves the removal of large quantities of earth that are processed in order to extract the uranium ore. Excavation is either via open pit mining (for near surface deposits) or underground mining (when the ore deposit is deep below the surface).
- In-situ recovery involves circulating a liquid solution (either acidic or alkaline) through the ore body, dissolving the uranium. The solution containing the uranium is then pumped to the surface for processing, recovering the uranium ore.

Once the ore is mined, it is processed into uranium oxide concentrate, U_3O_8, also known as 'yellowcake'. Uranium oxide concentrate generally contains more than 80 per cent uranium, whereas the ore may contain as little as 0.1 per cent uranium.

Uranium oxide concentrate typically contains relatively low (less than one per cent) levels of uranium-235 (U_{235}) with the remainder being largely uranium-238 (U_{238}). In order to sustain a reaction in most nuclear reactors, concentrations of between three and five per cent of U_{235} are required. Therefore, the uranium oxide concentrate is transported to facilities to enrich the proportion of U_{235}.

Production targets for uranium mining are set according to long term contract export commitments. Only a small portion of uranium is sold through the spot market.

2.1.2 Conversion and enrichment

The enrichment process first requires the uranium oxide to be converted to uranium hexafluoride (UF_6). The uranium hexafluoride can then be enriched to achieve the 3.5 to 5.0 per cent U_{235} required by most reactors.

There are currently two enrichment processes in commercial use, gaseous diffusion and centrifuge. Gaseous diffusion is an older technology requiring large amounts of energy to perform the enrichment. The World Nuclear Association expects that gaseous diffusion technologies will be phased out by 2015, and replaced by the more efficient centrifuge technology. A third technology, laser enrichment, was developed by an Australian company, SILEX. This technology was sold to General Electric in 2006, but has yet to be developed for commercial use.

2.1.3 Nuclear fuel fabrication

The fabrication of nuclear fuel involves pressing the low enriched uranium oxide into pellets and baking at a high temperature. The pellets are encased in metal rods to form fuel rods that are then inserted into the core of a nuclear reactor.

2.1.4 Nuclear power generation

The generation of electricity from a nuclear reactor is based upon the same principle as coal and gas turbines, whereby water is converted to steam and used to drive a turbine. The difference is that nuclear power generation uses a nuclear reaction to generate heat rather than the burning of fossil fuels.

A nuclear reaction involves the splitting of atoms (fission), which releases vast amounts of energy to heat water or a gas to turn the turbines. A nuclear reaction is created by a neutron colliding with the U_{235} or U_{238} in the fuel rods. The atomic properties of U_{235} mean that when it undergoes fission it releases neutrons, which are then available to create more reactions, whereas the fission of U_{238} does not release neutrons. It is this property of U_{235} that makes it of central importance in sustaining a nuclear reaction. In order to control the number of reactions within a nuclear reactor, moderators are used to absorb some of the neutrons released during the fission of U_{235}.

2.1.5 Reprocessing and waste

Used fuel from a nuclear reactor is removed and stored in special ponds temporarily to allow it to cool and for radiation levels to decrease. Used fuel contains around 95 per cent U_{238}, one per cent U_{235}, about one per cent plutonium and three per cent waste. The fuel can be processed to extract the waste, allowing plutonium and U_{235} to be reprocessed into new nuclear fuel. Fuel waste is then prepared for storage. Low level waste from ore processing are stored in tailings and high level waste is generally sequestered in deep repositories.[22]

2.2 Demand side of global uranium market

Australian uranium is generally purchased by nuclear reactor utilities. Total demand is a function of the number of generators, the capacities and efficiency of these generators, and the inventory policies of the nuclear utility companies.

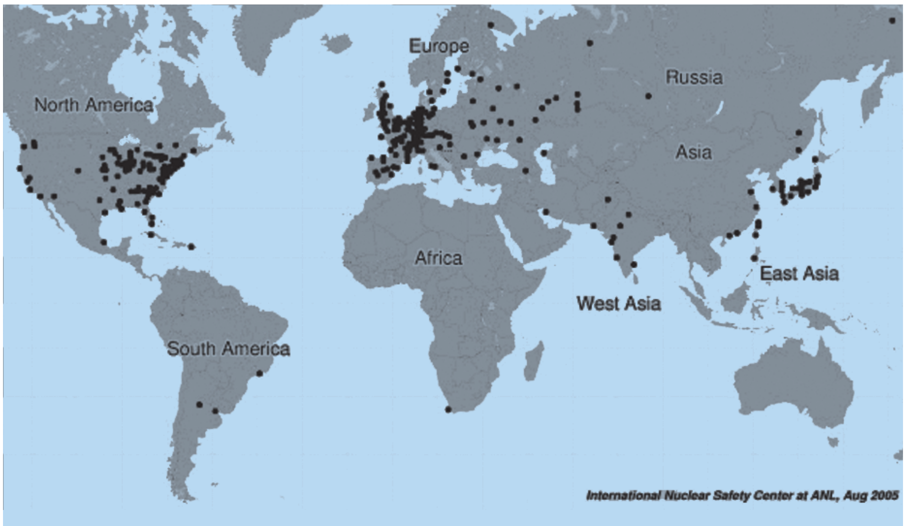
As at October 2007, the World Nuclear Association reported there are currently 439 nuclear power reactors in operation globally, spread across 30 countries and supplying approximately 16 per cent of total world energy demand (Figure 2.2). Currently, however, demand is heavily concentrated in the United States, Western Europe, South Korea and Japan. Of the 30 countries with nuclear power reactors, the United States has 104 reactors, followed by France (59), Japan (55), Russia (31), South Korea (20), United Kingdom (19), Canada (18), Germany (11), India (11) and China (11). Combined these reactors had an installed capacity of 372,002 MWe and in 2006 generated 2,658 billion KWh of electricity.

In 2007, some 66,500 tonnes of uranium was required globally to power nuclear reactors.

Looking forward, demand is expected to diversify into Asia, with significant expansions in nuclear power expected in China in particular.

- Currently there are 33 reactors under construction, seven of which are in Russia, six in India and five in China. These reactors under construction will add 26,838 MWe in capacity.
- There are also a further 94 reactors on order or planned for construction, 30 of which are planned for China, 11 in Japan and 10 in India, which would add 101,595 MWe in capacity.
- In addition, there are 222 proposed reactors, 86 of which would be located in China, 25 in the United States and 24 in South Africa. These reactors currently under construction, planned, or proposed have a capacity equal to around 86 per cent of current installed capacity.

Figure 2.2: Current nuclear reactors

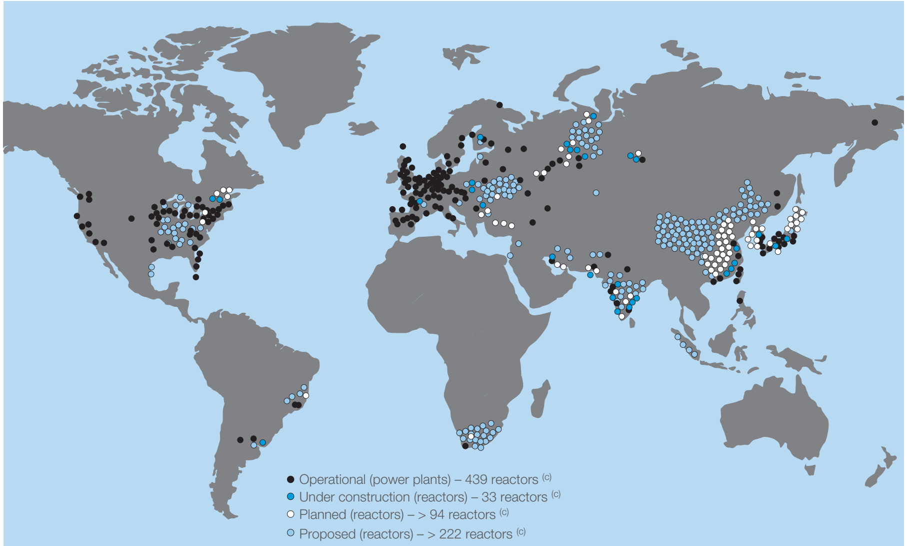


Source: International Nuclear Safety Centre, 2007, Maps of Nuclear Power Reactors: World Map, Argonne National Laboratory for the US Department of Energy, http://www.insc.anl.gov/pwrmaps/map/world_map.php [14 February 2008], Argonne.

22 The first European repository is expected to commence operations around 2020. See Department of Prime Minister and Cabinet, 2006, *Uranium Mining, Processing and Nuclear Energy: Opportunities for Australia?,* Uranium Mining, Processing and Nuclear Energy Review, Australian Government, Canberra.

Figure 2.3 shows the projected expansion of nuclear power globally, which will in turn increase the demand for uranium.

Figure 2.3: Existing and planned nuclear power reactors



Source: (c) World Nuclear Association information as at 17 October 2007, reproduced in BHP Billiton, 2007, *BHP Billiton and Rio Tinto: A Matter of Value*, BHP Billiton, Melbourne, p 29.

The strong expansion by Eastern countries is driven by rapid economic development in some nations and a lack of indigenous energy resources in others. Reflecting the premium these countries place on securing additional nuclear energy generation, significant equity stakes have been taken in the development of some deposits, including in Kazakhstan. Kazakhstan has 15 per cent of the world's uranium resources and is aiming to expand its uranium production to 15,000 tonnes by 2010 and 30,000 tonnes by 2018. In April 2007, a number of high-level agreements on energy cooperation were signed with Japan by Kazatomprom, including to supply 40 per cent of the Japanese market for both natural uranium and fabricated fuel from 2010. These included some relating to uranium supply to Japan, and technical assistance to Kazakhstan.

In relation to fuel cycle developments and nuclear reactor construction, in August 2006, the Japan Bank for International Cooperation had signed an agreement with Kazatomprom to support and finance Japanese firms in developing Kazakh uranium resources to supply Japan's power generation.[23]

Nuclear power utilities globally place a premium on long term security of supply and prices. They therefore pursue long term supply agreements with uranium producers, a diverse supply base and control over the nuclear value chain through agreements with suppliers at all stages of the fuel cycle.

Three examples of countries that are gearing up to invest significantly in nuclear power are the US, the UK and South Africa. These are considered briefly below.

2.2.1 US Nuclear Power 2010 program

As a result of public concern about the industry, particularly after Chernobyl in 1986, it became much more difficult to build, own and operate nuclear power stations in the United States. Private investors were effectively warned off nuclear power when additional regulations added greatly to capital costs and insurance became extremely difficult to obtain.

This situation has now changed substantially, with significant government action being taken, for example, in the United States, to facilitate the industry's future development. Under the NP 2010 program, government and industry are working closely together in the US to establish a technical and regulatory framework:

"The technology focus of the Nuclear Power 2010 program is on Generation III+ advanced light water reactor designs which offer advancements in safety and economics over the Generation III designs certified by the Nuclear Regulatory Commission (NRC) in the 1990's. To enable the deployment of new Generation III+ nuclear power plants in the United States in the relatively near-term, it is essential to complete the first-of-a-kind Generation III+ reactor technology development and to demonstrate the untested Federal regulatory and licensing processes for the siting, construction, and operation of new nuclear plants. The Department utilizes competitive procurement processes and conducts program activities in cost-share cooperation with industry. The Department has initiated cooperative projects with industry to obtain NRC approval of three sites for construction of new nuclear power plants under the Early Site Permit (ESP) process, to develop application preparation guidance for the combined Construction and Operating License (COL) and to resolve generic COL regulatory issues, to obtain NRC approval of COL applications.

23 World Nuclear Association, 2007, *Uranium and Nuclear Power in Kazakhstan*, World Nuclear Association, http://www.world-nuclear.org/info/inf89.html [February 2007], London.

The COL process is a "one-step" licensing process by which nuclear plant public health and safety concerns are resolved prior to commencement of construction, and NRC approves and issues a license to build and operate a new nuclear power plant." [24]

In addition, as discussed briefly in Section 1.4.2 above, substantial work in the US is being undertaken on Generation IV reactors which offer further major advantages in terms of their efficiency, safety and economics.

While in 2002 a concern with energy security, particularly with the availability and cost of future gas supplies, provided almost the entire rationale for the establishment of the NP 2010 program, it has now segued seamlessly into a program that is ostensibly directed towards reducing GHG emissions.

2.2.2 UK White Paper on nuclear power

Around half of the thirty member countries of the OECD use nuclear power, as well as a number of developing economies. Yet some nations have rejected it, while others have installed nuclear generators in the past but then renounced the technology for the future. Britain and Germany fall into this latter category. In the last few years, both countries have stated that nuclear power would play no part in their future energy plans, and that existing nuclear generators would be retired at the end of their economic lives and not replaced.

In Germany this approach has not been changed officially, although it appears that the Merkel government will re-examine a policy that was devised by the previous SDP/Greens coalition. In Britain, however, the government has changed its approach to nuclear power. Faced with a commitment to a testing emissions reduction target for 2020, it appears that the substantial economic advantages of nuclear power have had a significant impact on government policy.

In January 2008 the British government published a White Paper supporting a new nuclear building program.[25] In the Foreword to the White Paper, the responsible Minister, John Hutton, sets out the various concerns about nuclear power that arose during the extensive consultation process and then concludes that:

"Having reviewed the evidence, and taking account of these points, the Government believes nuclear power should be able to play a part in the UK's future low-carbon economy. We have also carefully re-examined the impact of excluding nuclear power from our future energy mix. Our conclusion remains that not having nuclear as an option would increase the costs of delivering these goals and increase the risks of failing to meet our targets for reducing carbon dioxide emissions and enhancing energy security.

"The Government believes new nuclear power stations should have a role to play in this country's future energy mix alongside other low carbon sources; that it would be in the public interest to allow energy companies the option of investing in new nuclear power stations; and that the Government should take active steps to facilitate this.[26]

It is clear that the economic advantages of nuclear power as a relatively low cost source of greenhouse-friendly electricity were the main drivers of the UK government's decision. As suggested in Chapter 1 above, the White Paper's main conclusion from its analysis is that nuclear power has the lowest cost of any current form of low- to zero- emissions generation technology, and its cost is also much lower than the projected costs of any of the new technologies, such as CCS, that are on the horizon.[27] In addition, the White Paper, which was written after a very extensive public consultation process, systematically evaluates all the arguments against nuclear power and finds them to be wanting.

2.2.3 South African nuclear power program

The Republic of South Africa uses half the electricity generated on the African continent. South Africa is similar to Australia in that it is a major supplier of black coal to global energy markets and that currently the vast majority of its electricity is generated by coal plants (over 90 per cent in South Africa's case). Both Australia and South Africa have significant uranium resources. In addition, both Australian and South African scientists and engineers have had some successes in nuclear research. While Synroc and a laser enrichment process were invented and developed in Australia, South Africans have designed a new type of reactor that has many advantages for countries with smaller loads and a lack of water for cooling.

Where South Africa is different, however, is that despite the fact that it is a non-Annex 1 country, and therefore not subject to binding emissions targets under the Kyoto Protocol, it is planning a substantial new program to build nuclear power generators. The South African economy requires significant new investment in electricity generation. By 2030, the government aims to double South African generation capacity. Approximately half of this additional 40GWe will be provided by nuclear power and, by 2030, 30 per cent of South Africa's electricity will be nuclear generated. The construction program will begin in 2009-10 and the first of the new reactors should be operational by 2016.[28]

24 Office of Nuclear Energy, 2008, op. cit.

25 Department for Business, Enterprise and Regulatory Reform, 2008, *Meeting the Energy Challenge: A White Paper on Nuclear Power*, http://www.berr.gov.uk/files/file43006.pdf [January 2008], London.

26 *Ibid*, page 7.

27 *Ibid*, pages 64-66.

28 Uranium Information Centre, *Nuclear Power in South Africa*, Briefing Paper 88, February 2008.

2.3 Supply side of global uranium market

2.3.1 Global resources

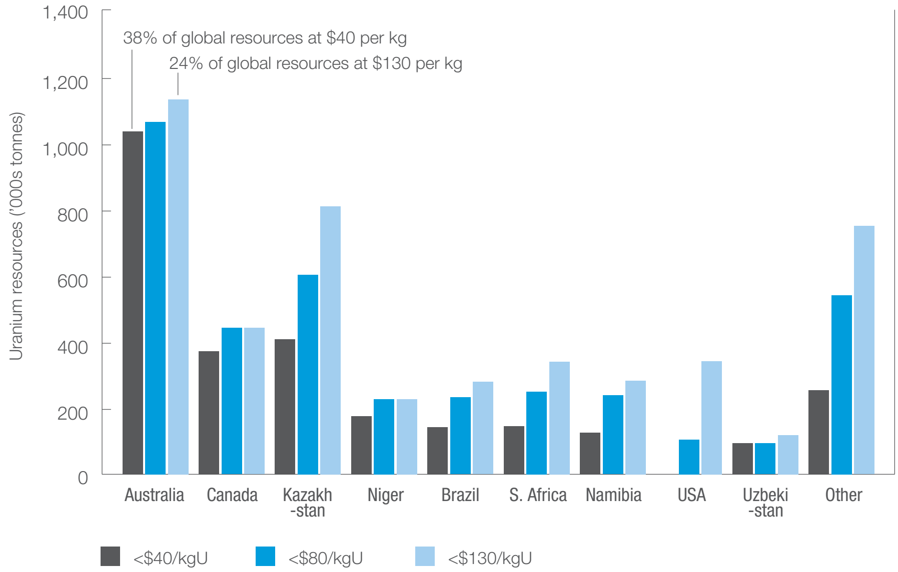
There are currently two sources of fuel supply for nuclear power – primary mine production of uranium and secondary sources of supply. Secondary sources include down-blending of weapons grade uranium, recycled material from reprocessing of spent fuel, uranium stockpiles compiled by utilities and uranium recovered from re-enriching tails assays. The secondary supply of down-blended uranium has provided the greatest downward pressure on the long-term contract price over the past three decades and it is not expected that significant volumes of down-blended fuel will be available beyond 2015.

Global primary uranium resources are measured according to the amount of uranium known to be economically recoverable. Given the dynamics between the costs of extraction and processing and market prices, resources are usually expressed based upon the cost of recovery. As is shown in Figure 2.4, identified deposits are highly concentrated in Australia, Kazakhstan and Canada.[29] The uranium concentrations of these deposits vary; high grade deposits are generally only found in Canada, and require significant safety precautions to mine.

Critically, current estimates of reasonably assured and inferred resources are a function of exploration to date and may not adequately reflect the global resource base. Exploration in the recent past has been limited due to low prices over the past two decades, which have rendered some investment uneconomic. In addition, there has been political resistance to the industry in some countries, and in Australia this has led to the development of regulatory restrictions on exploration and/ or mining of uranium.

Reflecting the recent growth in uranium prices, the draft 2008 *Nuclear Technology Review* prepared by IAEA has reported that 'higher uranium prices helped to prompt new exploration and reassessments and the identified uranium resources reported in this year's 'Red Book' [the IAEA's assessment of world uranium resources] will be 17 per cent higher than in the last edition.'[30]

Figure 2.4: Global reasonable assured and inferred resources



Source: Nuclear Energy Agency, 2005, *Uranium 2005: Resources, Production and Demand*, Tables 2 and 3.

Table 2.1: Major producers of uranium (2006 estimates)

Company	Tonnes of Uranium	Proportion of Global Production
Cameco	8,249	20.9%
Rio Tinto (including ERA)	7,094	18.0%
Areva	5,272	13.4%
KazAtomProm	3,699	9.4%
TVEL	3,262	8.3%
BHP Billiton	2,868	7.3%
Navoi	2,260	5.7%
Uranium One	1,000	2.5%
Other	5,725	14.5%
Total	**39,429**	**100%**

Source: World Nuclear Association, 2007, World Uranium Mining, available from www.world-nuclear.org/info/inf23.html

2.3.2 Major suppliers

Although Australia has the largest resources, it is not currently the largest producer of uranium. Currently Canada is the largest producer, with 25 per cent global market share, followed by:

- Australia, with 19 per cent market share;
- Kazakhstan, with 13 per cent market share;
- Niger, with 9 per cent market share; and
- Russia, with 8 per cent market share.

The supply of uranium is highly concentrated around a small number of major producers, as shown in Table 2.1, as it is typically dominated by a small number of large deposits.

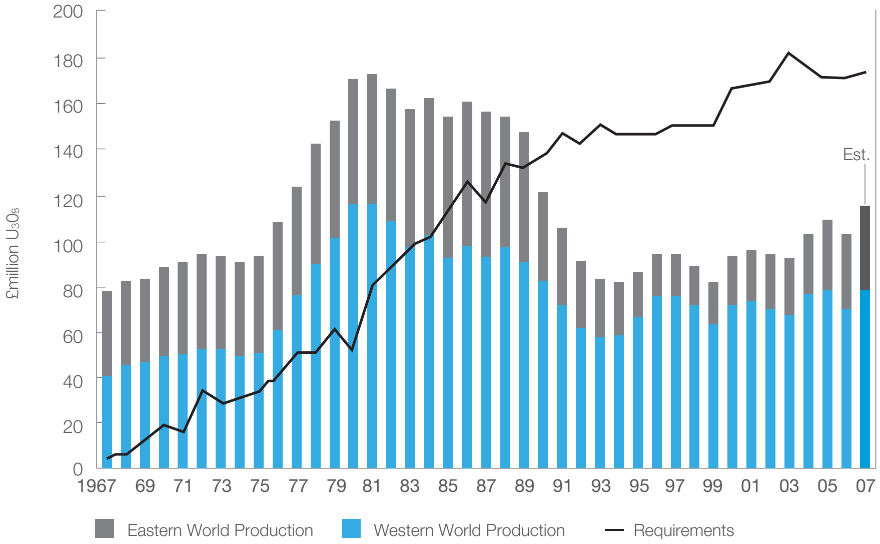
29 According to the IEA, identified deposits include both reasonably assured resources and inferred resources. Reasonably assured resources have a high assurance of existence and are based upon specific sample data and measurements of the deposits and knowledge of the deposits characteristics. Inferred resources are based on direct geological evidence or in deposits in which geological continuity has been established, but where specific data and measurements of the deposits and knowledge of the deposits characteristics are insufficient to classify the resources as reasonably assured.

30 See International Atomic Energy Agency, 2008, Director General Addresses Board on Nuclear Issues, International Atomic Energy Agency, http://www.iaea.org/NewsCenter/News/2008/board030308.html [March 2008], Vienna.

2.4 Economics of new mine development

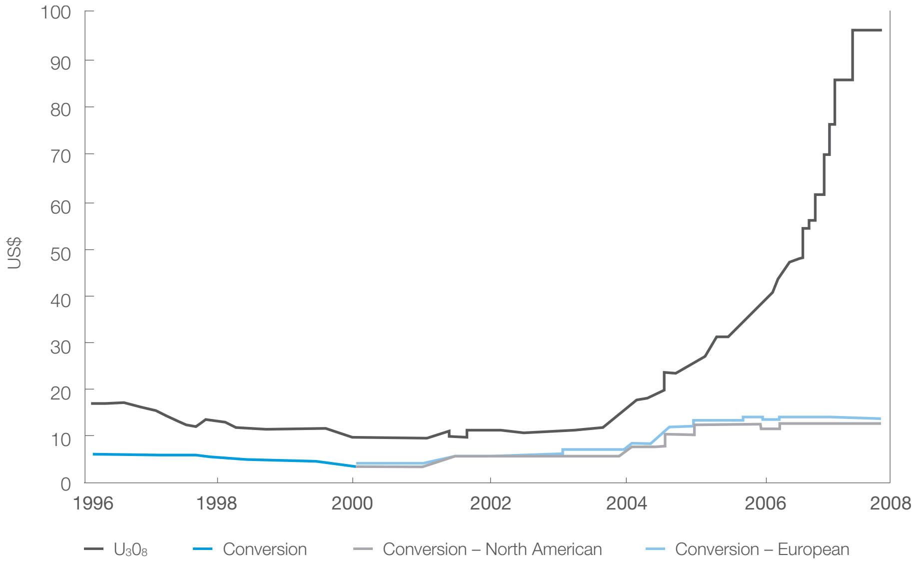
The uranium market has been in oversupply for several decades as a result of unrealised projections for continued nuclear industry expansion, high excess inventories built up in the 1970s as a result of oil crises, the release of military fuel supplies from the de-nuclearisation of Cold War states and negative community attitudes towards nuclear power investment following accidents at Chernobyl and Three Mile Island.

Figure 2.5: Primary production compared to commercial demand



Source: UxC Consulting Company, 2007, www.uxc.com [January 2008], Roswell.

Figure 2.6: Long term contract prices for uranium



Source: TradeTech, 2007, www.uranium.info [January 2008]. Note Price data published by Trade Tech is based on information collected on as many uranium sales as possible (but not all sales are captured).

New mine development has been slow during this period, as the shortfall between primary mine production and total global demand for uranium fuels has been filled by the supply of uranium through secondary sources (Figure 2.5).[31] The historic oversupply of uranium has kept long term contract prices low in real terms, at less than US$20 per pound.

The historical over-supply situation has reversed in the past several years, with demand currently exceeding supply. This has been caused by the eventual run down of excess inventories and the recent change in community attitudes towards nuclear power as a result of climate change. As a result of global concerns for climate change, there has been a marked increase in demand for nuclear power, and the IAEA's recent draft 2008 Nuclear Technology Review has revised its estimates for nuclear power generation in 2030 by 53 per cent.[32]

The recent shift in the demand/supply balance has driven both a significant recovery in the spot price for uranium oxide, to more than US$80 per pound – more than ten times its low point in 2000 – and a very significant recovery in the long term contract price (Figure 2.6).[33]

In turn, expenditure on exploration has significantly increased. In Australia exploration expenditure has increased more than 13 times the levels seen five years ago, and nearly six times 2004 expenditure levels to $114 million per annum. Increased exploration has occurred not just in Australia but worldwide. In March 2008, the IAEA reported that in only two years since its last estimate of global uranium resources (2005), total identified resources had jumped by 17 per cent (Table 2.2).[34]

31 Highly enriched uranium from military stockpiles (with U-235 concentrations of 90 plus per cent) can be down blended to suitable concentrations for use as fuel in nuclear reactors. In 1994 the United States and Russia established a bilateral agreement to sell highly enriched uranium, which is estimated to displace around 10,000 tonnes of uranium mine production per annum (approximately 13 per cent of world demand), over a 20 year period. Plutonium, because of its similar atomic properties to U-235, can be mixed with depleted uranium to provide a mixed oxide nuclear fuel.

31 See International Atomic Energy Agency, 2008, op. cit.

33 UxC Consulting Company, 2007, www.uxc.com/review/uxc_g_price.html. [8 November 2007].

34 *Ibid*.

Table 2.2: Known recoverable uranium resources (as of 1 January 2005)

	Tonnes of Uranium Oxide		
	<US40/kg	<US80/kg	<US130/kg
Country			
Australia	1,231,132	1,266,509	1,347,877
Kazakhstan	481,241	715,399	962,381
Canada	438,443	523,349	523,349
USA		120,283	403,302
South Africa	168,808	293,340	401,646
Namibia	145,493	280,186	332,971
Niger	203,851	265,871	265,871
Brazil	164,976	272,759	328,656
Russia	93,281	203,304	203,304
Uzbekistan	107,033	107,033	115,959
Ukraine	40,705	89,962	105,939
Mongolia	19,104	73,054	73,054
Rest of world	75,018	275,248	528,678
Total U_3O_8	**3,238,656**	**4,486,298**	**5,592,987**

Source: OECD NEA & IAEA, 2005, *Uranium 2005: Resources, Production and Demand*, converted to tonnes uranium oxide from tonnes of uranium.

Critically, the information contained in Table 2.2 is based upon the survey responses from individual countries. Although it is considered the most comprehensive source of uranium information, a number of stakeholders – *including organisations not involved in the commercial mining of uranium* – have indicated concern about the accuracy of the information, particularly for the <US$80 and <US$130 cost ranges. Stakeholders indicated that because uranium prices have been so low historically, very little exploration has occurred historically to prove up resources at higher costs of uranium.

Table 2.2 also excludes the IAEA's 'undiscovered resources' which include both prognosticated resources and speculative resources. 'Undiscovered resources' are resources that the IAEA expects to occur in well defined geological trends of known deposits, and geologically favourable yet unexplored areas. Only some countries collect this data, however; Australia, for example, which is the world's largest known region for uranium resources, does not contribute to data on other undiscovered resources. Considering other undiscovered resources adds a potential further 7.5 million tonnes of uranium to total world resources: more than twice the identified resources reported in 2005 by the IAEA (even excluding key countries from the estimate, such as Australia). The IAEA has also underscored that many countries, including Australia, were 'considered to have significant resource potential in as yet sparsely explored areas'.[35]

With current mine production only able to meet 64 per cent of current demand[36], and the remainder being met by rapidly reducing secondary sources, there is a need for an increase in global uranium supply over the medium term. Indeed there are a number of developments underway, and the current shortfall in production is expected to be closed by 2015, with a number of mine expansions and new mines coming online over that timeframe, including Canada's Cigar Lake and Midwest mines, a number of mines in Kazakhstan. There is also the proposed expansion of Olympic Dam in Australia.

Thus while the price recovery for uranium oxide has strongly supported growth in exploration and expected mine development, there are also risks that the rapid price rise may drive a wave of new supply that will slow future growth in the uranium price and additional mine development. In the future, the economics of new mine development and the rate of exploration will be affected by:

- the extent to which the market reacts to the price recovery and new supply becomes available over time;
- future contract terms and arrangements;
- new reactor technologies that may improve fuel efficiency or expand the capacity of existing reactors;
- the grades of uranium deposits;
- inventory behaviour by utilities; and
- changes in the global price for carbon.

35 International Atomic Energy Agency, 2005, op. cit.

36 World Nuclear Association, *Uranium Market*, World Nuclear Association, www.world-nuclear.org [15 February 2008].

3 Australia's uranium industry

This chapter identifies the current resources, levels of production and export, exploration patterns and regulatory framework of Australian uranium. It concludes by outlining the current competitive position of Australia within the global uranium market and locates opportunities for Australia going forward.

3.1 Australia's uranium resources

At 1.1 million tonnes, Australia has the largest reasonably assured and inferred resources of uranium of any nation. To put this in context, Australia has a greater share of the world's uranium resources than Saudi Arabia's share of global oil resources. In terms of energy security, Australia is one of the few remaining developed nations with significant uranium resources.[37]

Figure 3.1: Australia's uranium resources

Source: Australian Uranium Association, *Australia's uranium*, www.uic.com.au/ozuran.htm [February 2007]; and Geoscience Australia, *Australia's Identified Mineral Resources 2007*, Australian Government, Canberra, 2007

More than three quarters of the known and inferred resources are found in South Australia, and more specifically, in the Olympic Dam deposit (Figure 3.1). Other significant resources have also been found in the Northern Territory, including in particular the Ranger deposit in the Alligator Rivers region.

Some resources have also been identified in Queensland and Western Australia; however, as uranium mining is not allowed in these States, exploration has been limited. Western Australia has significant calcrete deposits that have been subject to minimal uranium exploration as a result of mining restrictions in that State.

3.2 History of uranium mining in Australia

Uranium mining in Australia began in the 1930's, with mines at Radium Hill and Mount Painter in South Australia producing small quantities of radium for medical purposes.[38]

In 1944, in the context of the Manhattan Project and no doubt reflecting a concern over a possible post-war nuclear arms race, the US and British governments requested that uranium exploration be encouraged in Australia. In 1948 the Commonwealth government offered tax free incentives for uranium discoveries. Uranium was then discovered at Rum Jungle and South Alligator River in the Northern Territory and at Mary Kathleen and Westmoreland in Queensland.

Radium Hill was reopened in 1954 as a uranium mine. Rum Jungle commenced mining in 1958 under Commonwealth Government ownership. In the same year, mining began at Mary Kathleen, while a mine at South Alligator River commenced operations in 1959. Production at most mines ceased by 1964 (Rum Jungle continued producing until 1971) either when ore resources were exhausted or contracts were filled. Sales of some 7,730 tonnes of uranium from these operations supplied material primarily intended for USA and UK weapons programs at that time. In fact, however, much of the uranium was used in civil power production.

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37 At $130/kgU, Australia's reasonably assured and inferred resources were estimated in 2005 to account for 24 per cent of total reasonably assured and inferred resources globally. Since then significant work has been completed in proving up the Olympic Dam resource that is not reflected in these figures. Saudi Arabia's share of proven resources was estimated to be 22 per cent in 2006. Organisation of the Petroleum Exporting Countries, 2006, *Annual Statistical Bulletin:* 2006, Organisation of the Petroleum Exporting Countries, Vienna.

38 This section of the report borrows heavily from information published by the Australian Uranium Association: http://www.world-nuclear.org/info/inf48.html

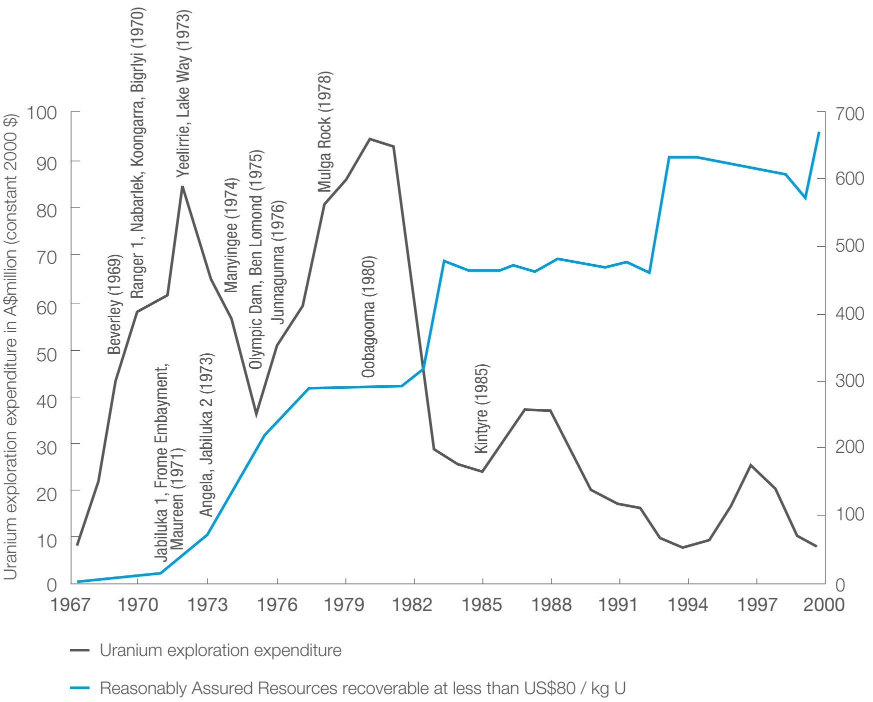
The growth of the nuclear power industry stimulated a second wave of exploration activity in the late 1960s. In the Northern Territory, Ranger was discovered in 1969, Nabarlek and Koongarra in 1970, and Jabiluka in 1971. Successive governments (both Liberal Coalition and Labor) approved sales contracts by these operations and Mary Kathleen began re-commissioning its mine and mill in 1974. Mary Kathleen recommenced production of uranium oxide in 1976, after the Commonwealth Government had taken up a 42 per cent share of the company. Consideration by the Commonwealth Government of additional sales contracts was deferred pending the findings of the Ranger Uranium Environmental Inquiry.

In 1976 the Ranger Uranium Environmental Inquiry (or 'Fox Inquiry') was set up by the Fraser Government to investigate and advise on both uranium policy and the prospect of opening up for development Australia's substantial uranium resources in the Northern Territory. Following the release of the findings of the Fox Inquiry, the Federal Government announced in August 1977 that it would provide approvals for the export of Australia's uranium subject to strict environmental requirements and safeguards to prevent the diversion of uranium for military purposes.

In this decision, the Government announced that new uranium mining was to proceed, commencing with the Ranger project in the Northern Territory. In 1979 it decided to sell its interest in Ranger, and as a result Energy Resources of Australia Ltd was established to own and operate the mine. The mine opened in 1981, producing 2,800 tonnes/year of uranium, sold to utilities in several countries. Production over three years to mid 2002 averaged 3,533 tonnes of uranium annually.

In 1980, Queensland Mines opened Nabarlek in the same region of Northern Territory. The ore body was mined out in one dry season and the ore stockpiled for treatment over time. A total of 10,858 tonnes of uranium oxide were produced and sold to Japan, Finland and France, over 1981-88. The mine site has now been rehabilitated.

Figure 3.2: Historical exploration expenditure and uranium resources



Source: McKay, A.D., and Miezitis, Y., 2002, *Australia's Uranium Resources, Geology and Development of Deposits*, Mineral Resource Report 1, GeoScience Australia, Australian Government, Canberra.

By the end of 1982 Mary Kathleen in Queensland had depleted its ore and finally closed down after 4,802 tonnes of uranium oxide had been produced in its second phase of operation. This then became the site of Australia's first major rehabilitation project on a uranium mine site, which was completed at the end of 1985. The Rum Jungle Rehabilitation project also took place in the 1980s.

The oil shocks of the 1970s led to a uranium price boom and revitalised exploration activity in Australia. In this period a number of uranium deposits were discovered, including Jabiluka, Angela, Yeeleerie, Lake Way, Olympic Dam, Ben Lomond and Mulga Rock (Figure 3.2).

Since the mid-1980s, however, activity in the uranium industry in Australia has been dominated by the ALP's policies, described in Chapter 1 of this report. In 1983 these policies restricted the industry to three mines and then, in 1996, to 'no new mines'. The removal of those restrictions in April 2007 at the federal level has yet to become operational as far as most ALP State governments are concerned. South Australia and the Northern Territory already allow for uranium mining.

Apart from these restrictions on mining, the Australian uranium industry is also very highly regulated. Each of the mines in operation today is subject to a range of Commonwealth and State based regulations, which are critical for allaying community concerns over the mining of uranium, but which are in some cases duplicative and could be streamlined without any decline in safety or environmental standards. The main Commonwealth regulations include the *Atomic Energy Act 1953*, the *Nuclear Non-Proliferation (Safeguards) Act 1987*, the *Australian Radiation Protection and Nuclear Safety Act 1998*, the *Environmental Protection and Biodiversity Conservation Act 1999, the Customs (Prohibited Exports) Regulations 1958*, the *Aboriginal Land Rights (Northern Territory) Act 1976*, and the *Native Title Act 1993*.

A short summary of the relevant State and Federal regulation is provided in Appendix A.

3.3 Current mines

Largely as a result of regulatory restrictions, Australia currently has only three operating uranium mines in the Northern Territory and South Australia. The three operating mines are:

- *Olympic Dam* – The BHP Billiton (BHPB) owned Olympic Dam mine in South Australia is predominantly a copper mine, but is also Australia's largest source of uranium oxide as well as the third largest mine in the world currently. Olympic Dam has a total mining capacity of 231,000 tonnes of uranium oxide (JORC classification of proved, probable, reserves, and stockpiles). In 2006, 3,382 tonnes of uranium was produced with an average grade of 0.057 per cent uranium oxide. BHPB is currently exploring the business case for a three-staged expansion of the mine, which would see uranium oxide production rise to 19,000 tonnes per annum and Olympic Dam become the largest uranium mine in the world.
- *Beverley* – The Beverley mine is owned by Heathgate Resources and is located in South Australia. According to Heathgate Resources, the Beverley mine currently produces around 1,000 tonnes of uranium oxide annually. The mine began operating only a few years ago and Heathgate Resources has stated it expects the mine to have a life of around 15 to 30 years. Beverley's production capacity is 1,500 tonnes uranium oxide per annum. Beverley was Australia's first in situ recovery (ISR) mine. Exports from the Beverley mine are contracted to go to energy utilities in the USA, Europe and Japan.
- *Ranger* – The Ranger mine is owned by Energy Resources of Australia Ltd (ERA), a majority owned subsidiary of Rio Tinto, and is located in the Northern Territory. It has a current production capacity of around 5,000 tonnes of uranium oxide per annum, making it the second largest mine in the world. The mine employs approximately 400 workers, including more than 60 indigenous employees.

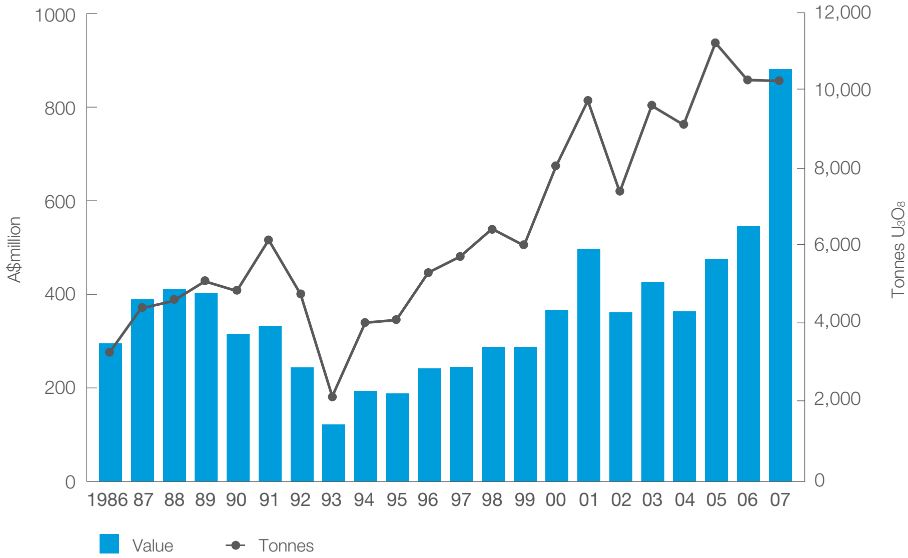
Table 3.1: Australian uranium mine statistics

Mine	Owner	Annual U_3O_8 production capacity (tonnes of U_3O_8)	Total mine capacity (tonnes of U_3O_8)	Average uranium grade (%U_3O_8)	Number of employees (direct)[a]
Olympic Dam	BHP Billiton	4,500	231,000	0.057%	3,000 persons
Ranger	ERA Ltd	5,000	49,671	0.15%	400 persons
Beverley	Heathgate Resources	1,100	21,000	0.18%	100 persons

Source: ERA, 2008, *Geology and Mining*, ERA, www.energyres.com.au/our_business/ranger_operation/geology_and_mining [January 2008], Darwin; Heathgate Resources. 2007, *The Mine*, www.heathgateresources.com.au/contentmine.jsp?xcid=129 [January 2008], Adelaide; Australian Uranium Association, 2008, *Uranium in Australia*, Australian Uranium Association, http://www.aua.org.au/page.php?pid=341 [January 2008], Melbourne.

Notes: (a) These numbers are whole of mine figures for employment.

Figure 3.3: Australian uranium exports



Source: Australian Uranium Association, 2008, Australia's Uranium and Nuclear Power Prospects, Briefing Paper 1; Australian Uranium Association, January, Melbourne; and BHP Billiton submission, 2007, *op. cit.*

Ranger first came into operation in the early 1980's and has gone through various expansions and redevelopments. There are plans for a further expansion of the mine that will extend the mine life to around 2020, add an additional 400 tonnes of production capacity per annum and create additional jobs. Exports from the Ranger mine are contracted to go to energy utilities in Japan, South Korea, UK, France, Germany, Spain, Sweden and the USA.

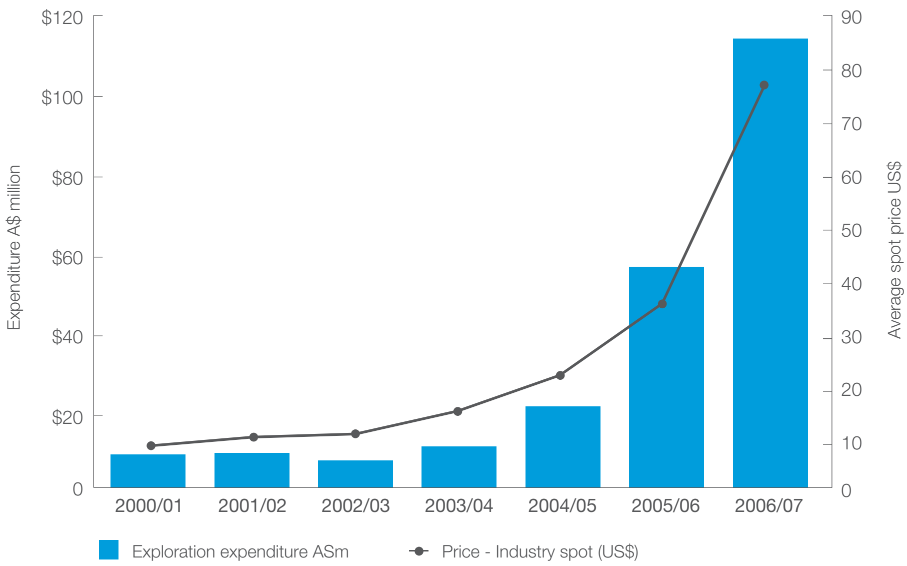
A fourth mine, the Honeymoon mine in South Australia, is scheduled to begin production in late 2008. Owned by UraniumOne, Honeymoon will be a new *in situ* recovery mine and is planned to produce an estimated 400 tonnes of uranium oxide per annum. The mine has a total capacity of 2,900 tonnes of uranium oxide, with an average uranium grade of 0.24 per cent.[39]

39 UraniumOne, 2008, *Honeymoon Project,* UraniumOne, www.uranium1.com/indexu.php?section=uranium%20projects&page=5 [January 2008], Adelaide

Currently, the three operating mines employ more than 3,500 persons directly and have an annual production capacity of more than 10,000 tonnes (Table 3.1). In the case of Olympic Dam, current production capacity is small relative to the total estimated resources but the mine also produces copper and gold. Critically, these mines also provide significant employment in rural and regional areas, including in particular for indigenous Australians. In 2007, for example, approximately 16 per cent of ERA's Ranger workforce was composed of indigenous Australians.[40]

Actual production levels from these mines vary depending on global demand for uranium and the weather conditions that impact actual uranium mining capability. In 2007, Australia produced and exported 10,232 tonnes of uranium oxide, valued at $881 million.[41] This quantity of uranium is sufficient for any fuel requirements of approximately 50 reactors of approximately 1,000 MW, which would produce around 295 TWh of electricity, approximately 1.3 times Australia's total electricity production.

Figure 3.4: Exploration expenditure and average spot prices



Source: Australian Bureau of Statistics, 2003, *Mineral and petroleum exploration*, cat. No. 8412, September quarter 2003, Australian Government, Canberra; Australian Bureau of Statistics, 2005, *Mineral and petroleum exploration, cat. No. 8412*, September quarter 2005, Australian Government, Canberra; Australian Bureau of Statistics, 2006, *Mineral and petroleum exploration, cat. No. 8412*, September quarter 2006, Australian Government, Canberra; ABS, *Mineral and petroleum exploration, cat. No. 8412*, June quarter 2007, Australian Government, Canberra; Australian Bureau of Agricultural and Resource Economics, 2003, *Australian Mineral Statistics*, December quarter 2002, Australian Government, Canberra; Australian Bureau of Agricultural and Resource Economics, 2005, *Australian Mineral Statistics*, December quarter 2005, Australian Government, Canberra; Australian Bureau of Agricultural and Resource Economics, 2006, *Australian Mineral Statistics*, December quarter 2006, Australian Government, Canberra; Australian Bureau of Agricultural and Resource Economics, 2007, *Australian Mineral Statistics*, September quarter 2007, Australian Government, Canberra.

3.4 Recent trends in exploration

In response to the recovery of the long term contract price for uranium, total exploration expenditure has increased significantly across Australia. Expenditure in 2006-07 was reported to be $114 million, which was more than five times the total expenditure reported in 2004-05 (Figure 3.4).

Major exploration occurred in the Northern Territory and South Australia, and was undertaken by mature MNEs, such as Cameco (Canada) and Areva (France), as well as a number of more junior miners. Both BHPB and ERA also invested in exploration of currently mined resources. Exploration expenditure in the Northern Territory and South Australia was $30.1million and $63.8million, respectively. In the Northern Territory, exploration has focused on the Alligator Rivers region, Western Arnhem Land and Ngalia Basin. In South Australia, exploration activities continued in the Gawler Craton-Stuart Shelf region and the Frome Embayment.

While the 'no mining' policy in Queensland and Western Australia represented a barrier to exploration, these States, too, saw an increase in total exploration expenditure:

- Exploration in Queensland increased from $0.4million in 2004-05 to $7.5 million in 2006-07[42]. The area around Mt Isa was the most active exploration area in Queensland, including the areas where previous discoveries have been made such as Valhalla, Skal, Andersons, Mirrioola, Watta, Warwai, and Bikini.
- Western Australia also experienced an increase in exploration expenditure in uranium mining, from a low of around $0.3 million in 2004-05 to $9.2 million in 2006-07. Exploration in first quarter of 2007-08 has been the highest in recent years, reaching $6.6 million.

Prospective opportunities for further uranium discoveries in Australia are significant due to Australia's geology and technological improvements making it cheaper to dig deeper.

40 Salisbury, C., 2007, op. cit, p 28.

41 As there is no nuclear power generation in Australia all of the demand for Australian uranium derives from international sources.

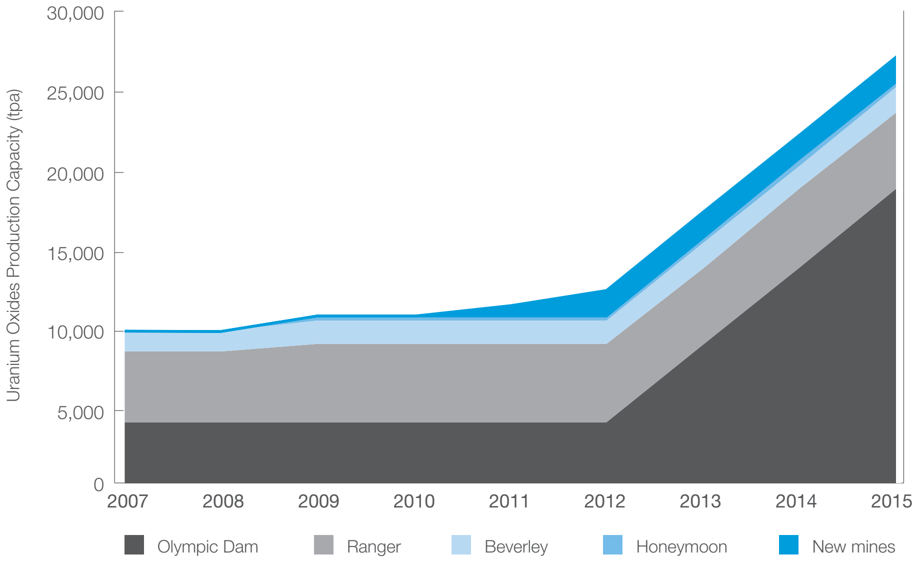
42 Data incomplete as a result of some unpublished data.

3.5 Prospective new mines and expansions

Australian productive capacity is expected to expand by more than double in the period to 2015. This is mainly a result of a large planned expansion at Olympic Dam, in addition to capacity expansion at Ranger, and the opening of Honeymoon mine. This is shown in Figure 3.5.

Beyond this, the prospects for industry development are set out on a State by State basis below. Estimates of the total resources for each mine are based on the best available information from GeoScience Australia as at January 2008, except where noted otherwise. Estimates of total resources for each mine published separately may differ from the estimates presented here due to either differences in resource or reserves definitions 0(JORC or IAEA) or as a consequence of additional information becoming available subsequent to this report.

Figure 3.5: Planned Australian productive capacity to 2015



Source: Australian Bureau of Agricultural and Resource Economics, *ABARE's List of Major Minerals and Energy Projects*, October 2007, available at www.abare.gov.au

3.5.1 South Australia

Within South Australia there are several prospects for future development, with the major opportunity being the potential three stage expansion of Olympic Dam.

- *Olympic Dam expansion* – Located 560km north of Adelaide, Olympic Dam is currently a large-scale underground mine producing copper, uranium, gold and silver. Most of the mines employees live in Roxby Downs, which is 16 km south of the mine and home to a population of about 4,000 people.[43]

  Development of the project started in December 1985 through a JV between WMC Resources Ltd and BP Minerals. Production commenced in 1988. Initially, the mine produced only 1,400t of U_3O_8, as well as 65,000t refined copper, and associated refined gold and silver. In 1993, WMC Ltd acquired full ownership of Olympic Dam from its previous JV partner BP minerals.

  Between 1989 and 1995, the annual capacity of the processing plant was increased in two stages to produce 1,700t U_3O_8. A major expansion of the project was completed in March 1999 at a cost of $1.94 billion. Annual production capacity was increased to 200,000t copper, 4,600t U_3O_8, 2,050 kg gold and 23,000 kg silver.[44]

  In 2005, BHP Billiton acquired WMC and has since committed to a pre-feasibility study of potential development options at the mine. Olympic Dam is the largest uranium deposit in the world. According to JORC measures, Olympic Dam is estimated to have approximately 231,000t U_3O_8. Separately, GeoScience Australia has estimated total identified resources at Olympic Dam to be 2.5Mt U_3O_8. In December 2007 BHPB announced it was scoping a conceptual three-stage expansion that would see production expand from 4,000t U_3O_8 per annum to 19,000t U_3O_8 per annum. Investments in the site could include pre-stripping the open pit, modifying the existing smelter and building a greenfields concentrator, developing and expanding the open pit, and adding a second and potentially a third greenfields concentrator.[45] In terms of other infrastructure BHPB may also invest in rail transport from Olympic Dam to Pimba, electricity transmission, a new airport, a coastal desalination plan and associated water pipeline infrastructure, a new construction camp and additional accommodation and other social services in Roxby Downs.[46]

- *Mount Gee deposit* – The Mount Gee prospect is a mid-size deposit of approximately 24,804t uranium oxide near Mount Painter in South Australia. Approximately one hundred exploration holes were drilled into this prospect between 1969 and 1971 by the Oilmin Group. Oilmin also discovered the nearby Beverley deposit to the east around the same time, one of the three mines currently in operation in Australia. The deposit is owned by Marathon Resources, which is seeking to develop the mine for production in the short term. A 72-hole drilling program was completed in March 2007. Marathon expects the mine could produce approximately 900t uranium oxide per annum.[47]

43 BHP Billiton, 2007b, op. cit.

44 McKay, A.D., and Miezitis, Y., 2002, op. cit.

45 BHPB, 2007a, op. cit.

46 BHPB, 2007b, op. cit.

47 Marathon Resources, 2008, *Frequently Asked Questions*, Marathon Resources, http://www.marathonresources.com.au/faq.asp [January 2008]

- *Crocker Well and Mount Victoria mine developments* – The Crocker Well-Mount Victoria deposit is a small deposit in the Curnamona Province of South Australia, estimated to have resources of approximately 8,576t uranium oxide. The mine is 60 per cent owned by Sino Steel and 40 per cent owned by PepinNini. SinoSteel has committed $11 million for further exploration of the deposits and the wider Curnamona area.
- *Four Mile mine development* — Four Mile comprises two deposits 5 to 10km northwest of the Beverley mine and is being explored by Quasar Resources Pty Ltd (affiliated with Heathgate Resources). Alliance Resources Ltd is a 25 per cent free carried joint venture partner. An 'initial resource estimate' of 15,000 tonnes U_3O_8 at 0.37 per cent was announced in May 2007 for the west deposit and this subsequently became inferred resources under JORC code. Alliance in January 2008 announced preliminary indications of a similar resource is in the east deposit. In January 2008 Alliance announced a concept study for the project with ISR mining commencing in 2010 at 680t U_3O_8 per annum and working up to 2,000t per annum if resources in the eastern deposit materialise in an initial resource estimate, expected in the second quarter of 2008. A field leach trial on the west deposit is scheduled for mid-2008 to provide the basis for a mine lease application.

3.5.2 Northern Territory

The Northern Territory is a uranium rich area. There are prospects for the expansion of the Ranger mine, as well as potential developments of other well known resources, many of which have already received approvals for mine development. Access to land is an important consideration, however, and companies have indicated that many of these mines will not be developed without the consent of traditional owners.

- *Ranger expansion* – The Ranger ore bodies were originally discovered in 1969 by joint venturers Electrolytic Zinc Company of Australasia Ltd and Peko-Wallsend Operations Limited. In 1974, the Commonwealth acquired half ownership of the deposits.

  First production from an open cut mine began in 1981 (Ranger Pit #1) by ERA, and was completed in 1994. Total production from the pit was estimated to be approximately 6.3Mt uranium oxide. ERA subsequently expanded its operations with a further pit development (Ranger Pit #3) for which it received final approval to mine Ranger Pit #3 from the Northern Territory Government in 1996. Open cut mining of Ranger Pit #3 commenced in 1997.

  Currently, the Ranger ore bodies are still estimated to have identified resources of approximately 81,000t uranium oxide, and ERA is seeking to expand Pit #3. In February 2008 ERA reported that a $57 million mine expansion announced in September 2007 is currently on budget and ahead of schedule. According to ERA the first new trucks have arrived and mining rates will increase from the first quarter of 2008. This expansion will result in the additional employment of 45 people at Ranger, from current employment of approximately 400 persons. Additional expenditure on laterite treatment and radiometric sorting plants will also be commissioned in the middle of 2008 at an estimated costs of $34.0 million and $17.1 million, respectively.[48]
- *Jabiluka deposit* – The Jabiluka deposit, also owned by ERA, was discovered in 1971 by Pancontinental Mining Ltd. The Jabiluka resource is located 22 km to the north of the Ranger deposit and is one of the largest undeveloped uranium deposits in the world. Jabiluka remains under long term care and maintenance following an agreement in 2005, whereby ERA agreed with the Gundjeihmi Aboriginal Corporation and the Northern Land Council, not to develop the deposit without the express consent of the Mirarr Traditional Owners.
- *Angela and Pamela mine developments* – The Angela deposit is located 25 km south of Alice Springs. It was discovered in 1973 and extensively drilled by Uranerz Australia in 1989, under a Uranerz-MIM joint venture. The resource is currently estimated to have approximately 10,250t uranium oxide. After Uranerz departed from Australia in 1991, the retention licence was subsequently relinquished. The NT government in February 2008 accepted a bid by 50-50 joint venturers Paladin Energy Ltd and Cameco Australia to explore the deposit with the adjacent Pamela deposit. The new Angela Project JV has committed to spend $5 million on confirming the resources once a licence is issued, with a view to then undertaking a feasibility study.[49]
- *Napperby mine development* – The Napperby deposit is a small deposit approximately 150 km northwest of Alice Springs owned by Toro Resources. Estimated reserves (JORC) for the deposit are currently 670t uranium oxide; the company is undertaking further exploration, however, and expects the reserves estimate to increase to 4,500t to 6,000t uranium oxide by 2009. Toro Energy announced in November 2007 that it was seeking to fast track the development of the Napperby mine along with its other deposit, Lake Way and Centipede.[50]
- *Mount Fitch mine development* – Discovered in 1965, Mount Fitch is a small deposit of approximately 3,400t uranium oxide, located 64 km south of Darwin. Compass Resources NL has been active in the area for some years, primarily focused on the Browns deposit, a copper-cobalt-nickel deposit, which it plans to put into production in early 2008.[51]

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48 ERA, 2008, *Full Year Results*, 1 February, ERA, http://www.energyres.com.au/__data/assets/pdf_file/3084/20080201_full_year_results_31-12-07_FINAL.pdf [February 2008].

49 Australian Uranium Association, 2008, *Australia's Uranium Deposits and Prospective Mines*, Australian Uranium Association, http://www.uic.com.au/pmine.htm [February 2008]

50 Toro Energy, 2007, *Project Team to Rapidly Progress Two Key Uranium Projects for Toro*, Toro Energy, http://www.novaenergy.com.au/projectteam.pdf [January 2008]

51 Australian Uranium Association, 2008, op. cit.

- *Koongarra deposit* – Koongarra is a small but relatively high grade uranium deposit in the Alligator Rivers region of the Northern Territory.
  It lies some 30 km south of Ranger and three kilometres east of Nourlangie Rock. When the Kakadu National Park was set up in 1979, the land covered by the Koongarra Special Mineral Lease was excluded. The Lease area is on Aboriginal land. Koongarra was discovered by Noranda Australia Ltd in 1970. In 1980 Denison Australia Pty Ltd took over Noranda's interests in the deposit. In 1992 Total acquired a 70 per cent interest in Koongarra, which was subsequently acquired by Cogema Australia Pty Ltd. In 1995 Cogema acquired the remaining 30 per cent interest in the project. In 2006 Cogema mining operations became part of Areva NC. When Denison Australia took over the deposit, a draft EIS was submitted to the Federal Government. The final EIS was approved in 1981.

  Denison negotiated Aboriginal agreements, but these did not receive the assent of the Federal Minister for Aboriginal Affairs, and development was stalled in 1983.There are no plans to develop Koongarra in the short to medium term. If it were to be developed in the future, the ore body has 14,500t uranium oxide, with expected production of approximately 1,375t per year.[52]
- *Bigrlyi mine development* – Located approximately 390km northwest of Alice Springs, Bigrlyi is estimated to contain 10,590t of uranium oxide and 19,809t of vanadium oxide. The deposit was discovered by Central Pacific Minerals in 1973 and is currently held by a joint venture between Energy Metals Ltd (53.7%), Paladin Energy (42.1%) and Southern Cross Exploration (4.2%).
- *Nolan's Bore mine development* – Nolan's Bore is a rare earths deposit containing nearly 4,000t uranium oxide. The prospect is owned by Arafura Resources NL.

3.5.3 Queensland

Queensland also has a number of large prospects, many of which are clustered in the Mount Isa region and many of which have obtained mining approvals. In spite of current government regulation many companies are also undertaking significant exploration activity.

- *Valhalla mine development*[53] – The Valhalla Uranium Deposit is located 40km northwest of Mount Isa city. Discovered in 1954 by a prospector, Mount Isa Mines (MIM) took it over and sunk an exploration shaft. In the 1960s, it passed to Queensland Mines Ltd, which drilled it extensively and held it until 1992, when Summit Resources Ltd took over. Currently the mine is being explored further through a JV partnership (the Isa Uranium Joint Venture) between Summit Resources and Paladin. A budget of $8 million has been allocated by the Isa Uranium Venture to the exploration of both Valhalla and the nearby Skal mine. The proposed plan includes 147 drill holes at Valhalla for a total of 49,620m. Of this 33,030m will be via reverse circulation (RC) drilling and the remaining 16,230m will be via diamond drilling. The program is aimed at ensuring that the majority of the top 400m of the resource will fall into the Measured and Indicated Resource categories. The prospect is expected to have resources of 25,900t uranium oxide.
- *Westmoreland mine developments* – The Westmoreland deposit straddles the Queensland and Northern Territory border, about 400 kilometres north of Mt Isa. The Westmoreland Project was discovered by Mount Isa Mines in 1956 by a prospector and has had a long history of exploration by the Bureau of Mineral Resources, Queensland Mines (1967-1985, with various partners), and CRA Exploration Pty Ltd, which is now Rio Tinto Exploration (1990-2000). Most recently it was acquired by Toronto-based Larimide Resources in 2004.

  Rio Tinto completed a pre-feasibility study which included infill drilling, detailed metallurgical test work and resource calculations. This work was focussed on three deposits Redtree, Huarabagoo and Junnagunna. There are a further 39 uranium occurrences throughout the project area. This work completed by Rio Tinto, showed that the uranium mineralization was readily amenable to acid leaching and had low acid consumption with high uranium recoveries.

  The deposit area is currently estimated to contain 22,000t uranium oxide. Laramide plans to complete a major exploration program at Westmoreland during the coming field season. This will include up to 30,000 metres of drilling to be used in upgraded resource calculations and metallurgical test work. This work will form the basis for a definitive feasibility study, which will pave the way for applying for permits to construct the project.[54]

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52 Australian Uranium Association, 2008, *op. cit*.

53 *Ibid*; Summit Resources, 2007, *Mt Isa Uranium Projects – Program for 2007/2008 Financial Year*, ASX announcement, Summit Resources, http://www.summitresources.com.au/ [February 2008]; Paladin Resources, 2007, Paladin Resources Ltd: Isa Uranium Joint Venture Project – Annual Programme, ASX announcement, Paladin Resources; and updated mine information from Summit Resources, January 2008, *Quarterly Report for Period Ending 31 December 2007*, ASX Announcement.

54 Larimide Resources, 2008, Westmoreland Uranium Project: "Lagoon Creek", Larimide Resources, http://www.laramide.com/SiteResources/ViewContent.asp?DocID=58&v1ID=&RevID=136&lang=1 [February 2008]; and Ibid.

55 Australian Uranium Association, 2008, op. cit.; and Summit Resources, 2007, op .cit.

- *Skal mine development* – The Skal mine is a small deposit, with approximately 4,200t uranium oxide resources, that is jointly owned by Summit and Paladin Resources Ltd, which each have a 50 per cent interest in the Skal ore body through the Isa Uranium Joint Venture. Summit, as the manager of the Joint Venture, advised a budget of $8 million for the financial year 2007-08 for exploration of both the Skal and the Valhalla mine, which represented a 320 per cent increase over the previous year's expenditure. This amount includes a proposed drilling program, metallurgical test work, and environmental and radiation baseline studies.[55]
- *Andersons Lode mine development* – Anderson's Lode is located 15 km north east of Mt Isa and is owned by Summit Resources. The deposit is currently estimated to contain approximately 3,700t uranium oxide.
- *Ben Lomond mine development* – This deposit, some 50 kilometres west of Townsville, was discovered in 1975 by Total Mining Australia Pty Ltd. Mining leases were granted in 1980 and 1983, however, due to the Three Mines Policy, no mining was undertaken. In 1994, following the transfer of Total's worldwide uranium assets to Cogema, the company changed its name to Afmeco Mining and Exploration Pty Ltd (AFMEX), which is a wholly-owned subsidiary of Cogema Australia Pty Ltd. In 2005 the deposit was sold for $1 million to Uranium Mineral Ventures Inc, a subsidiary of Maple Minerals Corp of Canada. In January 2005 Mega Uranium Ltd agreed to acquire 100% of UMV and in February 2006 the Queensland government approved transfer of the leases to UMV. The deposit is estimated to have approximately 4,100t uranium oxide, which if developed would be an open cut mine with annual production of 500t uranium oxide and 250t molybdenum.[56]
- *Maureen mine development* – The small Maureen uranium deposit near Georgetown in north Queensland was bought in July 1997 by Anaconda Uranium Corporation, but in 1998 reverted to its previous private owners. Measured and indicated resources are almost 2,500t uranium oxide that would be accessible by open pit. Some $8 million was spent on the deposit in the 1970s. In 2005 the deposit was owned by Georgetown Mining Ltd and in August 2005 Mega Uranium Ltd acquired the rights to the deposit and surrounding mineralised areas.[57]

3.5.4 Western Australia

Western Australia has some significant identified calcrete deposits.

- *Yeelirrie mine development* – The Yeelirrie deposit is located about 500 kilometres north of Kalgoorlie and close to the Goldfields gas pipeline. The deposit was discovered in 1972 by WMC, who sold it to Urangesellschaft Australia in1978 before buying it back in 1993. Currently owned by BHPB, acquired through its take over of WMC, Yeelirrie is the world's largest calcrete hosted deposit, and is estimated by GeoScience Australia to contain approximately 41,250t uranium oxide, making it one of the largest uranium mines in Australia.

  The deposit is shallow and would be expected to be a low-cost mining operation, capable of producing approximately 2,500t uranium oxide per annum, with 1,000t per year of vanadium oxide by-product. Yeelirrie received approvals from Western Australia and the Commonwealth to mine the prospect, and in the twelve years to 1983 WMC and its partners invested a total of $35 million to develop Yeelirrie as an open cut mine, including building and operating the pilot metallurgical plant at Kalgoorlie. A $320 million project was envisaged and sales contracts were being planned. However, the Three Mines Policy meant that permission to negotiate sales contracts was withdrawn in the early 1980s.[58]
- *Kintyre mine development* – The Kintyre deposit is a significant high-grade uranium ore body with a small surface outcrop in the remote Rudall region of Western Australia. This is on the western edge of the Great Sandy Desert in the Eastern Pilbara Region of Western Australia, approximately 70 km south of Telfer and some 1200 kilometres NNE of Perth. It was discovered by Rio Tinto Exploration in 1985 through surface follow-up of a number of radiometric anomalies detected during an airborne survey.[59]

  In 1996, Canning Resources, a Rio Tinto company, advised the Commonwealth and Western Australian Governments of its intention to develop the Kintyre deposit, and work commenced on the environmental impact assessment of the proposed mining operation. The operation planned to produce 1,200t uranium oxide per annum through open pit mining, with the potential to increase production up to 2,000t uranium oxide per annum over a twenty-year period. The company proposed to mine each of the ore bodies using separate open pits.

  Before being milled, the ore was to be upgraded by radiometric sorting and the smaller size fraction was to be concentrated using ferrosilicon heavy-medium separation. Uranium was to be extracted using an acid leach process. However, the company decided in 1997 to delay the development of the deposit because of the low uranium prices at that time.[60] In 2002 it was decommissioned and rehabilitated.[61]

  In 2007-08, Kintyre was put up for sale by Rio Tinto, with deadline for bids in March. The resource is estimated to be approximately 36,000t uranium oxide.

56 *Ibid*.

57 Australian Uranium Association, 2008, op. cit

58 *Ibid*.

59 *Ibid*.

60 McKay, A.D., and Miezitis, Y., 2002, op. cit.

61 *Ibid*.

62 Mega Uranium, 2007, *First Time Disclosure: Mega Uranium Resources for Lake Maitland Uranium Deposit*, Mega Uranium, http://www.megauranium.com/UserFiles/File/lakeMaitland-report.pdf [February 2008]

- *Lake Maitland mine development* – Located 100 km southeast of Wiluna, the Lake Maitland calcrete deposits (also known as Mount Joel) are currently owned by Mega Uranium, which acquired the prospect from its 2005 acquisition of Redport. Since its discovery in 1979, eight companies have undertaken work at Lake Maitland: Australis Mining, Asarco (Wiluna Gold Mines), Carpentaria Exploration Company (Mt. Isa Mines), BP Minerals Australia, Esso (Exxon Coal and Minerals), Acclaim Uranium, Redport and Mega. The prospect is estimated to contain approximately 7,000t uranium oxide. Vanadium is also present in the uranium mineralisation at Lake Maitland, as at Yeelirrie.[62]
- *Mayningee mine development* – The Mayningee deposit was discovered in 1974 in the northern part of the Carnarvon Basin, 85 km south of Onslow in Western Australia. The prospect is estimated to contain approximately 6,700t uranium oxide, with potential for 6,750 tonnes. The prospect was granted mining leases in 1989, and two pumping tests and one five-spot ISR test have been run to evaluate whether the ore is amenable to in situ leaching and whether the leach solutions can be confined.

  The prospect is currently owned by Paladin Resources, which acquired it from AFMEX through a wholly owned subsidiary in 1998, at a cost of $1 million plus $0.75 million on project approval plus increased but capped royalties. Paladin reported it had hoped to bring the deposit into production in about 2005, but has concentrated on its African prospects while WA government policies continue to preclude uranium development.[63]
- *Oobagooma mine development* – The Oobagooma deposit is located 75km north east of Derby in the Kimberley Region of Western Australia on freehold land owned by the Commonwealth and used by the military. The deposit was held owned by Afmeco Mining and Exploration Pty Ltd, but was sold to a wholly-owned subsidiary of Paladin Resources in 1998 for $0.9 million plus one per cent royalty. The deposit is estimated by GeoScience Australia to have identified resources of 8,500t uranium oxide, which would be likely to be extracted by the ISR process.[64]
- *Lake way and Centipede mine developments* – The Lake Way deposit, close to Wiluna, 750 kilometres north east of Perth in Western Australia, was discovered in 1972 and is estimated to collectively contain approximately 7,600t uranium oxide. Lake Way is a very shallow low-grade sedimentary deposit in calcrete and clays. The smaller Centipede calcrete deposit is 12 km south of the Lake Way deposit, but is higher grade. A JV between Delhi International Oil Corporation and Vam Ltd had planned to develop Lake Way into several open cut mines but plans were abandoned in 1983 due to the ALP policy. In 2005 Nova Energy, now merged with Toro Energy, acquired the title to the prospect and is currently undertaking feasibility studies to develop open cut mining of both deposits. The deposits would be expected to produce 750t uranium oxide per year and would also involve investment in a carbonate leach plant.[65]
- *Mulga Rock mine developments* – The Mulga Rock prospect, also known as the Officer Basin, is a series of multi-mineral deposits located 250 km north east of Kalgoorlie. The prospect was discovered by PNC Exploration (Power Reactor and Nuclear Fuel Development Corporation of Japan) in 1978. Mineralisation consists principally of uranium, scandium, nickel and cobalt in lignite within a sedimentary basin, with uranium apparently comprising half or less of the recoverable value of minerals. PNC evaluated only the uranium content and identified an estimated resource of 46,000t uranium oxide. In 2006 the mine was acquired by Energy & Minerals Australia Ltd when it acquired Narnoo Mining, which has recently raised $5 million dollars to start an active drilling program in 2008.[66]

3.5.5 Implications

Some implications can be drawn from this brief survey:

- there is an impressive list of highly prospective uranium resources located in at least three States and one territory that could make a very substantial contribution to uranium production and exports if they were developed;
- that these resources include some very significant prospects in Western Australia and Queensland;
- any analysis of this list of prospects suggests that many of them have not been thoroughly explored, particularly in the surrounding areas, as a result of both government policy issues and low prices;
- there is currently no exploration in NSW (although uranium exploration in South Australia abuts the State's border) and Victoria (where there are thought to be few prospective areas for exploration); and
- that any calculation of Australia's total uranium resources based on current knowledge of these prospects, therefore, is likely significantly to underestimate the industry's potential.

63 *Ibid*.

64 Paladin Resources, 2008, Oobagooma Project (Paladin 100%), Paladin Resources, http://www.paladinenergy.com.au/PROJECTS/Oobagooma/tabid/66/Default.aspx [January 2008]; and UIC, 2008, op. cit.

65 Australian Uranium Association, 2008, op. cit.

66 *Ibid*; and updated mine data from Energy and Minerals Australia, 2008, Energy and Minerals Australia, http://www.eama.com.au/ [February 2008]

3.6 Australia's advantages and challenges

Other things being equal, Australia's plentiful uranium resources give us a strong competitive advantage in the global uranium oxide market. Australia also enjoys:

- developed nation status and political stability;
- a strong reputation for quality and reliable product supply;
- comprehensive safety standards;
- a reputation for strong environmental management programs; and
- a longstanding and consistent commitment to non-proliferation.

The global market is intensely competitive, however, and Australian firms cannot rely on their natural endowments alone to succeed. As key competitor nations such as Kazakhstan and Namibia, for example, develop their resources, buyers face low switching costs and will seek to both diversify their sources of supply as well as minimise the cost of those supplies.

Offsetting Australia's strengths are a number of significant inefficiencies in the regulation of uranium mining in Australia that, other things being equal, will reduce the competitiveness of local producers in the global market. While the current regulatory framework is effective in maintaining high levels of environment protection and radiation safety standards, regulation may have been a significant barrier to potential expansion of the uranium mining sector.

Key issues in the regulation of the uranium mining sector include:

- *The involvement of different levels of government in the regulation of environmental issues associated with uranium mining* – Both the Commonwealth Government – under the *Environment Protection and Biodiversity Conservation (EPBC) Act* 1999 – and the States and Territories under their own legislation – are required to play an active role in the environmental assessment, approval and monitoring processes for uranium mining. This results in a range of different agencies at both levels of government having a very 'hands-on' role in the regulatory process. Considerable regulatory overlap and duplication of effort – for both regulators and industry participants themselves – are occurring as a result.
- *Skills shortages* – Significant bottlenecks exist in the current regulatory framework, particularly in relation to land access issues in the Northern Territory, and the assessment of radiation protection issues in all jurisdictions. To a large degree, these bottlenecks can be attributed to a shortage of appropriately skilled resources. This issue presents as a major barrier to industry development if new jurisdictions seek to develop a uranium mining industry, or if activity in jurisdictions where mining currently occurs were to increase rapidly. It should also be noted that, as a consequence of the long 'nuclear power holiday', the availability of suitably qualified human resources is now a global constraint on industry development.
- *Lack of access to transport and port infrastructure* – Inconsistent regulations applying to the transport of hazardous materials across jurisdictions, and the prohibition of uranium exports at some major ports, are presenting barriers to the efficient transport of uranium around Australia.
- *Duplicative reporting and consultative requirements* – Uranium mining companies are currently required to comply with an extensive array of legislated requirements for performance reporting and stakeholder consultations. In some cases, up to six major meetings– as well as a series of supporting reports – are required annually for a single mine. As with skills shortages, this issue will be exacerbated as the industry expands, and potentially presents a barrier to development.

Regulatory inefficiencies reduce the returns to Australian communities for the development of their assets through both higher costs and potentially reduced pricing power caused by supply delays. Significant work is being undertaken by the Uranium Industry Framework, the Australian Government, and the South Australian and Northern Territory governments to reform the regulatory framework. An appropriate regulatory framework is essential for enabling Australia's uranium producers to maximise their natural competitive advantages. This is not to argue that uranium mines should not continue to be treated differently to other mines. In this context, it is not the actual hazard that is important but the community's *perception* of the hazard. It is also not to suggest that environmental and safety standards should be compromised in any way. Having accepted this, however, it would appear not to be beyond the reach of people of goodwill to devise a less onerous regulatory framework that would deliver similar or improved benefits to the Australian community.

4 Economic impact of the Australian uranium industry

This chapter quantifies the economic impact of the growth of the Australian uranium industry to 2030 depending on the rate of climate change realised and associated policy responses to stabilise emissions globally.

4.1 Australian uranium: Outlook to 2030

To evaluate the economic impact of Australia's uranium industry to 2030, a series of scenarios were developed and modelled using a full model of the Australian economy operated by the Centre of Policy Studies at Monash University.

Table 4.1: Comparison of 2030 forecasts for nuclear power generation capacity (GWe)

Source	Scenario	Installed Nuclear Power Capacity (GWe)	Multi-lateral policies to address climate change	Global carbon price
IEA	Reference	416 GWe	✗	✗
	Alternative	519 GWe	✗	✗
IAEA	Low	433 GWe(1)	✗	✗
	High	533 GWe(1)	✗	✗
IPCC	<US$50/t$CO_2$-e	960 GWe	✓	✓
ABARE	Reference	560 GWe	✗	✗
	Alternative	620 GWe	✓	✗
CTNS		1,970 GWe	✗	✗

Notes: (1) Forecasts are for 2025 and are currently being revised upwards

Scenario mapping is a useful method for estimating the potential range of outcomes that might be possible for Australia, given changes in a number of key variables. From a government perspective, scenario planning can help identify the trade-offs involved in different policy decisions to ensure the welfare of its citizens is maximised.

In order to develop credible scenarios, the project team undertook an extensive literature review and stakeholder consultations.

The literature review suggested that most projections for the nuclear power and uranium industries are based on global, 'bottom up' or 'business as usual' analyses of committed nuclear power generation expansions. It is evident that most of these projections did not consider in any depth the impact of a carbon price on global demand. Projections of future demand for uranium – even those undertaken by some major players in the industry – still tend to be based on bottom up analyses, recent trends and considerations around energy security.

Very little work has been done to date explicitly to consider the impact of a significant carbon price on global demand, and how a shift in the market fundamentals may drive growth in uranium deposit development. The work done by the IAEA, the IEA and WNA, for example, has not factored in a major shift in demand caused by the response to global warming. Yet there are signs that this may be starting to change, perhaps as a result of the IPCC report and the Bali conference. In March 2008, for example, the IAEA reported an increase of over 50 per cent in its projections for global nuclear power generation by 2030 compared with estimates made only two years earlier.[67] Almost no body is factoring in emissions reductions of the magnitude being discussed at the COP in Bali. One exception to this has been the IPCC, which in its Fourth Assessment Report (AR4) explicitly considers the impact of a carbon price on the global nuclear power industry and consequently projects total nuclear power generation by 2030 to be nearly double the estimates previously published by the IAEA, IEA and other international bodies.

ABARE also considers the impact of multilateral action on climate change, but no carbon price or emissions cuts are reported. Moreover, no work has been completed to date to evaluate the implications of growth in demand for nuclear power for Australia's uranium industry, and the potential economic impacts of such an industry expansion (Table 4.1).

This study explicitly considers the impact of a global carbon price on demand for uranium and the share of global demand under different carbon-constrained worlds that Australia may capture, depending on the regulatory settings in place in various States and territories.

The findings of the literature review and its implications for the scenarios developed for this study are presented in Appendix B.

67 International Atomic Energy Agency, 2008, op. cit.

In parallel to its literature review, the team also undertook a series of stakeholder consultations to test potential assumptions about the future of the Australian industry under a range of demand projections. A list of organisations and industry experts consulted is provided in Appendix C.

The scenarios were then modelled using MMRF-Green, a computable general equilibrium (CGE) model of the Australian economy operated by the Centre of Policy Studies at Monash University. Key assumptions underpinning the modelling are discussed below with further detail supplied in Appendix B.

4.2 Uranium market scenarios to 2030

In order to develop a series of internally consistent scenarios, the range of demand forecasts analysed in the literature review were used to inform the potential range for future nuclear power demand, and in turn, uranium demand. A base case and two scenarios were established to examine possible future outcomes for the Australian uranium industry. These are described below.

4.2.1 Base case

The base case, or business as usual scenario, is required as the basis of comparison for the outcomes from the scenarios that model specified diversions from business as usual outcomes, or 'shocks'. For example, the economic impacts from modelling the Climate Action scenario will be expressed 'relative to the base case'. In most modelling exercises, the base case usually represents a projection of existing and recent trends in the economy.

In this instance, the base case is based on the IEA Alternative scenario forecasts for 519 GWe (519 reactors each with an installed capacity of 1,000 MWe) by 2030. This was considered to be the level of demand that would occur globally if no significant action on climate change were taken.

While this may seem a modest increase in the light of the present planned expansion of the industry worldwide, this needs to be considered in the context of the fact that many of the older reactors around the world will need to be decommissioned by 2030. In order that the base case can provide a yardstick against which the impact of industry growth may be assessed, the base case assumes that Australia's uranium production remains at around current levels.

4.2.2 Climate Action scenario

In the *Climate Action* future, a concerted global effort to address climate change is pursued which gives rise to a global carbon price of US$50t CO_2-e. This was expected to be a likely minimum rate of change in key economic variables as a result of global action on climate change. The Climate Action scenario was based on the IPCC's mid-range forecast for nuclear power growth, which would see total nuclear power generation grow to 960MWe by 2030. This implied that uranium demand would grow such that by 2030 an additional 68,500t would be required globally (Figure 4.1). The increase in demand for nuclear power was expected to support a conservative, long run average contract price for uranium of US$100 per pound of U_3O_8 (compared with recent contract prices of around US$90).

Importantly, the Climate Action scenario represents a conservative growth path for global demand in nuclear power (Figure 4.1). Compared with recent negotiations at the United Nations Climate Change conference at Bali in 2007, where emissions cuts of between 25 and 40 per cent of 1990 levels by 2030 were canvassed,[68] Climate Action represents a 'low end' rate of change for climate change policy and associated carbon prices in the near term. The US$50 carbon scenario also represents the IPCC's 'mid case' scenario for future carbon prices.

Figure 4.1 also shows that although the UMPNER review (which was based on ABARE forecasts) did not explicitly consider a carbon price, the Action scenario is similar to the UMPNER projection for global uranium demand by 2030.

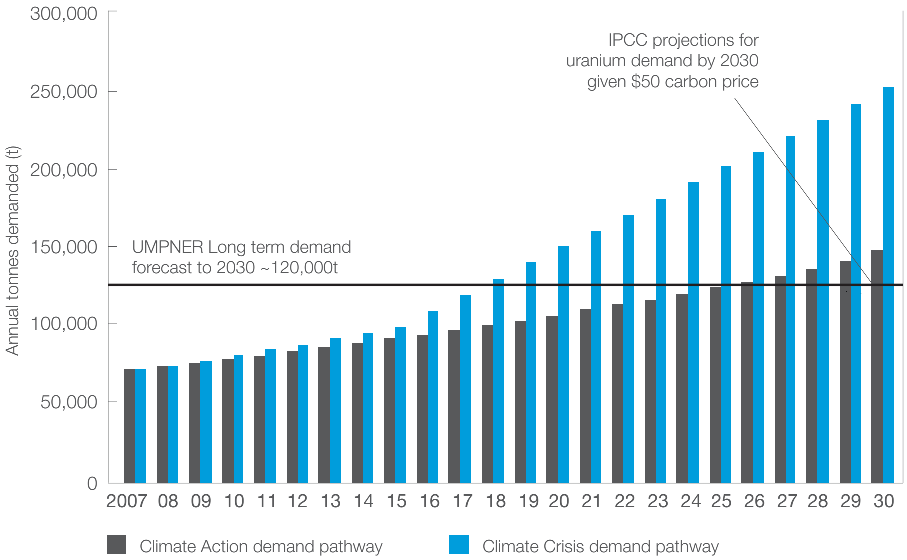
We consider that Climate Action is a moderately conservative scenario. This is an outcome where the world makes a lesser effort to reduce emissions than was proposed at Bali. It represents a platform from which carbon concentrations in the atmosphere might be stabilised at 550 parts per million, consistent with an average rise in global temperatures of around three degrees Celsius. While it suggests a significantly higher demand for uranium than some of the earlier projections by the IEA, IAEA and WNA, it is not clear that those studies made adequate provision for a significant carbon price. It is also notable that recent forecasts by the IAEA have been substantially revised upwards. The specified price of CO_2-e, at US$50/tonne, is consistent with the IPCC estimates.

Is a long run average projected price of US$100/lb of U3O8 by 2030 justified? Under this scenario, in 2030 demand will be higher by 85 per cent than under the business-as-usual base case. Substantial additional supply, year by year, will need to be developed globally to keep pace with this substantial increase in demand, including from some areas that require substantial infrastructure investment and that manifest significant sovereign risk. Given a current contract price of around US$90/lb, a projected price of US$100 to 2030 is both possible and conservative to quantify the likely benefits of the development of Australia's uranium resources.

The implications for the global demand for uranium under both scenarios are shown in Figure 4.1.

68 AAP, 2007, 'Rudd urges US to adopt greenhouse target', *Sydney Morning Herald*, 12 December, http://news.smh.com.au/rudd-urges-us-to-adopt-greenhouse-target/20071212-1ghu.html [December 2008], Sydney

Figure 4.1: Global uranium demand futures to 2030



Source: Deloitte Economics

4.2.3 Climate Crisis scenario

The *Climate Crisis* future is based on an assumption that climate outcomes are assessed as being near the top of the range presented in IPCC reports and that, as a consequence, the nations of the world agree to take very substantial action to reduce emissions. The development of this scenario is less certain, and depends significantly on the rate of climate change realised over the short term and the extent to which governments pursue more aggressive emissions cuts than is generally contemplated by the broader community today. The Climate Crisis scenario assumes deep cuts in global emissions of 60 per cent or more by 2050. In this demand future, reductions in emissions would result in a high carbon price of US$100/tonne of CO_2-e. At such a carbon price, whilst renewable energy sources would become more competitive, there would be assumed to be much more rapid uptake of nuclear power, such that the number of nuclear power stations worldwide would grow to around 1,634, each rated at 1,000 MWe.

This would in turn drive rapid growth in demand for uranium sufficient to underpin a long run average contract price for uranium of US$150 per pound of U_3O_8 by 2030.

The Climate Crisis scenario is unlikely to emerge immediately. Nevertheless, given recent evidence of more rapid climate change than has historically been projected by the IPCC,[69] this represents a sobering but plausible eventuality. The Climate Crisis scenario is directed towards meeting a challenging target under which carbon concentrations in the atmosphere might be stabilised at 450 parts per million, consistent with limiting the average rise in global temperatures to around two degrees Celsius. In his interim report, for example, Ross Garnaut focuses on one of the highest projections of climate change made by the IPCC and accordingly postulates that Australia may need to reduce its emissions by 80 per cent by 2050.[70] Under any emissions reduction scenarios of this magnitude, a price of US$100/tonne of CO_2-e is on the conservative side.

For example, economic modelling undertaken for the Australian Business Roundtable estimated a range of CO_2-e prices ranging from about US$170 to US$570 in order to deliver emissions reductions of 60 per cent by 2050.[71]

Some observers may be sceptical as to whether such a high increase in nuclear power capacity world wide can be achieved by 2030, particularly since it is a generation since nuclear reactors were being ordered and built in any significant quantity. In evaluating the Climate Crisis scenario, we should take account of the following points:

- Even now, before the nations of the world have committed to significant post-Kyoto action on emissions, around 350 new nuclear power generators are at the construction, planning or feasibility stage worldwide (see Section 2.2 above).
- During the previous boom period for nuclear power, new reactors were ordered and constructed at a rapid rate – in the US alone, 103 of its current 104 nuclear power generators were ordered in just six years from 1967, while in the period 1980-87 France's nuclear build program allowed it to reduce emissions from electricity generation by 80 per cent.[72]
- In many countries, the imposition of even a relatively modest carbon price will fundamentally change the economics of electricity generation in favour of nuclear power.
- Technological changes in the nuclear power industry are bringing about standardised and modular designs that involve lower capital costs than previously and are capable of being constructed in a much shorter period of time.
- New reactor designs tend to be more flexible, meaning that nuclear power can be used in systems where demand would previously have been too low to justify a nuclear solution.

69 The Climate Institute, 2007, *Evidence of Accelerated Climate Change*, Prepared by the Climate Adaptation Science and Policy Initiative, The University of Melbourne for the Climate Institute, http://www.climateinstitute.org.au/images/stories/CI056_EACC_Report_v1.pdf [February 2007], Melbourne.

70 Garnaut Climate Change Review, 2008, op. cit., pages 20-40.

71 The Allen Consulting Group, 2006, *Deep Cuts in Greenhouse Gas Emissions: Economic, Social and Environmental Impacts for Australia.*

72 Muckerheide, J., 2005, 'How to Build 6,000 Nuclear Plants by 2050', *Executive Intelligence Review*, Center for Nuclear Technology and Society, pages 36-55.

- While there is currently a supply bottleneck in regard to the manufacture of reactor pressure vessels, competition in the industry is strong, there are few market imperfections and there is no reason why additional capacity will not be installed to meet demand.
- Governments, particularly the US and UK, are supporting the rapid development of the nuclear industry, with a more streamlined regulatory framework, fewer barriers to development and some cost sharing.
- Some industry observers believe that China, which is currently building coal-fired generators at a very rapid rate, is preparing to make a major switch to nuclear power as concerns about pollution and climate change increase.

Critically, however, the Climate Crisis demand future is also contingent on the discovery of additional uranium resources. As discussed in Chapter 2, the upsurge in exploration activity points to very significant discoveries of uranium following the recent long term contract price recovery:

- Expenditure on exploration for uranium has significantly increased. In Australia, for example, exploration expenditure has increased by more than 13 times the levels seen five years ago and nearly six times 2004 expenditure levels to $114 million per annum.
- Increased exploration has occurred not just in Australia but worldwide and has already led to further discoveries. In March 2008, the IAEA reported that in only two years since its last estimate of global uranium resources (2005), total identified reserves had increased by 17 per cent.[73]
- A number of stakeholders consulted for this report – including organisations not involved in the commercial mining of uranium – have indicated concern about the accuracy of the Red Book estimates, particularly for the <US$80 and <US$130 cost ranges. Stakeholders suggested that because uranium prices have been so low historically, very little exploration has occurred to prove up resources at higher cost levels.
- The IAEA estimates there is at least 7.5 million tonnes of 'undiscovered resources' which critically excludes estimates of additional resources in Australia.

Accordingly, in both scenarios it is expected that the supply of identified resources will expand significantly from current estimates. Nevertheless, under the Climate Crisis scenario, total supplies of uranium are over three times higher than in the base case. Some of these new supplies may be uneconomic at a price of US$40-50/kg. At the same time, the carbon price will mean that nuclear energy is likely to be the most economically attractive source of electricity well before 2030, with utilities around the world competing for access to the world's uranium supplies. In this context, we consider that a contract price of US$150/lb is entirely plausible, if not conservative, under the Climate Crisis scenario.

Another factor is that, over the next two decades, new reactor designs will increasingly use reprocessed fuel. Some nuclear engineers look forward to a time when nuclear fission is almost renewable, with a situation in fuel usage that is very close to a closed cycle.

4.2.4 Other issues

In all scenarios it was also assumed that current uranium requirements per 1,000 MWe will gradually decline by one per cent per annum over the forecast horizon due to increased generation efficiencies. The resulting uranium demand requirements are summarised in Table 4.2.

4.2.5 Australian policy scenarios

As well as responding to the influences from the demand side of the market, uranium production in Australia will also be influenced by government policy. Therefore, for each demand scenario, there will also be two Australian supply scenarios:

- *Constrained Supply future* – it is assumed that South Australia and the Northern Territory continue to be the only Australian jurisdictions to allow uranium mining; and
- *Regulation Reform future* – it is assumed that Queensland and Western Australia, which currently allow uranium exploration, change current policy and allow uranium mining, such that South Australia, the Northern Territory, Queensland and Western Australia all allow for the mining and export of uranium.

In the Climate Action future it was projected that if Western Australia and Queensland were allowed to mine that together with South Australia and the Northern Territory, Australia would capture 25 per cent of global demand. In practice this meant that most known mines could export 37,000 tonnes of uranium annually by 2030. No new discoveries would be required to support this industry growth. If Western Australia and Queensland were not allowed to mine, the Climate Action scenario assumed that some currently uncommitted mines come online in the Northern Territory and that the Olympic Dam would continue with its planned three stage expansion.

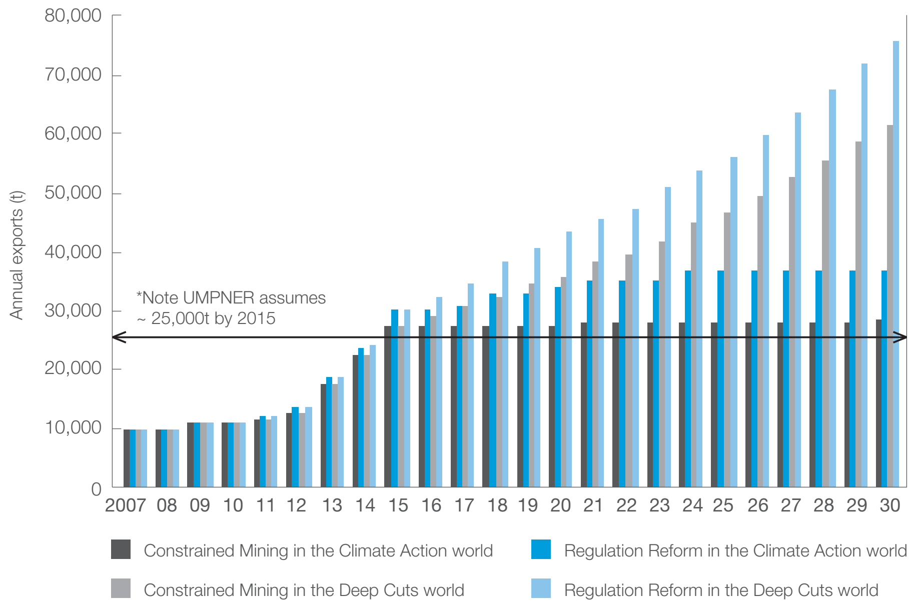
Table 4.2: 2030 uranium requirements in 2030

Source	Number of Nuclear Power Reactors (each of 1,000 MWe)	Forecast Uranium Demand in 2030 (tonnes)
Base Case	519	80,000
Climate Action	960	148,500
Climate Crisis	1,634	253,000

Sources: Deloitte Economics

73 International Atomic Energy Agency, 2008, op. cit.

Figure 4.2: Australian supply pathways to 2030



Source: Deloitte Economics

This would result in Australia exporting 28,500 tonnes annually, capturing 19 per cent of global demand, which is in line with current production rates. No new discoveries would be required to support this industry growth. We are very confident that Australia could find, mine and export the uranium quantities projected in the Climate Action scenario.

In the Climate Crisis future, which is less certain and depends on the rate at which governments pursue significant emissions cuts by 2030, the strong growth in demand for nuclear power will drive very strong growth in demand for uranium. If Western Australia and Queensland were allowed to mine in a Climate Crisis future, Australia could export 76,000 tonnes annually by 2030, capturing 30 per cent of global demand in that year. In practice this would mean that Olympic Dam would expand at a more rapid pace than is currently planned.

It also would mean that more known resources in the Northern Territory would be developed, and that a further 1.3 mines and 2.7 mines[74] would be discovered and developed by 2030 in Queensland and Western Australia respectively. If Western Australia and Queensland continued to prohibit mining in a Climate Crisis future, Australia would export 61,250 tonnes annually by 2030, capturing 24 per cent of global demand in 2030 through the expansion of mining in South Australia and the Northern Territory.

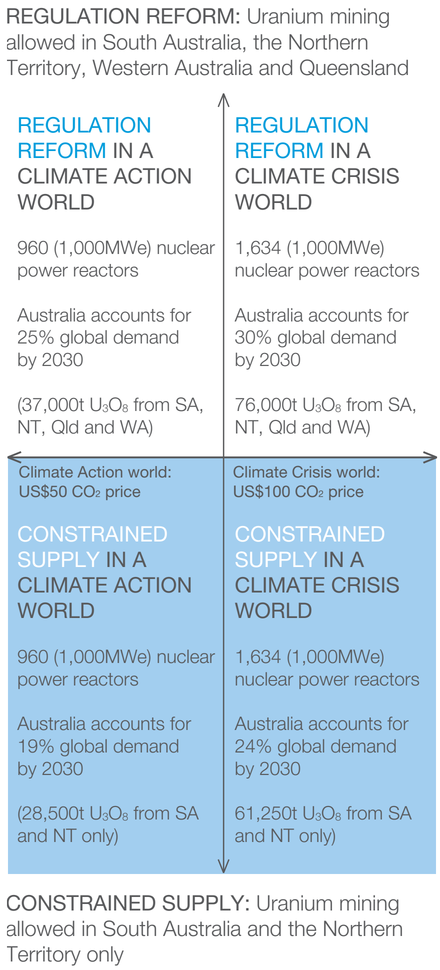
Figure 4.2 shows that both of the supply scenarios considered in the Climate Action future are conservative and track with UMPNER projections for Australian exports to 2015. It is important to note that UMPNER only reported Australian uranium production to 2015, that no carbon price was assumed, and that no mining was assumed to occur in Queensland or Western Australia.

Together these two demand and supply projections produce four projected outcomes:

- Constrained Supply under the Climate Action scenario;
- Regulation Reform under the Climate Action scenario;
- Constrained Supply under the Climate Crisis scenario; and
- Regulation Reform under the Climate Crisis scenario.

The major assumptions underlying each of these four scenarios are shown in Figure 4.3. They are discussed in further detail in Appendix B.

Figure 4.3: Key modelling assumptions by scenario



Source: Deloitte Economics

74 Where the average mine size in Australia produces an average of 1,500 tonnes of uranium oxide per year. Deloitte Economics analysis of ABARE data.

4.3 Economic impact: 'Climate Action' scenario

The Climate Action future represents a conservative projection for global uranium demand and Australia's potential market share. Both demand and supply projections are consistent with IPCC and UMPNER projections for the global and domestic industry. As such, the Climate Action scenario represents a likely minimum level of economic benefits that would accrue to Australia with the industry's expansion to 2030.

The level and distribution of the benefits, however, are contingent on the regulatory settings of Australia's States and territories. The modelling shows that under Constrained Supply, South Australia and the Northern Territory see strong growth in consumer welfare, employment, investment and government revenues as a result of the uranium industry's development, while other States, such as Western Australia and Queensland, do not. In a Regulatory Reform future, however, Western Australia and Queensland, like South Australia and the Northern Territory also see significant benefits in terms of consumer welfare, employment, investment and government revenues as a result of the uranium industry's expansion.

Critically, this modelling is designed to isolate the impact of the Australian uranium industry's growth. While a carbon price has been considered to analyse and develop global demand and supply scenarios, a global carbon price has not been applied in the CGE modelling.

The reason is that the impacts of a carbon price on Australia's other exporting industries, such as coal, for example, and throughout the economy would make it very difficult to isolate the economic impacts of the uranium industry's growth.

It is important to note that while this study has been developed to measure the benefits of the uranium industry's expansion, these economic impacts would be occurring against a backdrop of slowing demand for Australia's historic export base compared to what would otherwise be expected if no carbon price eventuates. IPCC modelling suggests that global demand for coal would be up to 42 per cent lower if significant action were taken than in a scenario where effectively no carbon price is assumed to occur (though growing in absolute terms).[75]

The expansion of the uranium industry in these scenarios would facilitate an improvement in the composition of some of Australia's currently carbon-intense export profile and strengthen the economy's ability to adjust to a highly carbon constrained world by 2050.

In reviewing the economic impact of Australia's uranium industry to 2030 it is also important to remember that the results are presented relative to a base case,[76] where only current and committed production is assumed to continue to 2030. Therefore, results show the additional outcomes, such as the additional employment or additional investment that would be expected to occur in addition to whatever might have occurred should only current and committed projects have continued to 2030. In this context, it should be noted that the proposed Olympic Dam expansion is not included in the base case.

4.3.1 Investment and employment growth in the Climate Action future

The expansion of Australia's uranium industry will result in both new investment and additional employment.

New investment will be undertaken to develop Australia's deposits. Most will be open cut and will require significant expenditure on energy, land transport, port and water services infrastructure to the site. Investments will also be made in processing facilities and safety systems to control access to the site. This will require substantial investments in capital. Using capital cost expenditure estimates available from ABARE and other minerals industry reports,[77] we evaluated the size and timing of future capital investments that would be made by uranium miners over the 2008-2030 period in the Constrained Supply and Regulation Reform futures.

Importantly, the total stimulation to investment in Australia will be greater than the direct expenditure requirements that would be made by the uranium miners. This is because the capital investment will be at least partially spent within Australia, which will stimulate demand for other businesses and cause second round investment effects. This is known as the multiplier effect. Examples of businesses that would supply inputs into the uranium industry include the building and construction sectors, the water supply industry, and the land transport sector. The expansion of demand for road transport, for instance, may require companies to invest in additional vehicles to meet demand created by the expansion of the uranium industry.

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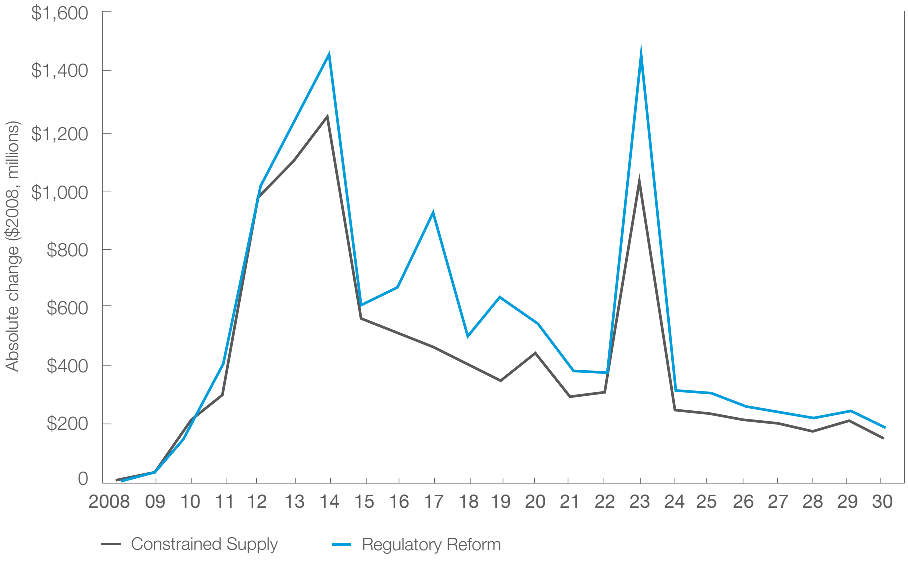
75 Demand for coal globally would grow by 25 per cent above 2010 levels by 2030 in a Climate Action future and by 15 per cent in a Climate Crisis future, compared to a near doubling of demand projected in the event that no carbon price emerges. See Sims, R.E.H., Schock, R.N., Adegbululgbe, A., Fenhann, J., Konstantinaviciute, I., Moomaw, W., Nimir, H.B., Schlamadinger, B., Torres-Martínez, J., Turner, C., Uchiyama, Y., Vuori, S.J.V., Wamukonya, N., Zhang, X., 2007, *Energy supply. In Climate Change 2007: Mitigation*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

76 Results are presented relative to the MMRF-modified base case unless otherwise specified.

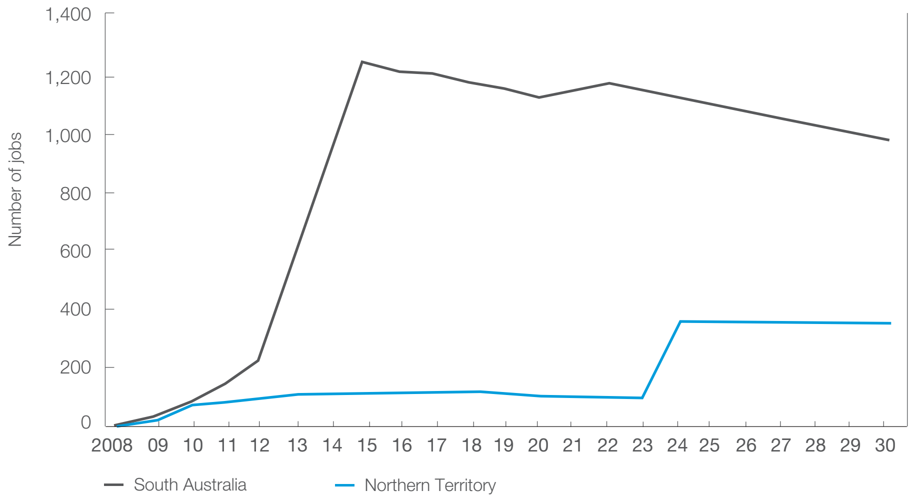
77 See Appendix B for further detail about the capital cost expenditure assumptions.

Figure 4.4: Australian investment in the Climate Action scenario



Source: MMRF

Figure 4.5: Direct employment in South Australia and the Northern Territory – constrained supply in the Climate Action scenario



Source: MMRF

Figure 4.4 shows the impact on total investment in Australia. The peaks in the graph correlate with the development of new production capacity at mines in Australia. The Regulatory Reform future shows greater stimulation to total investment in Australia as a result of the additional production capacity coming online in Western Australia and Queensland.

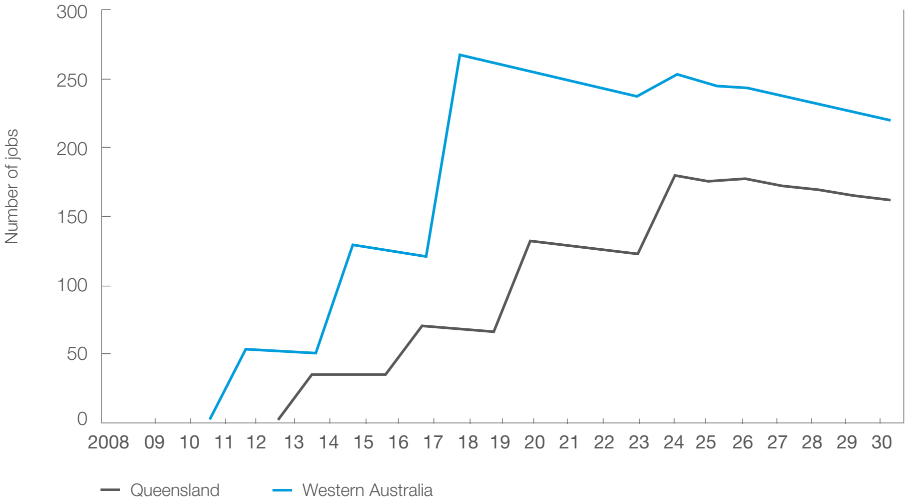
Total growth in national investment above base case projections under Constrained Supply is estimated to be $4.8 billion in $NPV_{7\%,\ 2008\text{-}2030}$ terms while total growth in national investment above base case projections in the Regulatory Reform future is estimated to be $6.0 billion in $NPV_{7\%,\ 2008\text{-}2030}$ terms.

The expansion of the uranium industry will also create jobs. Using ABARE data, information about current mine operations and submissions by companies to the UMPNER review, the Deloitte Economics and Centre of Policy Studies estimated the approximate stimulation to direct employment in the Constrained Supply future. As shown in Figure 4.5, in South Australia it was estimated the expansion of the industry in that State will create approximately 1,100 jobs from 2015. In the Northern Territory it was estimated that the expansion of mining there would create approximately 260 additional jobs relative to the base case from 2020 as investment in new production capacity will fill in the expected eventual wind down of the Ranger mine.

In the Regulatory Reform future, growth in employment would also be expected in Western Australia and Queensland. The mines in Queensland would be expected to employ an additional 121 persons on average from 2015-2030, peaking at 180 in 2024. Western Australian mines would be expected to employ an additional 220 persons on average from 2015, peaking at an additional 270 jobs above base case projections in 2018.

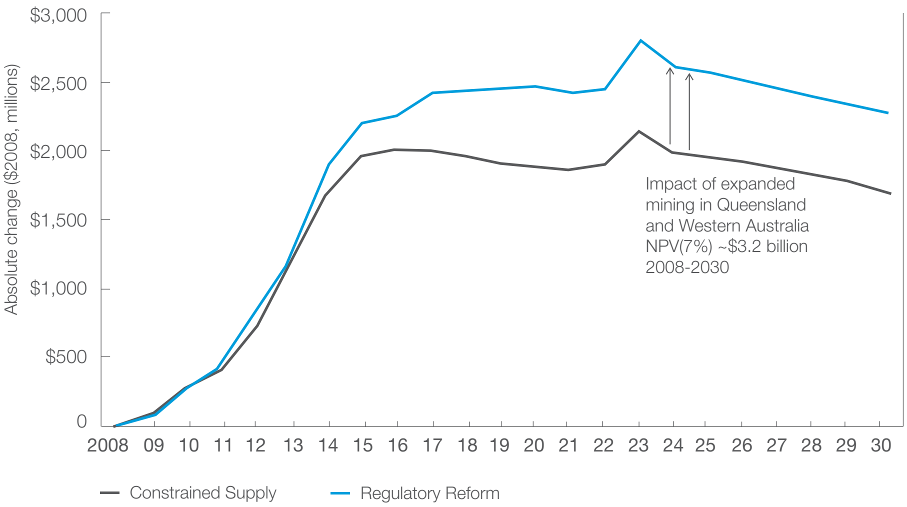
In total, direct employment would be expected to increase by 1,110 persons on average over the 2008-2030 period (above base case projections) under Constrained Supply, while direct employment would be expected to increase by 1,380 persons on average in the Regulatory Reform future.

Figure 4.6: Direct employment in Queensland and Western Australia – regulatory reform in the Climate Action scenario



Source: MMRF

Figure 4.7: Impact on Australian GDP in the Climate Action scenario



Source: MMRF

In terms of total employment in the Australian economy, the expansion of the uranium mining industry would not have a sufficiently large impact on the economy to cause national labour force levels (currently ~10 million people) to deviate from base case projections.

4.3.2 Export growth

Once operational, the additional production capacity would result in significant export growth in uranium oxide to overseas markets.

In the Constrained Supply future, uranium oxide exports from South Australia and the Northern Territory would expand significantly.

South Australia was projected to produce 23,500 tonnes of uranium oxide by 2030 and the Northern Territory was assumed to replace expected declines in production from current mines such that by 2030 the territory was producing 5,000 tonnes of uranium oxide. The $NPV_{7\%,\ 2008\text{-}2030}$ of Australia's *growth in exports* relative to the base case was estimated to be $26.0 billion.

If the bans on mining in Queensland and Western Australia were removed it would be expected there would also be significant growth in exports from those States as well. Export production in Queensland and Western Australia was projected to grow to 3,600 tonnes and 4,900 tonnes by 2030 respectively. In both cases this assumed the development of known mines, many of which have already completed environmental impact assessments.

The $NPV_{7\%,\ 2008\text{-}2030}$ of Queensland's growth in exports relative to the base case was estimated to be $1.9 billion while the $NPV_{7\%,\ 2008\text{-}2030}$ of Western Australia's growth in exports was estimated to be $4.0 billion. In total, if the Regulatory Reform future were to eventuate such that mining could occur in South Australia, the Northern Territory, Queensland and Western Australia, the growth in export values above base case projections in $NPV_{7\%,\ 2008\text{-}2030}$ terms would be $31.9 billion.

4.3.3 GDP, GSP and welfare outcomes

Growth in investment, employment and exports will cause Australia's GDP to grow faster than it would have otherwise occurred.

As shown in Figure 4.7:

- Australia's GDP in the Constrained Supply future would peak at $2.1 billion in 2023 above base case projections for that same year. In $NPV_{7\%}$ terms, Australia's GDP under these assumptions would be $14.2 billion higher than otherwise over the period 2008-2030.

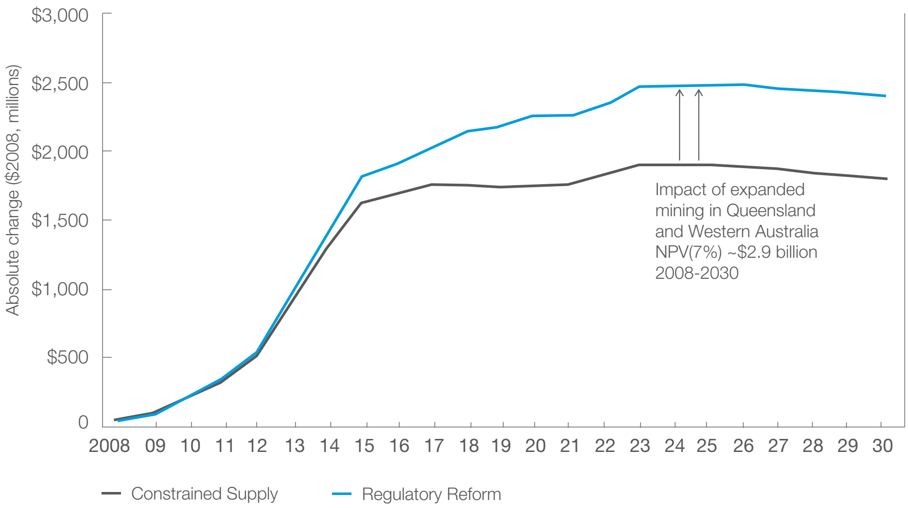
- Under Regulatory Reform, Australia's GDP would grow even more rapidly, as Queensland and Western Australian developments came into production. The peak deviation above base case projections would occur in 2023 at \$2.8 billion above what would have been expected if the uranium mining industry did not expand. In $NPV_{7\%}$, terms, Australia's GDP in this future would be \$17.4 billion higher than otherwise over the period 2008-2030.

Thus from a national perspective, Australia's GDP would be \$3.2 billion higher in $NPV_{7\%,\ 2008\text{-}2030}$ terms to 2030 if Queensland and Western Australia allow mining compared with the Constrained Supply scenario where only South Australia and the Northern Territory export.

When evaluating the benefits to Australians generally of the growth in uranium mining, it is important to consider the net impact on private consumption, which is a proxy for the community's economic welfare. Consumption is a better measure of welfare than GDP, because GDP measures the income generated by all economic factors, including both labour and capital, and as such may also include payments to foreigners. Consumption, by contrast, is essentially determined by total household income. Household disposable income is the sum of wages, dividends to Australians, and government transfer payments, less direct income tax. Thus consumption is a better measure of welfare for incumbents because it reflects the income available for consumption by Australians.

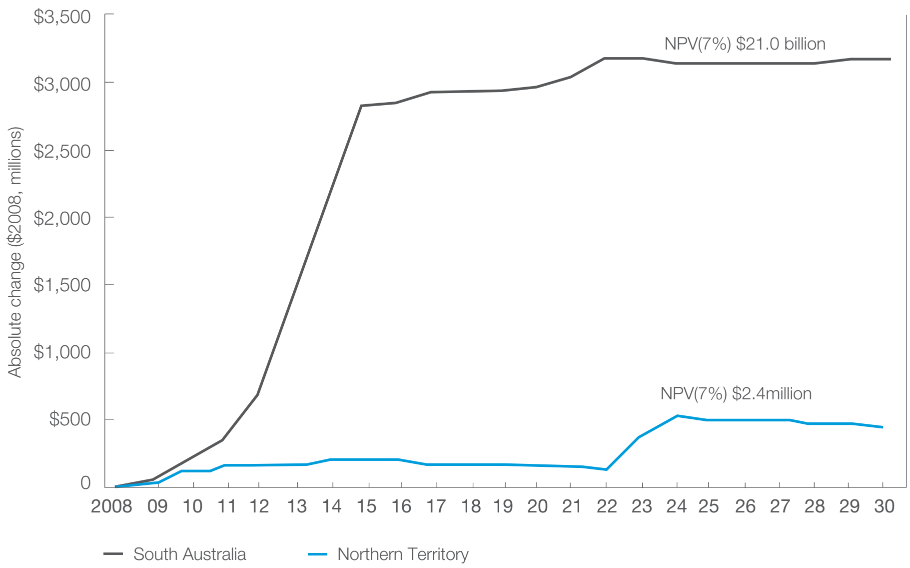
As shown in Figure 4.8, private consumption broadly tracks with GDP, and is expected to be more strongly stimulated above base case projections under Regulation Reform where Queensland and Western Australia also mine and export uranium. For the period 2008-2030, the $NPV_{7\%,\ 2008\text{-}2030}$ of Australian consumption under the Constrained Supply future shows it to be \$12.3 billion higher than otherwise. When Queensland and Western Australia enter the picture under the Regulatory Reform assumption, the equivalent figure was estimated to be \$15.3 billion, or \$2.9 billion greater.

Figure 4.8: Australian consumption in the Climate Action scenario



Source: MMRF

Figure 4.9: South Australian and Northern Territory GSP – constrained supply in the Climate Action scenario



Source: MMRF

At a State and territory level, the stimulation to GSP correlates strongly with the stimulation to export revenue. In the Constrained Supply future, South Australia's GSP would grow above base case levels by \$21.0 billion in $NPV_{7\%,\ 2008\text{-}2030}$ terms while the Northern Territory's GSP would expand by \$2.4 billion in $NPV_{7\%,\ 2008\text{-}2030}$ terms (Figure 4.9).

These are very significant impacts for these jurisdictions, which have smaller economies than the traditional resource States, Queensland and Western Australia, and NSW and Victoria, which are the major population centres of Australia. In percentage terms South Australia's GSP would be 3.3 per cent above base case levels on average from 2010-2030, while the Northern Territory economy would be 1.8 per cent above base case levels on average.

For South Australia, this shows the potentially massive impact of Olympic Dam on the State's economy.

In the Constrained Supply future the growth in uranium exports from South Australia and the Northern Territory will cause the Australian dollar to appreciate. Holding all else constant, this would make other Australian export industries marginally less competitive. As major exporting States, Queensland and Western Australia would expect to be 'crowded out' relative to South Australia and the Northern Territory under Constrained Supply, which is dominated by the three stage expansion of the Olympic Dam mine. Should the Olympic Dam mine go ahead, the exports from this mine would tend to cause the Australian dollar to appreciate such that Queensland and Western Australia's economies would be worse off than base case expectations by approximately \$2.5 billion in $NPV_{7\%,\ 2008\text{-}2030}$ terms.

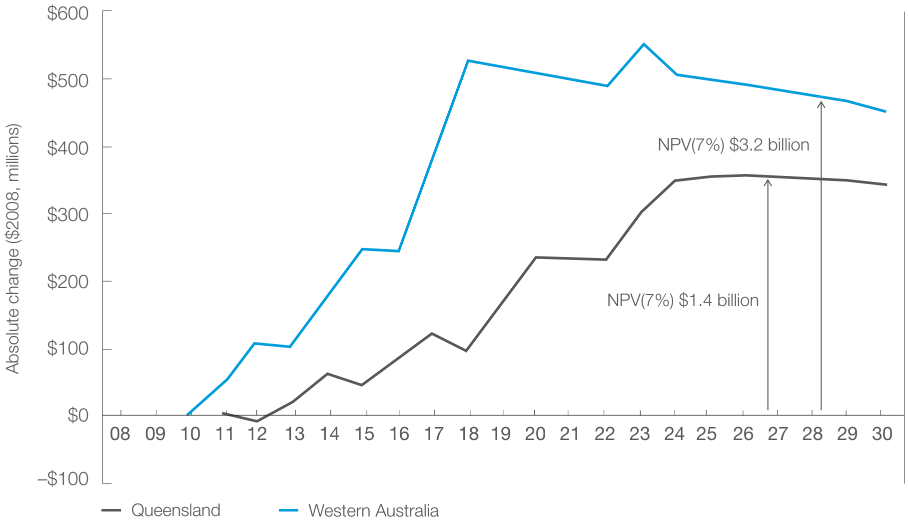
However, when compared with the potential impacts that would occur under Constrained Supply, the Regulatory Reform future is strongly positive for both Queensland and Western Australia. Queensland and Western Australia's participation in the Regulatory Reform future reduces the crowding out effect of South Australia. The $NPV_{\%,2008\text{-}2030}$ of the improvement in Queensland and Western Australia's GSP relative to the Constrained Supply future was estimated to be \$1.4 billion and \$3.2 billion, respectively (Figure 4.10).

Considering the distribution of national improvements in consumer welfare among South Australia, the Northern Territory, Queensland and Western Australia shows that while South Australia accrues the greatest benefits in NPV terms, positive improvements in consumer welfare are also observed in every other region, assuming they are able to mine for uranium (Figure 4.11).

The $NPV_{\%,2008\text{-}2030}$ of the positive growth in consumer welfare in the Regulatory Reform future was estimated to be:

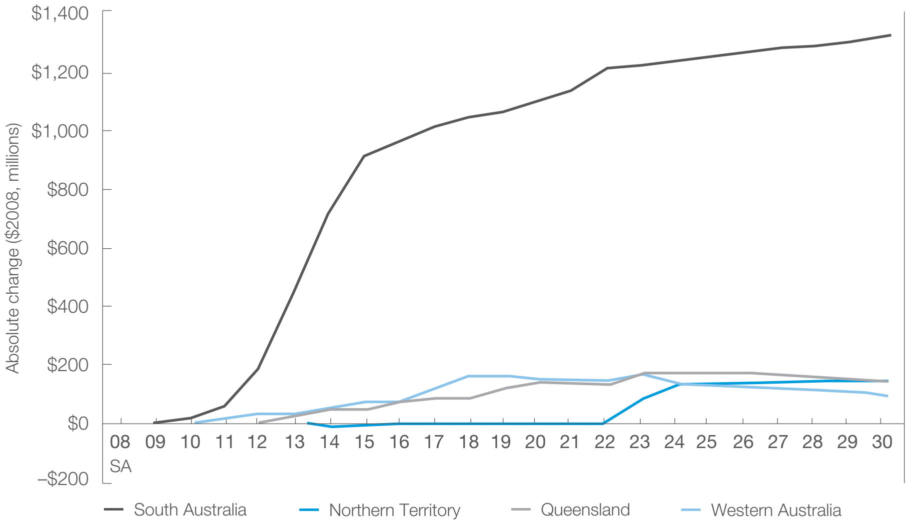
- \$9.3 billion in South Australia;
- \$845 million in the Northern Territory;
- \$910 million in Queensland; and
- \$865 million in Western Australia.

Figure 4.10: Queensland and Western Australian GSP – regulatory reform relative to constrained supply in the Climate Action scenario



Source: MMRF

Figure 4.11: Private consumption – regulatory reform in the climate action scenario



Source: MMRF

4.3.4 Government revenues

Growth in the economy will also increase revenues to the Commonwealth and the State and territory governments (Table 4.3).

The Australian Government would receive an additional \$2.7 billion in $NPV_{7\%,\ 2008\text{-}2030}$ terms in revenue through additional GST, income tax, corporate tax and other taxes in the Constrained Supply future.

It would receive an additional \$637 million in tax revenues, bringing the total increase in revenues above base case projections to \$3.4 billion, under Regulatory Reform, due to the increase in economic activity in Western Australia and Queensland.

Table 4.3: Government revenues above base case in the Climate Action scenario

	Constrained Supply $NPV_{7\%, 2008\text{-}2030}$		Regulation Reform $NPV_{7\%, 2008\text{-}2030}$		Difference in revenue between Reg Reform and Constrained Supply
	Royalties ($2008, millions)	Total tax ($2008, millions)	Royalties ($2008, millions)	Total tax ($2008, millions)	Total tax ($2008, millions)
Australian Government	–	$2,767m	–	$3,404m	$637m
South Australia	$786m	$2,510m	$786m	$2,510m	$0m
Northern Territory	$150m	$337m	$150m	$330m	–$7m
Western Australia	–	–$177m	$200m	$285m	$462m
Queensland	–	–$157m	$69m	$46m	$204m

Source: MMRF and Deloitte Economics

The South Australian Government would receive approximately $2.5 billion in $NPV_{7\%, 2008\text{-}2030}$ terms in additional revenues in both scenarios, including $786 million in uranium royalties.

The Northern Territory Government would receive an additional $337 million in revenues above base case projections in the Constrained Supply future, including a further $150 million in royalties. It would receive slightly less tax overall under Regulation Reform due to the marginal impact of the additional exports from Queensland and Western Australia tending to crowd out some other activities relative to the Constrained Supply future. Under Regulation Reform the Northern Territory Government would receive an additional $330 million in total tax revenue above base case projections.

In Queensland and Western Australia total tax revenue would be negative under Constrained Supply as a consequence of some crowding out of other exports from those States caused by the increase in uranium exports from South Australia and the Northern Territory. No royalty revenue would be available to the States under Constrained Supply, and total tax revenue would be $177 million and $157 million less than base case projections in Western Australia and Queensland, respectively (in $NPV_{7\%, 2008\text{-}2030}$ terms).

The Queensland and Western Australian governments, however, would see positive increases in total tax revenues under Regulation Reform. In $NPV_{7\%, 2008\text{-}2030}$ terms, Queensland and Western Australia would see total tax revenues increase by $69 million and $200 million above base case projections in the Regulation Reform future. Moreover, comparing these outcomes to the Constrained Supply assumption, which includes the potential three stage expansion of the Olympic Dam deposit, shows that Queensland and Western Australia would see an increase in total tax revenue of $204 million and $462 million in $NPV_{7\%, 2008\text{-}2030}$, respectively.

4.3.5 Global greenhouse gas emissions avoided

The export of uranium will contribute to the reduction of global greenhouse gas emissions. The IAEA has estimated that emissions from coal-fired electricity generation are 46 times more carbon intensive than the highest estimate of nuclear generation's carbon intensity and that the low estimate for gas-fired emissions is 20 times more carbon intensive than nuclear.

In the Constrained Supply future, Australia would export in total approximately 348,500 tonnes of uranium oxide from 2008 to 2030 above base case levels. This is enough uranium to supply more than 150 nuclear reactors (1,000 MW) and would produce more than 12,000 TWh of power.[78] To produce an equivalent amount of power would require 4.8 billion tonnes of coal,[79] which would have produced 11,379 Mt additional tonnes of carbon compared to nuclear. In 2030 alone, the export of 28,500 tons of uranium oxide would help to avoid 930 Mt CO_2-e, which is more than ten times the amount of emissions abatement required for Australia to meet its Kyoto target (Figure 4.12).

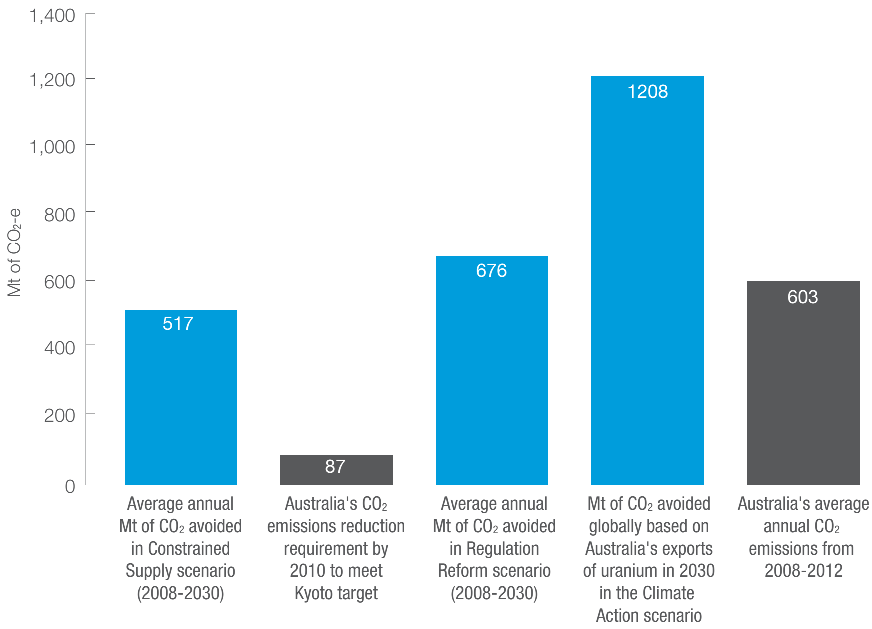
In the Regulatory Reform future, Australia would export 456,950 tonnes of uranium oxide from 2008-2030 above base case levels. Using the same ratios as above, this is enough uranium to produce more than 15,000 TWh of power and would avoid 14,970 Mt CO_2-e that would have otherwise been produced had coal fired generation been used. In 2030 alone, the export of 37,000 tonnes of uranium oxide would help to avoid 1,208 Mt CO_2-e, which is more than thirteen times the emissions that Australia will need to reduce to meet its Kyoto target, and more than double Australia's annual emissions (Figure 4.12).

Overall, the amount of uranium that would be exported under the two scenarios will go a substantial way towards helping meet the challenge of stabilising global CO_2-e levels by 2050 while also facilitating economic growth in developing nations.

78 Based on ratios published in BHP Billiton, 2007, *op. cit*.

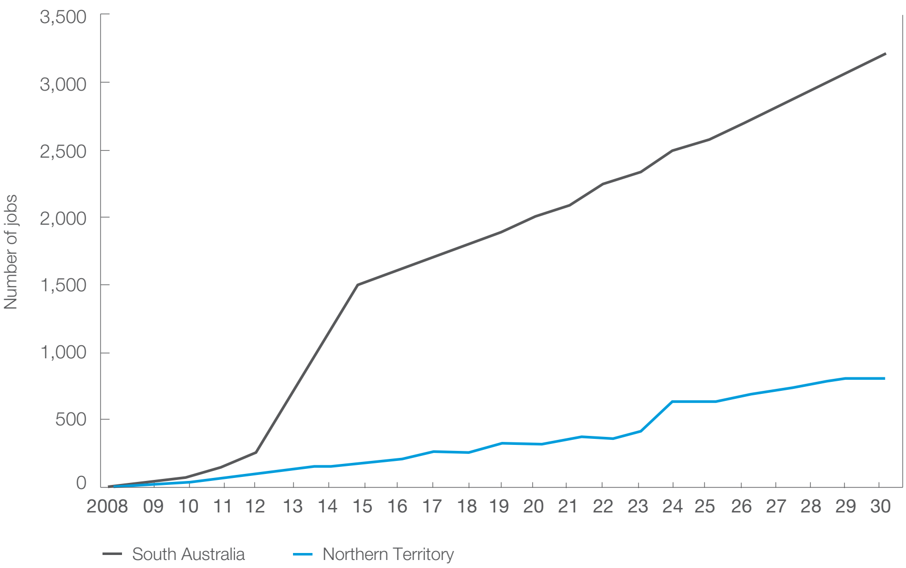
79 Based on low conversion estimate of 1 tonne uranium = 14,000-23,000 tonnes of coal equivalent (TCE). See conversion factors and energy equivalence for fossil fuel comparison, available in Nuclear Energy Agency, 2005, *Uranium 2005: Resources, Production and Demand*, Organisation for Economic Cooperation and Development, Paris, p 377.

Figure 4.12: Greenhouse gas outcomes in the Climate Action scenario



Source: Deloitte Economics and Australian Greenhouse Office, 2006, Tracking to the Kyoto Target: Australia's Greenhouse Emissions Trends 1990 to 2008–2012 and 2020, Department of Environment and Heritage, Australian Government, Canberra.

Figure 4.13: Direct employment in South Australia and Northern Territory – constrained supply and regulation reform in the climate crisis scenario



Source: MMRF

4.4 Economic impact: 'Climate Crisis' scenario

The Climate Crisis scenario postulates a future where substantial cuts in GHG emissions are implemented internationally to 2030. In a sense, the Climate Crisis future represents a sensitivity analysis on the more conservative Climate Action future.

In the Climate Crisis future, more aggressive emissions reductions targets are assumed to be introduced, which will drive a higher carbon price (US$100 per tonne CO_2-e) and greater uptake of nuclear power. The rapid increase in demand would strongly increase the price for uranium. For modelling purposes we have incorporated a long run contract price of US$150 per pound of uranium oxide. The higher price would drive a very rapid increase in investment in new and expanded mines to meet this growth in demand, as well as significant exploration.

Under Regulation Reform Australia would expand its production to 76,000 tonnes of uranium oxide by 2030 and to 61,250 tonnes under the Constrained Supply assumption. The difference between the two is the subtraction of exports from Queensland and Western Australia under Constrained Supply. This assumes a more aggressive expansion of the Olympic Dam mine and that additional deposits come online in the Northern Territory. It further assumes, under the Regulation Reform future, that a further 1.7 mines of average production size (1,500 tonnes per annum) are discovered and developed in Queensland while a further 2.4 mines of average production size are discovered and developed in Western Australia.

4.4.1 Growth in investment, employment and exports

To expand production to these levels, it is expected that very significant investment would be required: in land transport, electricity, port and water infrastructure to the deposits, in processing facilities, and in safety systems.

To support the construction phases of investment and operational phases of production very significant growth in jobs would also be expected.

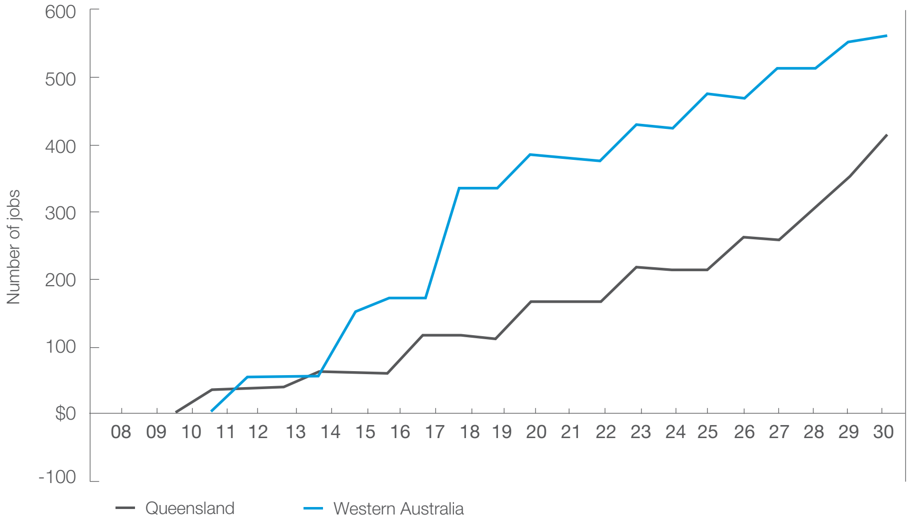
Nationally more than 2,200 direct jobs would be expected to be created on average under the Constrained Supply assumption from 2010 to 2030, with the peak increase in direct employment expected in 2030 at approximately 4,000 direct jobs above base case projections. In the Climate Crisis scenario approximately 2,700 direct jobs would be generated nationally on average from 2010-2030, with a peak increase in direct employment expected to occur in 2030 at approximately 4,950 additional jobs.

In terms of the distribution of these jobs, most would be in South Australia, however significant increases would also be expected in the Northern Territory, Queensland and Western Australia.

In South Australia, a further 1,850 direct jobs would be added on average from 2010 to 2030 in both the Constrained Supply and Regulation Reform futures, with a peak increase of 3,180 projected for 2030 above base case expectations. In the Northern Territory approximately 390 jobs on average would be added above base case projections from 2010 to 2030, with a peak increase of 810 persons in 2030. Figure 4.13 shows the growth in direct jobs in South Australia and the Northern Territory, which would be expected under both the Constrained Supply and Regulation Reform outcomes.

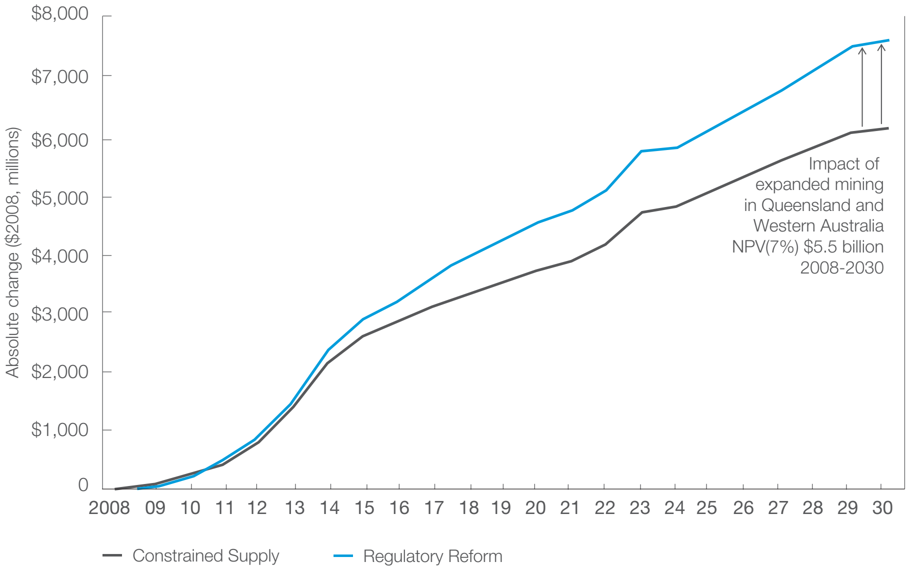
Queensland and Western Australia would only see an increase in employment in the uranium industry under Regulation Reform (Figure 4.14). In Queensland, a further 155 direct jobs would be added on average from 2010 to 2030 in both the Constrained Supply and Regulation Reform futures, with a peak increase of 410 projected for 2030 above base case expectations. In Western Australia, a further 300 direct jobs would be added on average from 2010 to 2030 under both Constrained Supply and Regulation Reform, with a peak increase of 560 projected for 2030 above base case expectations.

Figure 4.14: Direct employment in Western Australia and Queensland – constrained supply and regulation reform in the Climate Crisis scenario



Source: MMRF

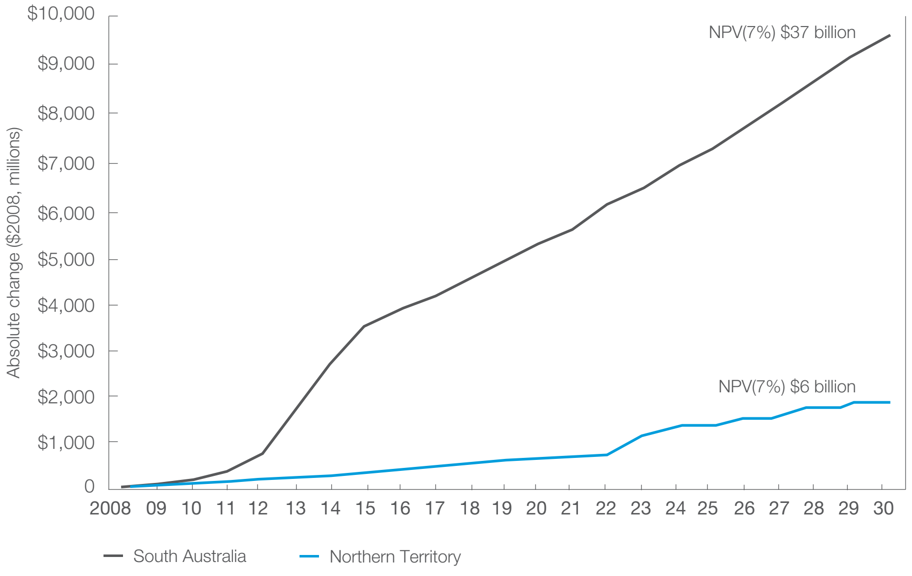
Figure 4.15: Australian GDP – constrained supply and regulation reform in the Climate Crisis scenario



Source: MMRF

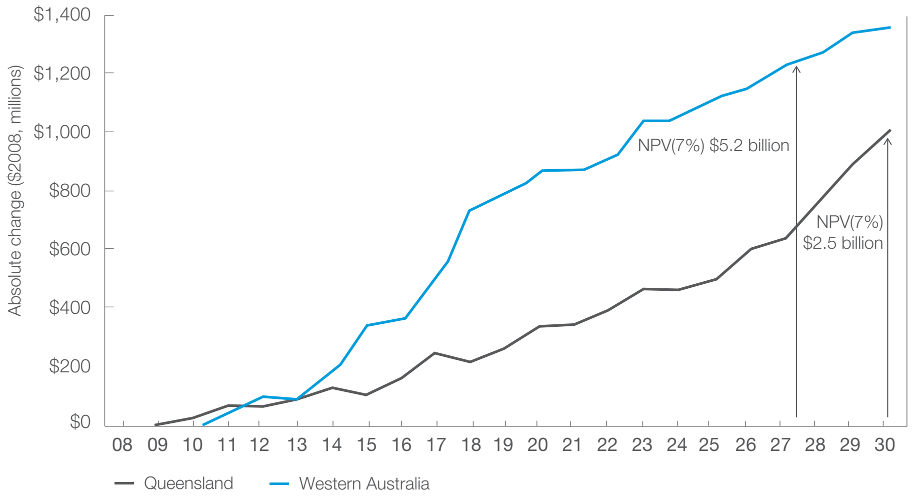
As the investments came online, export levels and values would increase significantly. Nationally, uranium exports would increase by $49 billion in $NPV_{7\%,\ 2008\text{-}2030}$ terms above base case levels under Constrained Supply and by $59 billion in $NPV_{7\%,\ 2008\text{-}2030}$ terms under Regulation Reform.

Figure 4.16: South Australian and Northern Territory GSP – constrained supply and regulation reform in the Climate Crisis scenario



Source: MMRF

Figure 4.17: The change between Queensland and Western Australian GSP under regulation reform compared to constrained supply in the Climate Crisis scenario



Source: MMRF

4.4.2 GDP, GSP and consumption outcomes

The growth in investment, employment and exports strongly boosts economic growth in the States where uranium mining expands. In the Constrained Supply scenario, Australian GDP would be $26.8 billion higher than otherwise in $NPV_{7\%}$ terms to 2030, which is approximately double the growth in GDP that would be expected in this scenario in the Climate Action future (Figure 4.15). In the Regulation Reform scenario, however, Australian GDP would be higher by $32.3 billion in $NPV_{7\%}$ terms to 2030. Thus reform to mining regulations in Queensland and Western Australia would be of even greater import in a Climate Crisis world: not only for greenhouse gas abatement goals but because Australia's economy would realise an additional $5.5 billion in economic benefit.

While it has not been modelled here for the reasons outlined in Section 4.2 it is important to remember the broader economic context for the industry's growth and that with $100 carbon prices global demand for coal would be expected to slow, holding all else constant. Even as coal will still remain a major electricity generation source for base load power, Australia will benefit by positioning itself to capture future demand for low-emission fuels.

At a State level, South Australia's GSP is projected to increase by $37 billion in $NPV_{7\%, 2008\text{-}2030}$ terms above base case projections under Constrained Supply. The larger growth in South Australia's GSP compared to Australia's GDP growth relative to the base case would be a result of South Australia growing faster than other States and territories and thereby 'crowding out' some economic activity in other States. The Northern Territory would be expected to see its GSP grow by $6 billion in $NPV_{7\%, 2008\text{-}2030}$ terms in the Constrained Supply future (Figure 4.16).

Table 4.4: Consumption under constrained supply and regulation reform in the Climate Crisis scenario

	Constrained Supply	Regulation Reform	Difference in revenue between Regulatory Reform and Constrained Supply
	$NPV_{7\%,\ 2008\text{-}2030}$	$NPV_{7\%,\ 2008\text{-}2030}$	
Australia	$23,600m	$28,500m	$4,881m
South Australia	$16,490m	$16,570m	$83m
Northern Territory	$2,104m	$2,064m	–$39m
Western Australia	–$832m	$1,330m	$2,161m
Queensland	$137m	$1,719m	$1,582m

Source: MMRF

As a consequence of rising exports and in turn an associated appreciation of the Australian dollar, Queensland and Western Australia would be crowded out under Constrained Supply, with GSP in those States expected to grow more slowly than under base case projections. In $NPV_{7\%,\ 2008\text{-}2030}$ terms Queensland and Western Australia's GSP would be reduced by $4.6 billion and $4.4 billion relative to the base case, respectively, in the Constrained Supply future.

Queensland and Western Australia's participation under Regulatory Reform reduces the crowding out effect of South Australia. The $NPV_{7\%,\ 2008\text{-}2030}$ of the improvement in Queensland and Western Australia's GSP relative to the Constrained Supply future was estimated to be $2.5 billion and $5.2 billion, respectively (Figure 4.17).

Critically, however, measures of GDP and GSP, while broad measures of economic activity, also include payments to foreigners and therefore do not measure the welfare of Australians as well as private consumption. As stated above, consumption is a superior proxy for economic welfare. Table 4.4 summarises the growth of consumption above base case projections in both the Constrained Supply and Regulation Reform futures.

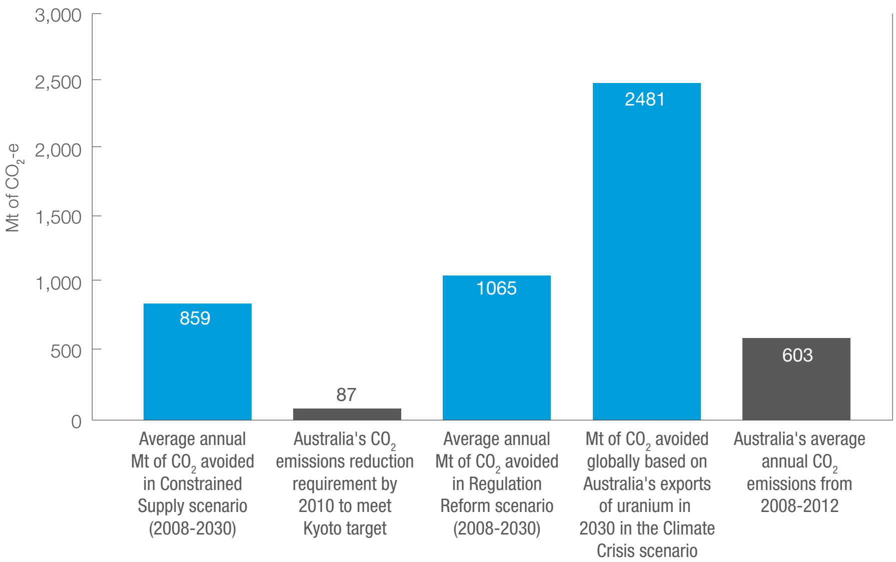
Overall, Australian consumption would be $4.9 billion higher in $NPV_{7\%}$ terms to 2030 under Regulation Reform compared with Constrained Supply in a Climate Crisis future.

4.4.3 Global greenhouse gas emissions avoided

Applying the same methodology used in Section 4.2, shows that Australia's export of uranium in the Constrained Supply future and the Climate Crisis scenario would produce more than 20,019 TWh of energy and result in 18,918 Mt CO_2-e being avoided, which equates to an average of 860 Mt CO_2-e per annum from 2010-2030. In 2030 alone, 2,000 Mt CO_2-e would be avoided.

In the Regulation Reform future in a Climate Crisis world, Australia's uranium exports would produce approximately 24,800 TWh of energy and contribute to the avoidance of 23,431 Mt CO_2-e, or an average of 1,065 Mt CO_2-e per annum from 2010 to 2030. In 2030 alone, 2,481 Mt CO_2-e would be avoided (Figure 4.18).

Figure 4.18: Comparing greenhouse gas outcomes in the Climate Crisis scenario



Source: Deloitte Economics

4.5 Summary

The following tables summarise economic impacts for Australia and the four key States and territories across the four outcomes.

Table 4.5: Macroeconomic and emission impacts relative to the base case for South Australia and the Northern Territory

	Climate Action Scenario		Climate Crisis Scenario	
	Constrained Supply ($NPV_{7\%,}$ 2008-2030)	Regulation Reform ($NPV_{7\%,}$ 2008-2030)	Constrained Supply ($NPV_{7\%,}$ 2008-2030)	Regulation Reform ($NPV_{7\%,}$ 2008-2030)
South Australia				
GSP	$21,034m	$20,929m	$37,244m	$37,044m
Consumption	$9,276m	$9,346m	$16,489m	$16,572m
Investment	$6,383m	$6,374m	$11,498m	$11,474m
Government Revenues	$2,510m	$2,510m	$4,484m	$4,476m
Northern Territory				
GSP	$2,409m	$2,301m	$5,982m	$5,811m
Consumption	$852m	$844m	$2,104m	$2,064m
Investment	$444m	$405m	$1,183m	$1,114m
Government Revenues	$337m	$330m	$820m	$808m
Greenhouse Gases Avoided Globally (2008-2030)	**11,379Mt**	**14,917Mt**	**18,918Mt**	**23,431Mt**

Source: MMRF and Deloitte Economics

Table 4.6: Macroeconomic outcomes relative to the constrained supply scenario for Western Australia and Queensland

	Regulation Reform Climate Action Scenario	Regulation Reform Climate Crisis Scenario
Western Australia		
GSP	$3,248m	$5,186m
Consumption	$1,362m	$2,161m
Investment	$838m	$1,236m
Government Revenues	$462m	$744m
Queensland		
GSP	$1,478m	$2,529m
Consumption	$931m	$1,582m
Investment	$508m	$830m
Government Revenues	$204m	$346m
Greenhouse Gases Avoided Globally (2008-2030)	**14,917Mt**	**23,431Mt**

Source: MMRF and Deloitte Economics

Appendix A

Regulation of the uranium industry

Governments have a legitimate role in regulating the activities of industry where those activities give rise to concerns about the well-being of either participants in the industry, or of the community more broadly. In relation to mining, the government also has a significant public interest role in managing access to limited and valuable Crown resources. The regulation of uranium mining in Australia is justified by:

- in return for *access to the uranium resource*, the obligation on mining companies to mine Australia's valuable resources in a responsible manner, and to provide a financial return to the Australian community;
- the need to ensure *protection of the environment*, particularly in sensitive areas;
- *indigenous land rights and cultural heritage issues* in areas in which mining activity is taking place;
- *occupational health and safety* concerns associated with mining activities;
- *radiation protection issues*[80] applying to workers along all parts of the uranium supply chain, and to local communities more broadly; and
- the *risks of proliferation* of nuclear materials. In particular, safeguards established under the Australian commitment to the international Nuclear Non Proliferation Treaty (NPT) aim to ensure that the use of Australia's exported uranium is only for peaceful and non-military applications.

The first four of these drivers for regulation apply to mining activities generally and are not specific to the uranium sector. However, radiation protection and proliferation issues (as well as those aspects of environment protection that derive from radiation) are unique to uranium mining and necessitate the implementation of a separate and specific framework for regulating uranium mining in Australia.

Across all types of mining activities, States/Territories hold regulatory responsibilities in the areas of mining operations and the environment, and the Commonwealth has a specific role in environmental protection in cases of national environmental significance under both the *Environment Protection (Impact of Proposals) Act 1974* (the EPIP Act) and the Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act). Arrangements between the Commonwealth and relevant States/Territories in relation to *uranium* mining are complicated by:

- the Commonwealth's national and international responsibilities for the management of nuclear activities. This includes responsibilities in relation to 'nuclear actions' under the EPBC Act, as well as in relation to managing radiation protection and proliferation risks; and
- the Commonwealth's specific responsibilities in relation to the Northern Territory, where it retains ownership of the uranium resource.

The resulting regulatory framework for uranium is a joint one where the States/Territories and the Commonwealth work in partnership, with the States and Territories overseeing day-to-day mining operations as well as many of the approvals processes, and the Commonwealth managing regulation of environmental assessment, oversight of the Territories and export controls.

The partnership between the Commonwealth and the States/Territories in relation to uranium mining is formalised in an Intergovernmental Agreement on the Environment signed by the Commonwealth and all States and Territories in 1992. The agreement seeks to achieve sound environmental management through a system of parallel and complementary legislation.

A.1 Commonwealth regulations

The main Commonwealth legislation affecting the uranium industry includes:

- *the Atomic Energy Act 1953*;
- *the Nuclear Non-Proliferation (Safeguards) Act 1987*;
- *the Australian Radiation Protection and Nuclear Safety Act 1998*;
- *the Environmental Protection and Biodiversity Conservation Act 1999*;
- *the Customs (Prohibited Exports) Regulations 1958*;
- *the Aboriginal Land Rights (Northern Territory) Act 1976*; and
- *the Native Title Act 1993*.

80 Many of the environment protection issues associated with uranium mining are also issues of radiation protection. There is therefore substantial cross-over in the 'environment' and 'radiation protection' rationale for regulation of the industry.

Table A.1: Summary of Commonwealth regulation of uranium mining

Relevant legislation	Relevant authority	Major intent	Mines affected
ACCESS TO THE RESOURCE			
Atomic Energy Act 1953	Minister for Resources (RET)	Authorisation of uranium mining in the Ranger Project Area Vests in the Commonwealth ownership of all uranium found in the Territories	All NT mines
ENVIRONMENT PROTECTION			
Customs (Prohibited Exports) Regulations 1958 under Customs Act 1901	Minister for Resources (RET)	To provide a licence for export of uranium. Allows RET to place environmental conditions on export permits for projects assessed under the now repealed EPIP and for the Ranger mine Also enacts regulation in the areas of radiation protection and proliferation risks	All
Environmental Protection (Impact of Projects) Act 1974	Minister for Resources (RET)	Requires Commonwealth environmental assessment in advance of mining activities, although does not provide approval for mines	Ranger Jabiluka Olympic Dam Beverley Honeymoon
Environment Protection and Biodiversity Conservation Act 1999	(Minister for the Environment (DEWHA) to advise)	Provides the Commonwealth with environmental jurisdiction in six areas of 'national environmental significance', including nuclear actions. Requires Commonwealth environmental approval and assessment process in advance of mining activities	Olympic Dam expansion Beverley expansion All future mine developments
Environmental Protection (Alligator Rivers Region) Act 1978	Minister for the Environment (DEWHA)	Provides for strong environmental protection measures for the Alligator Rivers Region Established the Office of the Supervising Scientist (OSS) now the Supervising Scientist Division (SSD) Established ARRAC and ARRTC	Ranger Jabiluka Future mine developments in the ARR
INDIGENOUS LAND RIGHTS			
Aboriginal Land Rights (Northern Territory) Act 1976	Minister for Indigenous Affairs (FaHCSIA)	Established Land Councils to represent to interests of Aboriginal traditional owners. Sets out conditions for access to Aboriginal land	All NT mines
Native Title Act 1993	Minister for Indigenous Affairs (FaHCSIA)	SA/WA/Qld Native title issues required to be resolved prior to the granting of a mineral lease in relevant jurisdictions	All non-NT mines
OCCUPATION HEALTH AND SAFETY			
No relevant CW legislation			

RADIATION PROTECTION			
Australian Radiation Protection and Nuclear Safety Act 1998	Minister for Health (ARPANSA)	To protect the health and safety of people, and to protect the environment, from the harmful effects of radiation. Regulates transport of uranium Established ARPANSA to administer the Act. Relevant Codes: Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (1987) Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores (1982) Codes of Practice for the Safe Transport of Radioactive Substances (1982) Recommendations for Limiting Exposure to Ionising Radiation (1995)	All
PROLIFERATION			
Nuclear Non-Proliferation (Safeguards) Act 1987	Minister for Foreign Affairs (ASNO)	Ensures physical safety of nuclear materials within Australia Provides permits for storage, transport and export of uranium.	All

Source: Deloitte Economics

A.2 State and territory responsibilities

At the State and Territory level, South Australia, the Northern Territory and Tasmania allow both the exploration and mining of uranium, while Western Australia and Queensland only currently allow exploration, and Victoria and New South Wales do not permit uranium exploration or mining at all. This prohibition extends to the transport and management of uranium through to export in some jurisdictions.

In addition to the Commonwealth regulatory arrangements on environmental protection, radiation protection, export controls and non-proliferation issues, the States and Territories that allow for uranium industry activity also have regulatory responsibilities. In particular, the States and Territories are responsible for the day to day operations of uranium mines, including the oversight of OH&S compliance, for example. As such, uranium mines have relatively rigorous legislative requirements to gain mining licence approvals as per any other mines. Table A.2 summarises the additional State and territory legislation that exists and in some cases overlaps with Commonwealth responsibilities by area of activity.

Table A.2: Summary of current state and territory regulations by area of activity

ACTIVITY	REGULATION
Access land	CW: Native Title Act 1993; Aboriginal Land Rights (NT) Act 1976; EPB C Act 1999
Exploration licence	CW: Aboriginal Land Rights (NT) Act 1976 SA: Mining Act 1971 NT: Mining Mgt Act 2001; Mining Act 1982
Mining lease	SA: Mining Act 1971; Mines & Works Inspection Act 1920; Development Act 1993; Roxby Downs (Indenture Ratification) Act 1982 NT : Mining Management Act 2001
Environmental approval	CW: Atomic Energy Act 1953; EPIP Act 1974; EPBC Act 1999 SA: Environment Protection Act 1993; Development Act 1993; Roxby Downs (Indenture Ratification) Act 1982 NT: Mining Management Act
Planning & development approval	CW: EPBC Act 1999 SA: Roxby Downs (Indenture Ratification) Act 1982; Development Act 1993 NT: Mining Management Act 2001
Licence to mine or mill radioactive ores	CW: The Mining Code 2005 (Australian Rad. Protection & Nuclear Safety Act 1998) SA: Rad. Protection & Control Act 1982 NT: Mining Management Act 2001
Monitoring and audit	CW: EPBC Act 1999 SA: Mines & Works Inspection Act 1920; Mining Act 1971; Water, Native Veg, Flora/Fauna Acts/Regs NT : Mining Management Act 2001
OH&S	SA: Occ. Health Safety & Welfare Act 1995; Dangerous Substances Act 1979 NT: Workplace Health & Safety Act 2007
Permit to transport and store nuclear material	CW: Code for Safe Transport of Radioactive Material 2001 (Australian Radiation Protection and Nuclear Safety Act 1998); Nuclear Non-Proliferation (Safeguards) Act 1987; EPBC Act 1999 SA: Transport Code (Australian Radiation Protection and Nuclear Safety Act 1998 (CW)) NT: Radioactive Ores and Concentrates (Packaging and Transport) Act
Licence to export	CW: Customs (Prohibited Exports) Regulations under the Customs Act 1901
Mine rehabilitation and closure	CW: EPBC Act 1999; Ranger Government Agreement SA: Mining Act 1971 NT: Mining Management Act 2001

Source: Adapted from Department of Prime Minister and Cabinet, 2006, op. cit.

Appendix B

Modelling assumptions

B.1 Projecting demand for uranium

B.1.1 Literature review

Future electricity demand will drive growth in demand for nuclear power generation and in turn demand for uranium. This section reviews available projections of demand for nuclear power generation and the assumptions underpinning these global projections.

International Energy Agency (IEA)

The IEA prepares updated forecasts for all energy sources in its *World Energy Outlook* series, which is released annually. The energy forecasts are based upon projections of economic and population growth for different jurisdictions around the world. In its *World Energy Outlook 2006* two future demand scenarios were considered – the Reference Scenario which assumed that existing climate change policies would continue into the future, and the Alternative Scenario, which assumes that individual governments adopt a range of climate change policies and measures aimed at enhancing energy security and mitigating CO_2-e emissions. No multi-lateral policy action to reduce carbon emissions is assumed in either case.

Under the Reference Scenario global demand for electricity was forecast to grow from the current installed capacity of 4,054 gigawatts electric (GWe) to 7,875 GWe in 2030, of which nuclear would provide 416 GWe (up from 364 GWe in 2005). This scenario suggested that nuclear power would have a declining market share of electricity generation capacity. In the Alternative Scenario, total generation capacity in 2030 was forecast as 7,104 GWe, with installed nuclear power generation capacity of 519 GWe.[81]

International Atomic Energy Agency (IAEA)

The IAEA in conjunction with the Organisation for Economic Co-operation and Development Nuclear Energy Agency (OECD NEA) also prepares forecasts for nuclear power electricity generation based upon official responses from member countries to questionnaires, providing both a low and high estimate. No carbon price or multi-lateral action by governments to reduce carbon emissions was assumed.

Forecasts for 2025 showed that nuclear power was expected to between 433 GWe and 533 GWe, slightly higher forecasts than estimated by the IEA.[82]

Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change, in its *Fourth Assessment Report*, considered the potential for different electricity generation technologies to meet the growing demand for electricity under various carbon price scenarios. It considered three carbon price scenarios (there was a fourth scenario in which there was no carbon price) of US$20, US$50, US$100 per tonne of carbon dioxide equivalent.

At a carbon price of US$50 per tonne of CO_2-e, the IPCC estimated that nuclear power would provide 6,867 TWh in 2030 (approximately 960GWe). In its analysis, the IPCC did not adjust the 2030 forecasts for electricity demand for potential energy efficiency savings that would be expected with the introduction of a carbon price (though it did consider this issue in a qualitative manner).[83]

Australian Bureau of Agriculture and Resource Economics,' (ABARE)

A 2007 ABARE research report into low emissions technologies developed two scenarios around climate change action. ABARE developed a Reference scenario which assumed continued development in addressing climate change along current trends, and an Alternative policy scenario which assumed that, from 2009, a concerted global effort to reduce global greenhouse gas emissions would be introduced but no carbon price was explicit in the modelling. Using the GTEM model, nuclear power was forecast to supply 4,032 TWh of global electricity demand (approximately 560 GWe) in the Reference scenario and 4,458 TWh (approximately 620 GWe) in the Alternative scenario.[84]

In 2006, ABARE prepared a separate research report on uranium, investigating the developments in global markets and the prospects for Australian exports. Uranium forecasts were also estimated by considering nuclear's future share of electricity generation from the GTEM model.

81 International Energy Agency, 2007, *World Energy Outlook 2006*

82 OECD Nuclear Energy Agency and International Atomic Energy Agency, 2005, *Uranium 2005: Resources, Production and Demand*

83 Intergovernmental Panel on Climate Change, 2007, *Energy supply. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*

84 ABARE, 2007, Technology: *Towards a Low Emissions Future*, research report 07.16

The results of this modelling were broadly in line with those of ABARE's 2007 reference case forecasts, with nuclear power producing 4,133 TWh, marginally higher than ABARE's later forecast. Based upon this it was estimated that global uranium oxide requirements would be 117,193 tonnes in 2030.

The UMPNER report forecasts were informed in part by the 2006 ABARE forecasts for future uranium oxide demand.

The World Nuclear Association (WNA)

The WNA details the number of reactors in operation, under construction, planned and proposed across most countries. There are currently 439 reactors, 33 under construction, 94 planned for construction and 222 planned for construction. For those projects which have sufficient detail, the WNA provides the expected timing of new reactors. Based upon these figures, there are 62 nuclear reactors scheduled to commence operation by 2015. Estimates beyond 2015 are not provided by the WNA.

Center for Nuclear Technology and Society

All of the above scenarios reviewed have relied upon a bottom up analytical approach to establishing future installed nuclear power capacity.

James Muckerheide, Director of the Center for Nuclear Technology and Society and the State Nuclear Engineer for the Commonwealth of Massachusetts, has analysed nuclear demand using a top down approach to determining the installed capacity of nuclear power in 2050. Upon reviewing energy demand forecasts, and the forecast trebling in demand by 2050, he assumed that one third of the world's energy needs in 2050 would need to be met by nuclear. He then outlined the required ramp up in reactor construction to meet the target. By 2030, 1,970 reactors (each with an installed capacity of 1,000 MWe) were assumed to be in operation to meet the target.[85]

Summary

The literature review showed that with respect to global demand, most projections for the nuclear power and uranium industries are based on global, 'bottom up' analyses of committed nuclear power generation expansions which do not explicitly consider the impact of a carbon price on global demand. The one exception to this has been the IPCC, which in its Fourth Assessment Report (AR4) considers the impact of a US$50/t CO_2-e price on the global nuclear power industry. A summary of the various forecasts available to 2030 for installed nuclear power generation capacity is shown in Table B.1. As the table illustrates, most of the forecasts are broadly in agreement about the installed capacity of nuclear power in 2030 with only the IPCC and CTNS forecasts being significantly different.

B.1.2 Future uranium scenarios: approach

This study explicitly considers the impact of a global carbon price on demand for uranium and the share of global demand under different carbon-constrained worlds that Australia may capture, depending on the regulatory settings in place in various States and territories.

B.1.3 Demand future assumptions

The range of forecasts analysed above were used to inform the potential range for future nuclear power demand, and in turn, uranium demand. A base case and two scenarios were established for future nuclear power generation.

The base case was developed based on the IEA Alternative scenario forecasts for 519 GWe (519 reactors each with an installed capacity of 1,000 MWe) by 2030. This was considered to be the level of demand that would occur globally if no significant action on climate change were to occur. The modelling analysed changes in demand, and in turn, changes in Australia's uranium industry relative to this base case.

The two future nuclear demand futures developed were a "Climate Action" scenario and a "Climate Crisis" scenario. These are described in Chapter 4 of the report.

Table B.1: Comparison of 2030 forecasts for nuclear power generation capacity (GWE)

Source	Scenario	Installed Nuclear Power Capacity (GWe)	Multi-lateral policies to address climate change	Global carbon price
IEA	Reference	416 GWe	✗	✗
	Alternative	519 GWe	✗	✗
IAEA	Low	433 GWe(1)	✗	✗
	High	533 GWe(1)	✗	✗
IPCC	<US$50/ tCO_2-e	960 GWe	✓	✓
ABARE	Reference	560 GWe	✗	✗
	Alternative	620 GWe	✓	✗
CTNS		1,970 GWe	✗	✗

Notes: (1) Forecasts are for 2025

85 Muckerheide, J., 2005, *How to Build 6,000 Nuclear Plants by 2050*, Executive Intelligence Review

B.2 Projecting uranium supply

B.2.1 Global uranium supply: IAEA estimates

Potential global uranium supply will be a function of global uranium resources. Current known resources are classified according to the estimated cost of extraction, as shown in Table B.3.

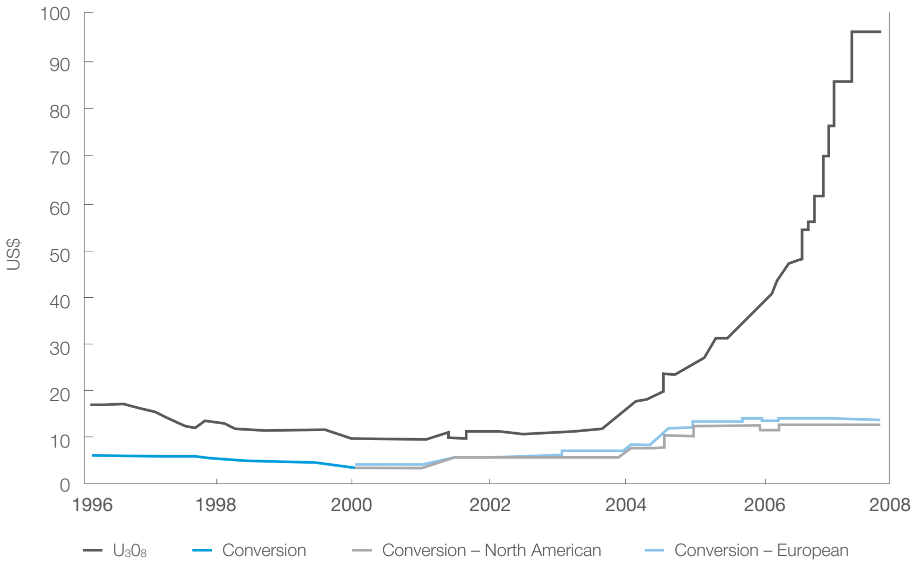
Critically, current estimates of reasonably assured and inferred resources are a function of exploration to date and may not adequately reflect the global resource base. At the time these resources were published, the long term contract price per pound of uranium was around one third of the current price. Current long term contract prices have increased to around $95 per pound uranium oxide (Figure B.2). Exploration in the recent past has been limited due to low prices over the past two decades, which have rendered some investment uneconomic.

Table B.3: Known recoverable uranium resources (as of 1 January 2005)

	Tonnes of Uranium Oxide		
	<US40/kg	<US80/kg	<US130/kg
Country			
Australia	1,231,132	1,266,509	1,347,877
Kazakhstan	481,241	715,399	962,381
Canada	438,443	523,349	523,349
USA		120,283	403,302
South Africa	168,808	293,340	401,646
Namibia	145,493	280,186	332,971
Niger	203,851	265,871	265,871
Brazil	164,976	272,759	328,656
Russia	93,281	203,304	203,304
Uzbekistan	107,033	107,033	115,959
Ukraine	40,705	89,962	105,939
Mongolia	19,104	73,054	73,054
Rest of world	75,018	275,248	528,678
Total U_3O_8	**3,238,656**	**4,486,298**	**5,592,987**

Source: OECD NEA & IAEA, 2005, *Uranium 2005: Resources, Production and Demand*, converted to tonnes uranium oxide from tonnes of uranium.

Figure B.2: Historical long term contract prices for uranium



Source: TradeTech, 2008, Long Term Contract Prices U_3O_8, www.uranium.info [January 2008]

In addition, there has been political resistance to the industry in some countries, and in Australia this has led to the development of regulatory restrictions on exploration and/or mining of uranium.

The strong long term contract price recovery for uranium oxide (Figure B.2), however, has driven significant growth in exploration and new uranium discoveries:

- Expenditure on exploration has significantly increased. In Australia, exploration expenditure has increased more than 13 times the levels seen five years ago and nearly six times 2004 expenditure levels to $114 million per annum.
- The draft 2008 *Nuclear Technology Review* prepared by IAEA has reported that 'higher uranium prices helped to prompt new exploration and reassessments and the identified uranium resources reported in this year's 'Red Book' [the IAEA's assessment of world uranium resources] will be 17 per cent higher than in the last edition.'[86] That would bring total identified resources to 6.5 million tonnes.

86 See International Atomic Energy Agency, 2008, Director General Addresses Board on Nuclear Issues, International Atomic Energy Agency, http://www.iaea.org/NewsCenter/News/2008/board030308.html [March 2008], Vienna.

- The IAEA estimates there is at least 7.5 million of 'undiscovered resources' which critically excludes estimates of additional resources in Australia.

Moreover, a number of stakeholders – *including organisations not involved in the commercial mining of uranium* – have indicated concern about the accuracy of the information, particularly for the <US$80 and <US$130 cost ranges. Stakeholders indicated that because uranium prices have been so low historically, very little exploration has occurred historically to prove up resources at higher costs of uranium and they expected continued discoveries would be made.

Table B.2 also excludes the IAEA's 'undiscovered resources' which include both prognosticated resources and speculative resources. Prognosticated resources refers to uranium resources that are expected to occur in well defined geological trends of known deposits, or mineralised areas with known deposits. Speculative resources refers to uranium resources that are thought to exist in geologically favourable yet unexplored areas. Reporting of speculative resources is incomplete, as only 28 countries have collected data and reported in this category. Even with incomplete country information (i.e. Australia does not collect this information), however, undiscovered resources would add a potential 7.5 million tonnes of uranium[87] more than twice current reasonably assured and inferred resources even excluding key countries from the estimate, such as Australia.

The IAEA has also underscored that many countries, including Australia, were 'considered to have significant resource potential in as yet sparsely explored areas [undiscovered resources]'.[88]

With current mine production only able to meet 64 per cent of current demand[89], with the remained being met by secondary sources, there is a need for the medium term. Indeed there are a number of developments underway, and the current shortfall in production is expected to be closed by 2015, with a number of mine expansions and new mines coming online over that timeframe, including Canada's Cigar Lake and Midwest mines, a number of mines in Kazakhstan. There is also the proposed expansion of Olympic Dam in Australia.

B.2.2 Supply side futures: assumptions for Australian production and exports

Australia's supply of uranium oxide is expected to respond to the demand side market forces. The two demand scenarios described above (Climate Action and Climate Crisis) will drive significant increases in the price of uranium oxide. As demand and prices rise, the production of uranium oxide from Australia will increase.

As well as responding to the influences from the demand side of the market, uranium production in Australia will also be influenced by government policy. Therefore, for each demand scenario, there will also be two Australian supply scenarios:

- *Constrained Supply future* – South Australia and the Northern Territory continue to remain the only Australian State and territory to allow uranium mining; and
- *Regulation Reform future* – Queensland and Western Australia, who currently allow uranium exploration, change current policy and allow uranium mining, such that South Australia, the Northern Territory, Queensland and Western Australia all allow for the mining and export of uranium.

The precise assumptions used to estimate the economic impact of the Australian uranium industry are discussed below.

Base case assumptions

Australian uranium oxide supply in the base case is assumed to be based upon all current existing uranium mining operations and any committed new mines or expansions. Therefore, in addition to the current production capacity of 9,800 tonnes of uranium oxide, the following additional mining capacity is included in the base case:

- Development of Honeymoon uranium mine – expected to add an additional 300 tonnes of uranium oxide per annum from 2009;[90]
- Expansion of Ranger uranium mine – the committed expansion of the mine by an additional 400 tonnes of production capacity;[91] and
- Increase in output of Beverley mine — production at Beverley is expected to increase by 400 tonnes per annum.[92]

In the base case, it is also important to recognise that existing mines may become depleted over the period to 2030. Mine depletion dates are estimated using the current known resources (as reported in the OECD NEA IAEA *Uranium 2005: Resources, Production and Demand* and updated by information supplied by GeoScience Australia in February 2008), and current or expected mine production capacity.

In the base case, the only mine still operating in 2030 is Olympic Dam, at a production capacity of 4,000 tonnes per annum.

87 As estimated in 2005. See IAEA, 2005, *op. cit*.

88 *Ibid*.

89 World Nuclear Association, *Uranium Market*, World Nuclear Association, www.world-nuclear.org [15 February 2008].

90 Uranium One, *Honeymoon Project*, available at www.uranium1.com, accessed 17 February 2008

91 Energy Resources of Australia, 14 June 2007, *Investor community site visits June 14* 2007, Presentation – Investor Visit (GM Ops)

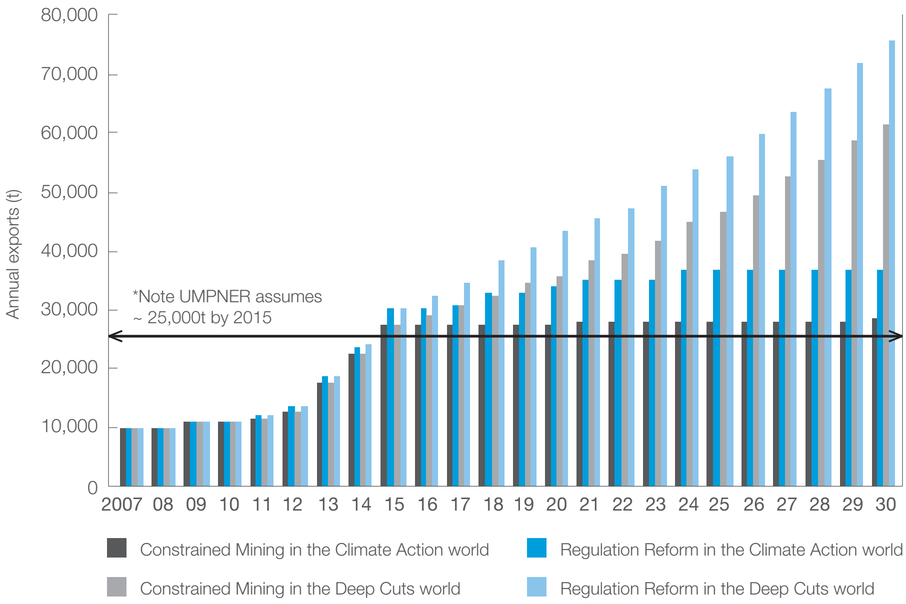
92 Uranium Information Centre, *Australia's Uranium Mines*, available at www.uic.com.au/emine.htm, accessed 17 February 2008.

Supply side scenarios

The Constrained Supply and Regulation Reform supply pathways are considered in both the Climate Action future and the Climate Crisis future, with varying market share captured by Australian miners in each case:

- It was assumed that if Western Australia and Queensland were allowed to mine in a Climate Action future, that together with South Australia and the Northern Territory Australia would capture 25 per cent of global demand. In practice this meant that most known mines would come online by 2030. No new discoveries would be required to support this industry growth.
- It was assumed that if Western Australia and Queensland were not allowed to mine in a Climate Action future that South Australia and the Northern Territory would together capture 19 per cent of global demand, which is in line with current production rates. This assumes that some currently uncommitted mines come online in the Northern Territory to compensate for the wind down of current mines in that territory and that the Olympic Dam would continue with its planned three stage expansion. Again importantly no new discoveries would be required to support this industry growth.
- It was assumed that if Western Australia and Queensland were allowed to mine in a Climate Crisis future, that together with South Australia and the Northern Territory Australia would capture 30 per cent of global demand. In practice this would mean that Olympic Dam would expand at a more rapid pace than is currently planned. It also would mean that more known resources in the Northern Territory would be developed, and that a further 1.3 mines and 2.7 mines[93] would be discovered and developed by 2030 in Queensland and Western Australia, respectively.
- It was assumed that if Western Australia and Queensland were not allowed to mine in a Climate Action future that South Australia and the Northern Territory would together capture approximately 20 per cent of global demand.

Figure B.3: Australian supply pathways to 2030



Source: Deloitte Economics

Figure B.3 shows that both of the supply scenarios considered in the Climate Action future are conservative and do not deviate significantly from UMPNER projections for Australian exports. It is important to note that UMPNER only projects Australian uranium production to 2015, that no carbon price is assumed, and that no mining is assumed to occur in Queensland or Western Australia.

These supply pathways would only plausibly arise if there were very significant cuts to global greenhouse gas emissions agreed by developed and developing nations.

B.2.3 Four scenarios to estimate the economic impact of the Australian uranium industry to 2030

Together these two demand and supply projections produce four scenarios:

- a Constrained Supply scenario in the Climate Action future;
- a Regulation Reform scenario in the Climate Action future;
- a Constrained Supply scenario in a Climate Crisis future; and
- a Regulation Reform scenario in a Climate Crisis future.

A summary of the various demand and supply scenarios is shown in Figure B.4.

B.2.4 Construction costs

Estimating the construction costs associated with the development of new uranium mines in Australia is complex, as construction cost will vary significantly by resource deposit, for the following reasons:

- Different types of mines require different extraction and processing techniques. For example an in-situ leaching extraction process will require different infrastructure to that of an open cut mine.
- The environment protection measures required under the Environmental Protection and Biodiversity Act (and other state based planning requirements).
- The nature of the ore body. For example, Olympic Dam is an uranium, gold and copper mine, with constructions costs including processing infrastructure to extract the other commodities.
- The local geography of deposits will also influence construction cost, through proximity of essential services (power, water, etc).

93 Where the average mine size in Australia produces an average of 1,500 tonnes of uranium oxide per year. Deloitte Economics analysis of ABARE data.

It is also difficult to estimate construction costs given that few feasibility studies around specific mines are available. An estimate of the average construction cost per tonne of production capacity is made based upon information contained with ABARE's *Major Projects Listing*, of $0.15 million per tonne of production capacity. In the case of Olympic Dam, given the size of the investment associated with its expansion, its cost has been excluded from the averaging, and its cost estimate directly inputted into the modelling based on industry reports.[94]

Figure B.4: Key modelling assumptions by scenario

REGULATION REFORM: Uranium mining allowed in South Australia, the Northern Territory, Western Australia and Queensland

REGULATION REFORM IN A CLIMATE ACTION WORLD	REGULATION REFORM IN A CLIMATE CRISIS WORLD
960 (1,000MWe) nuclear power reactors	1,634 (1,000MWe) nuclear power reactors
Australia accounts for 25% global demand by 2030	Australia accounts for 30% global demand by 2030
(37,000t U_3O_8 from SA, NT, Qld and WA)	76,000t U_3O_8 from SA, NT, Qld and WA)
Climate Action world: US$50 CO_2 price	Climate Crisis world: US$100 CO_2 price
CONSTRAINED SUPPLY IN A CLIMATE ACTION WORLD	CONSTRAINED SUPPLY IN A CLIMATE CRISIS WORLD
960 (1,000MWe) nuclear power reactors	1,634 (1,000MWe) nuclear power reactors
Australia accounts for 19% global demand by 2030	Australia accounts for 24% global demand by 2030
(28,500t U_3O_8 from SA and NT only)	61,250t U_3O_8 from SA and NT only)

CONSTRAINED SUPPLY: Uranium mining allowed in South Australia and the Northern Territory only

Source: Deloitte Economics

B.3 The MMRF model

The scenarios were modelled using MMRF, a computable general equilibrium (CGE) model of the Australian economy operated by the Centre of Policy Studies at Monash University. The model's architecture and key assumptions underpinning how the model operates are discussed below.

B.3.1 Model overview and enhancements

The MONASH suite of CGE models has a lengthy history of development. They are the most comprehensive models available in Australia, are extensively documented and have been subject to comprehensive peer review. They have a very high level of credibility among governments, academics and other expert bodies.

MMRF is a detailed dynamic, multi-sectoral, multi-regional model of Australia. The current version of the model distinguishes 54 industries, 58 products, eight States/territories and 56 sub-State regions.

MMRF is founded on the Monash Multi-Regional (MMR) model, and was built in three stages. In the first stage, MMR was transformed into a dynamic system by the inclusion of dynamic mechanisms. These were added as self-contained blocks, allowing MMRF to include MMR as a special case. The second stage involved a range of developments designed to enhance the model's capacity for environmental analysis. In the third stage, a regional disaggregation facility was added, which allows state-level results to be disaggregated down to sub-state regions.

B.3.2 MMR

MMR divides Australia into the six states and two territories. There are five types of agents in the model: industries, capital creators, households, governments, and foreigners. The number of industries is limited by computational constraints. For each industry in each region there is an associated capital creator. The sectors each produce a single commodity and the capital creators each produce units of capital that are specific to the associated sector. Each region in MMR has a single household and a regional government. There is also a federal government. Finally, there are foreigners, whose behaviour is summarised by export demand curves for the products of each region and by supply curves for international imports to each region.

MMR determines regional supplies and demands of commodities through optimising behaviour of agents in competitive markets. Optimising behaviour also determines industry demands for labour and capital. Labour supply at the national level is determined by demographic factors, while national capital supply responds to rates of return. Labour and capital can cross regional borders so that each region's stock of productive resources reflects regional employment opportunities and relative rates of return.

The specifications of supply and demand behaviour co-ordinated through market clearing equations comprise the general equilibrium (GE) core of the model. There are two blocks of equations in addition to the core. They describe regional and federal government finances and regional labour markets.

B.3.3 From MMR to MMRF: dynamics

There are two main types of inter-temporal links incorporated into MMRF: physical capital accumulation and lagged adjustment processes. These are explained below.

Physical capital accumulation

It is assumed that investment undertaken in year t becomes operational at the start of year t+1. Thus, given a starting point value for capital in t=0, and with a mechanism for explaining investment through time, the model can be used to trace out the time paths of industry capital stocks.

Investment in industry i in state/territory s in year t is explained via a mechanism that relates investment to expected rates of return. The expected rate of return in year t can be specified in a variety of ways.

94 See Yeeles, R., 2007, *Olympic Dam: South Australia*, presentation to 30th ATSE Symposium – Resources Boom: Opportunities and Consequences, Perth - 19 November 2007, BHP Billiton, www.atse.org.au/uploads/Yeeles%20-%20Session%202.ppt [January 2008], Adelaide.

In MMRF two possibilities are allowed for, static expectations and forward-looking model-consistent expectations. Under static expectations, it is assumed that investors take account only of current rentals and asset prices when forming current expectations about rates of return. Under rational expectations the expected rate of return is set equal to the present value in year t of investing $1 in industry i in region r, taking account of both the rental earnings and depreciated asset value of this investment in year t+1 as calculated in the model.

Lagged adjustment processes

One lagged adjustment process is included in MMRF. This relates to the operation of the labour market in year-to-year policy simulations.

In comparative static analysis, one of the following two assumptions is made about the national real wage rate and national employment:

- the national real wage rate adjusts so that any policy shock has no effect on aggregate employment; or
- the national real wage rate is unaffected by the shock and employment adjusts.

MMRF's treatment of the labour market allows for a third, intermediate position, in which real wages can be sticky in the short-run but flexible in the long-run and employment can be flexible in the short-run but sticky in the long-run. For year-to-year policy simulations, it is assumed that the deviation in the national real wage rate increases through time in proportion to the deviation in aggregate employment from its Base Case-forecast level. The coefficient of adjustment is chosen so that the employment effects of a shock are largely eliminated after about ten years. This is consistent with macroeconomic modelling in which the NAIRU is exogenous.

B.3.4 Closure assumptions

Supply-side structure

The standard MMRF treatment of input-structure applies to all industries, including the three new industries representing the core elements of the Project. Capital and agricultural land is assumed to be industry specific, while there is only one type of labour employed by all industries in all regions.

There is no explicit allowance for natural-resource as a fixed factor of production. The primary-factor substitution elasticity is set to 0.5 for all industries. Trade elasticities for international and interstate imports and exports are available on request.

Labour markets

At the national level, we assume that the deviation in the national real wage rate from its Base Case level increases in proportion to the deviation in economy-wide employment from its Base Case level. Eventually, the real wage adjustment eliminates the deviation in national employment. Thus in the long-run the national labour-market impacts of the Project will be revealed as changes in the national real wage rate, rather than as changes in national employment.

At the state/territory level, we assume that labour is imperfectly mobile between State economies. Thus a region that is favourably affected by the Project will experience a mix of increased employment and increased wage-rates relative to regions that are less favourably affected.

People move between regions so as to maintain unemployment rates at their Base Case levels.

Public expenditure, taxes and government budget balances

We assume that real consumption by regional governments and real consumption by the federal government are unaffected by the Project. We assume that all indirect tax rates have the same values as in the Base Case simulation. The Federal government's budget balance is fixed to its Base Case value via endogenous adjustments to the average PAYG tax rate. State government budget balances are fixed via endogenous changes in direct transfer payments to households.

Consumption, investment, ownership of capital and measurement of welfare

In each year of the deviation scenarios, the composition of aggregate real consumption across states/territories diverges from its Base Case level by an amount reflecting the divergence in real income available to residents.

In calculating real income available for consumption we take account of: direct income from factors (with an allowance for the net flow of foreign income); income from other sources such as government welfare payments; and income tax. Because the balances on government accounts are kept fixed, the impacts on real private consumption in each region are reliable indicators of the impact of the Project on the economic welfare of incumbents.

Rates of return on capital

In deviation simulations MMRF allows for short-run divergences in rates of return on industry capital stocks from their levels in the Base Case forecasts. Such divergences cause divergences in investment and capital stocks. The divergences in capital stocks gradually erode the divergences in rates of return, such that in the longer term rates of return have returned to their Base Case values.

Production technologies

MMRF contains many types of technical change variables. In the deviation simulations we assume that all technology variables, other than those required to implement the shocks, have the same values as in the Base Case simulation.

B.3.5 Public documentation

Public documentation of the MMRF model is available at:

- Pezzey, J.C.V. and Lambie, N.R., 2001, *Computable general equilibrium models for evaluating domestic greenhouse policies in Australia: A comparative analysis*, Report to the Productivity Commission, AusInfo, Canberra.
- Adams, P.D., Horridge, J.M. and Parmenter, B.R., 2000, *MMRF: A Dynamic, Multi-sectoral Model of Australia*, Centre of Policy Studies, Monash University, Melbourne.

Appendix C

Stakeholders consulted

A wide range of stakeholders were contacted to participate in this research. Participating organisations or persons included:

Alliance Resources

Australian Nuclear Science and Technology Organisation

Areva

Australian Safeguards and Non-Proliferation Office

BHP Billiton

Cameco

Centre for Aboriginal Economic Policy Research (ANU)

CSIRO Energy Technology

Department of Foreign Affairs and Trade

Department of Industry Tourism and Resources

Energy Resources Australia

Eromanga Uranium

Flinders University

GeoScience Australia

Heathgate Resources

Northern Territory Department of Primary Industries, Fisheries and Mines

NuPower

Paladin Resources

Queensland Department of State Development

Rio Tinto

South Australian Department of Primary Industries and Resources

South Australian Department of Trade and Economic Development

Summit Resources

Toro Energy

Uranium Mining, Processing and Nuclear Energy Review (Dr Ziggy Switkowski)

Uran Limited

Uranium Equities Limited

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