House Standing Committee on Industry and Resources

Committee activities (inquiries and reports)

Inquiry into developing Australia's non-fossil fuel energy industry

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Report

On Monday, 4 December 2006, the Standing Committee on Industry and Resources tabled its report on the Inquiry into developing Australia's non-fossil fuel energy industry *Australia's uranium: Greenhouse friendly fuel for an energy hungry world*.

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This report is comprised of **preliminary pages, 12 chapters and 8 appendices**.

Australia's uranium: Greenhouse friendly fuel for an energy hungry world

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Last reviewed 9 February, 2011 by Committee Secretariat

Australia’s uranium — Greenhouse friendly fuel for an energy hungry world

A case study into the strategic importance of Australia ’s uranium resources for the Inquiry into developing Australia ’s non-fossil fuel energy industry

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Foreword

The Committee's inquiry commenced in March 2005, when there was little mention in Australia of uranium mining and even less of nuclear power's much predicted global expansion. Throughout the course of the Inquiry the Committee noted a significant shift in the debate in relation to nuclear power, driven by community concerns about greenhouse gas emissions and climate change. This shift was reflected at the federal level with the establishment in August 2005 of a Steering Group to develop a Uranium Industry Framework and, in June 2006, with the Prime Minister's Taskforce commissioned to review uranium mining, processing and nuclear energy in Australia.

There is now a growing recognition that nuclear power makes a significant contribution to the mitigation of greenhouse gas emissions. Worldwide, nuclear power plants currently save some 10 per cent of total carbon dioxide (CO_2) emissions from world energy use. This represents an immense saving of greenhouse gas emissions that would otherwise be contributing to global warming. If the world were not using nuclear power, emissions of CO_2 would be some 2.5 billion tonnes higher per year.

Nuclear power plants emit no greenhouse gas emissions at point of generation and very small quantities over the whole nuclear fuel cycle, from uranium mining through to waste disposal. Indeed, the Committee reports that nuclear power emits only 2 to 6 grams of carbon per kilowatt hour of electricity produced. This is two orders of magnitude less than coal, oil and natural gas, and is comparable to emissions from wind and solar power.

A single nuclear power plant of one gigawatt capacity offsets the emission of some 7–8 million tonnes of CO_2 each year, if it displaces use of coal. Nuclear power also avoids the emission of sulphur dioxide, nitrous oxide and particulates, thereby significantly contributing to air quality.

Australia's uranium exports displace some 395 million tonnes of CO_2 each year, relative to black coal electricity generation, and this represents some 70 per cent of Australia's total greenhouse gas emissions for 2003.

Nuclear power represents the only current reliable and proven means of limiting increased emissions while meeting the world's voracious appetite for energy. While the Committee recognises that there is a role for renewables and certainly for greater use of efficiency measures, renewables are limited in their application by being intermittent, diffuse and pose significant energy storage problems. Renewables also require substantial backup generation, which needs to be provided by conventional baseload power sources. Promised baseload contributions from geothermal, which will be welcome, are yet to be developed on any scale. For the generation of continuous, reliable supplies of electricity on a large scale, the only current alternative to fossil fuels is nuclear power.

Naturally, the Committee welcomes the contribution that renewables and energy efficiency measures can make to greenhouse gas mitigation, but these measures alone have no prospect whatsoever of meeting rapidly growing demands for energy and abating greenhouse gas missions to the degree required. There is a clear need for a mix of low-emission energy sources and technologies, in which nuclear power will continue to play a vital part.

The Committee believes that the 'nuclear versus renewables' dichotomy is a false debate and misses the point: while renewables have a contribution to make, other than hydro and potentially geothermal and novel combinations of existing technologies, they are simply not capable of providing baseload power on a large scale. The relevant comparison, if one needs to be made, is between baseload alternatives. On this issue the evidence is absolutely clear—nuclear power is the only proven technology for baseload power supply that does not release substantial amounts of CO_2.

The Committee also recognises that, given its comparative advantage in fossil fuels and the world's projected continued reliance on these fuels, Australia has a strong economic interest in supporting technologies that reduce the greenhouse intensity of fossil fuel use. The Committee therefore agrees that nuclear power should not be seen as competing with or substituting for clean- coal technologies, and indeed for renewables such as photovoltaics in which Australia has expertise.

No-one asserted to the Committee during the course of the inquiry that nuclear power alone can 'solve' climate change. Being restricted at the present time to the generation of electricity, nuclear energy obviously cannot reduce emissions from all sectors, although nuclear power does have the potential to reduce emissions in the transport sector through the production of hydrogen. However, electricity generation, which is already the largest contributor of CO_2 emissions at 40 per cent of the global total, is also the fastest growing. It is imperative that emissions from this sector be reduced, particularly in fast growing developing nations such as China.

In view of the projected growth in energy demand and the imperative for large developing nations to reduce their reliance on fossil fuels, the Committee believes that, with its immense endowment of uranium, Australia is uniquely placed to make a significant contribution to emissions reductions through increased production and supply of uranium. The Committee wholeheartedly agrees with a submitter who stated that through its supply of uranium ' Australia should throw the world a climate lifeline.'

The Committee recognised from the outset of the inquiry that, in coming to a considered view about the possible expansion of uranium mining in Australia, the Committee needed to examine the three key issues associated with uranium mining and use of nuclear power which some submitters claim are 'unresolved'. These issues relate to the: generation and management of radioactive waste across the nuclear fuel cycle; safety of the fuel cycle, particularly the operation of nuclear reactors and the risks to health from fuel cycle industries, including uranium mining; and the risk of proliferation of nuclear materials and technologies, and their diversion for use in weapons programs. The Committee's report comprehensively addresses each of these issues.

The Committee does not question the sincerity with which those people expressing 'moral outrage' at the very existence of the uranium industry hold their views. However, the Committee believes that these views are not informed by an accurate assessment of the benefits and risks associated with the industry and from use of nuclear power.

Negative public perceptions of the uranium industry, misconceptions about the nature of the industry's operations on the issues of waste, safety and proliferation, combined with political timidity, have clearly impeded the uranium industry's growth and Australia's involvement in the nuclear fuel cycle over several decades. There have, for example, been several missed opportunities for Australia to add value to its resources by processing uranium domestically prior to export.

It is notable that on such an historically controversial subject as uranium mining and exports the Committee has produced a unanimous report. All members are agreed that the present restrictions on uranium exploration and mining are illogical, inconsistent and anti-competitive. Restrictions have impeded investment in the industry, and have resulted in a loss of regional employment and wealth creation opportunities, royalties and taxation receipts. The only beneficiaries of restrictions are the existing producers and foreign competitors. The Committee concludes that state policies preventing development of new uranium mines should be lifted and legislative restrictions on uranium mining should be repealed.

Uranium is Australia 's second largest energy export in terms of contained energy content. Uranium is an immensely concentrated source of energy—one tonne of

uranium oxide generates the same amount of energy as 20 000 tonnes of black coal. The uranium produced from just one of Australia's mines each year—Ranger, in the Northern Territory—contains sufficient energy to provide for 80 per cent of Australia's total annual electricity requirements, or all of Taiwan's electricity needs for a year.

However, while Australia is well endowed with energy resources for its own needs, other countries are not so fortunate. These include developing countries such as China. As a matter of energy justice, Australia should not deny countries who wish to use nuclear power in a responsible manner the benefits from doing so. Neither should Australia refuse to export its uranium to assist in addressing the global energy imbalance and the disparity in living standards associated with this global inequity.

Finally, in turning from a past in which Australia has consistently missed opportunities to add value to its uranium resources, a majority of the Committee concludes that the federal and state governments should now prepare for the possible establishment of other fuel cycle industries in Australia by: examining how value-adding could occur domestically while meeting non-proliferation objectives; developing an appropriate licensing and regulatory framework; and rebuilding Australia's nuclear skills base and expertise.

On behalf of the Committee, I thank the three companies that facilitated the Committee's inspections of the currently operating uranium mines—BHP Billiton Ltd, Energy Resources of Australia Ltd and Heathgate Resources Pty Ltd.

Finally, I wish to thank my Committee colleagues who participated keenly throughout the Inquiry. In particular, I wish to express my sincere thanks to the members of the Committee from the Opposition, whose enthusiasm and spirit of bipartisanship for this important and historic inquiry was admirable.

The Hon Geoff Prosser MP

Chairman

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Membership of the Committee

Chairman	The Hon Geoff Prosser MP
Deputy Chair	Mr Michael Hatton MP
Members	The Hon Dick Adams MP
	The Hon Bronwyn Bishop MP
	The Hon Alan Cadman MP
	Mr Martin Ferguson MP
	Mr Barry Haase MP
	The Hon Robert Katter MP
	The Hon Jackie Kelly MP
	Mr David Tollner MP

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Committee Secretariat

Secretary	Mr Russell Chafer
Inquiry Secretary	Mr Jerome Brown
Research Officers	Mr Muzammil Ali (until December 2005)
	Ms Peggy Danaee (from January 2006 until October 2006)
Administration Officer	Ms Penelope Humphries

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Terms of Reference

On 15 March 2005 the Minister for Industry, Tourism and Resources, the Hon Ian Macfarlane MP, referred the following inquiry to the Committee .

The House of Representatives Standing Committee on Industry and Resources shall inquire into and report on the development of the non-fossil fuel energy industry in Australia .

The Committee shall commence its inquiry with a case study into the strategic importance of Australia's uranium resources. The case study shall have particular regard to the:

a) global demand for Australia's uranium resources and associated supply issues;

b) strategic importance of Australia's uranium resources and any relevant industry developments;

c) potential implications for global greenhouse gas emission reductions from the further development and export of Australia's uranium resources; and

d) current structure and regulatory environment of the uranium mining sector (noting the work that has been undertaken by other inquiries and reviews on these issues).

Additional issues

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

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

3. Examination of health risks to workers and to the public from exposure to ionising radiation from uranium mining.

4. Adequacy of regulation of uranium mining by the Commonwealth.

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

6. The effectiveness of safeguards regimes in addressing the proliferation of fissile material, the potential diversion of Australian obligate fissile materials, and the potential for Australian obligate radioactive materials to be used in 'dirty bombs'.

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List of abbreviations

Acronyms

AAEC	Australian Atomic Energy Commission
ACF	Australian Conservation Foundation
ALRA	*AboriginalLand Rights Act*
AMEC	Association of Mining and Exploration Companies
AMP CISFT	AMP Capital Investors Sustainable Funds Team
ANA	Australian Nuclear Association
ANF	Australian Nuclear Forum
ANSTO	Australian Nuclear Science and Technology Organisation
AONM	Australian Obligated Nuclear Material
AP	Additional Protocol
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency

ARR	Alligator Rivers Region
ARRAC	Alligator Rivers Region Consultative Committee
ARRTC	Alligator Rivers Region Technical Committee
ASNO	Australian Safeguards and Non-Proliferation Office
ASMV	Australian Student Mineral Venture
BHPB	BHP Billiton Ltd
BSS	International Basic Safety Standards for Protection against Ionising Radiation and for the Safety of Radiation Sources
CIM	Chief Inspector of Mines
COAG	Council of Australian Governments
DEH	Department of the Environment and Heritage
DITR	Australian Government Department of Industry, Tourism and Resources
DPIFM	Northern Territory Department of Primary Industry, Fisheries and Mines
ECNT	Environment Centre of the Northern Territory
EDR	Economic Demonstrated Resources
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
EPIP	*Environment Protection (Impact of Proposals) Act 1974*
ERA	Energy Resources of Australia Ltd
ERISS	Environmental Research Institute of the Supervising Scientist
FOE	Friends of the Earth–Australia
GA	Geoscience Australia
GAB	Great Artesian Basin
GAC	Gundjeihmi Aboriginal Corporation
GHG	Greenhouse gas
HEU	High-enriched uranium
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IR	Inferred Resources
ISL	In-situ leaching
KBM	Kakadu Board of Management
KRSIS	Kakadu Regional Social Impact Survey
LEU	Low-enriched uranium
MAPW	Medical Association for the Prevention of War
MOX	Mixed oxide fuel
MSTC	Mine Site Technical Committee
MUF	Material Unaccounted For
NLC	Northern Land Council
NNPA	Nuclear Non-Proliferation Agreement
NNWS	Non-Nuclear weapons state(s)
NPT	*Treaty on the Non-Proliferation of Nuclear Weapons*
NRC	US Nuclear Regulatory Commission
NT	Northern Territory
NTMC	Northern Territory Minerals Council
NWS	Nuclear weapon state(s)
OSS	Office of the Supervising Scientist
PIRSA	Department of Primary Industries and Resources, South Australia
PWR	Pressurised Water Reactor
RAR	Reasonably Assured Resources
SA	South Australia
SACOME	South Australian Chamber of Mines and Energy
SIA	Submarine Institute of Australia
SSD	Supervising Scientist Division
SWU	Separative work unit
SXR	Southern Cross Resources Inc
UIC	Uranium Information Centre
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

UOC	Uranium oxide concentrate
WMD	Weapons of mass destruction

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Units

Bq	becquerel
g	grams
g/t	grams per tonne
gC_{eq}/kWh	grams of carbon equivalent per kilowatt-hour
GtC	gigatonnes (billions) of carbon (emissions)
GW	gigawatt (giga = billion, 10 9 watts)
GWe / GWt	gigawatts of electrical / thermal power
kg	kilogram
kWe	kilowatts of electrical power
kWh	kilowatt-hour
m^3	cubic metres
mSv	millisievert
MtC	million tonnes of carbon (emissions)
MWe / MWt	megawatts of electrical / thermal power (mega = million, 10 6 watts)
MWh	megawatt-hour of electrical power
Mt	million tonnes
Pu-239 (or Pu^{239})	isotope 239 of plutonium
Sv	Sievert
µSv	microsievert
ppm	parts per million
ppb	parts per billion
Pu	plutonium
Pu-239 (or Pu^{239})	isotope 239 of plutonium
t	tonnes
toe	tonnes of oil equivalent
tpa	tonnes per annum
tU	tonnes of uranium
TW	terawatt (tera = trillion, 10 12 watts)
TWa	terawatt-year
TWh	terawatt-hour
µg/L	micrograms per litre
U	uranium
U-233 (or U^{233})	isotope 233 of uranium
U-235 (or U^{235})	isotope 235 of uranium
U-238 (or U^{238})	isotope 238 of uranium
UF_6	uranium hexafluoride
UO_2	uranium dioxide
$UO_4.2H_2O$	hydrated uranium peroxide
U_30_8	uranium oxide (triuranium octaoxide)
W	watt

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Glossary[1]

Actinide	An element with atomic number of 89 (actinium) or above.
Aquifer	A permeable underground soil or rock formation capable of storing and allowing flow of water.
Australian Obligated Nuclear Material (AONM)	Australian uranium and nuclear material derived there from, which is subject to obligations pursuant to Australia's bilateral safeguards agreements.
Becquerel (Bq)	The unit of measure of actual radioactivity in material, where one Bq equals one nuclear disintegration per second.
Depleted uranium	Uranium having a U-235 content less than that found in nature (e.g. as a result of the uranium enrichment processes). Depleted uranium can be blended with highly enriched uranium (e.g. from weapons) to make reactor fuel.
Economic Demonstrated Resources (EDR)	Category from the Australian National Classification System for Identified Mineral Resources which refers to resources for which profitable extraction or production under defined investment assumptions is possible.
Enrichment	A physical or chemical process for increasing the proportion of a particular isotope. Uranium enrichment involves increasing the proportion of U-235 from its level in natural uranium, which is 0.711%: for low enriched uranium fuel the proportion of U-235 (the enrichment level) is typically increased to between 3% and 5%. Weapons-grade uranium is more than 90% U-235.
Fertile material	A fertile material is one that is capable of becoming fissile through the capture of a neutron(s), possibly followed by radioactive decay. Important examples are U-238, which is fissionable but can also transmute into fissile Pu-239, and Th-232, which can transmute into fissile U-233.
Fissile material	Referring to a nuclide capable of undergoing fission by 'thermal' neutrons (e.g. U-233, U-235, Pu-239).
Fission	The splitting of an atomic nucleus into roughly equal parts, often by a neutron. In a fission reaction, a neutron collides with a fissile nuclide (e.g. U-235) and splits, releasing energy and new neutrons. Many of these neutrons may go on to collide with other fissile nuclei, setting up a nuclear chain reaction.
Fission fragments (or products)	When a nucleus undergoes fission, it splits into two fragments, releases neutrons and energy. The fragments are often called fission products, which may be stable or unstable, i.e. radioactive. Important fission product isotopes (in terms of their relative abundance and high radioactivity) are bromine, caesium, iodine, krypton, rubidium, strontium and xenon. They and their decay products form a significant component of nuclear waste.
Fissionable material	A fissionable material is a material that is capable of undergoing fission, normally differentiated from fissile in that these will fission if impacted by a fast neutron (e.g. U-238).
Fusion	Fusion is a nuclear reaction where light nuclei combine to form more massive nuclei with the release of energy. This process takes place continuously in the universe. In the core of the sun, at temperatures of 10–15 million degrees celsius, hydrogen is converted into helium, providing energy that sustains life on earth.
Highly enriched uranium (HEU)	Uranium enriched to at least 20% U-235. HEU is used principally for producing nuclear weapons and fuel for reactors to propel submarines and other vessels. Weapons grade HEU contains at least 90% U-235.
Indicated Mineral Resource	A sub-category of Mineral Resource from the JORC Code. An 'Indicated Mineral Resource' is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a reasonable level of confidence. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are too widely or inappropriately spaced to confirm geological and/or grade continuity but are spaced closely enough for continuity to be

	assumed.
Inferred Mineral Resource	A sub-category of Mineral Resource from the JORC Code. An 'Inferred Mineral Resource' is that part of a Mineral Resource for which tonnage, grade and mineral content can be estimated with a low level of confidence. It is inferred from geological evidence and assumed but not verified geological and/or grade continuity. It is based on information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes which may be limited or of uncertain quality and reliability.
Inferred Resources (IR)	Category from the NEA / IAEA uranium resource classification scheme which refers to uranium, in addition to Reasonably Assured Resources (RAR), that is inferred to occur based on direct geological evidence, in extensions of well-explored deposits, or in deposits in which geological continuity has been established but where specific data are considered to be inadequate to classify the resource as RAR.
In-situ leach (ISL)	The recovery by chemical leaching of minerals from porous orebodies without physical excavation. Also known as solution mining. ISL is the mining method employed at Beverley uranium mine in South Australia.
Ionising radiation	Radiation which when absorbed causes electrons to be added or removed from atoms in absorbing matter, producing electrically charged particles called ions. This process is known as ionisation.
Isotopes	Different forms of a chemical element having the same number of protons in their atoms, but different numbers of neutrons, e.g. U-235 (92 protons and 143 neutrons) and U-238 (92 protons and 146 neutrons). The number of neutrons in an atomic nucleus, while not significantly altering its chemistry, does alter its properties in nuclear reactions.
JORC Code (or 'the Code')	The Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves, developed by the Joint Ore Reserves Committee of The Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia. The Code sets out minimum standards, recommendations and guidelines for public reporting in Australasia of exploration results, mineral resources and ore reserves. The Code has been adopted by and included in the listing rules of the Australian Stock Exchange.
Kilowatt-hour (kWh)	The kilowatt-hour (kWh) is a unit ofenergy equivalent to one kilowatt (1 kW = 1 000 W) of power expended for one hour of time. This equals 3.6 million joules (megajoules or MJ). The kilowatt-hour is not a standard unit in any formal system, but it is commonly used in electrical applications.
Material Unaccounted For (MUF)	A term used in nuclear materials accountancy to mean the difference between operator records and the verified physical inventory. A large MUF may indicate diversion of material or loss of control, however, a certain level of MUF is expected due to measurement processes.
Measured Mineral Resource	A sub-category of Mineral Resource from the JORC Code. A 'Measured Mineral Resource' is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a high level of confidence. It is based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are spaced closely enough to confirm geological and grade continuity.
Megawatt (MW)	A megawatt is the international unit of power equal to one million (10 6) watts. A megawatt electrical (MWe) refers to electrical output from a generator. A megawatt thermal (MWt) refers to the thermal (i.e. heat) output from a reactor. The difference is the measure of the efficiency of the power generation process—transforming the heat energy into electricity. Typically, the heat output of a nuclear reactor is three times its electrical output, thus a reactor with a thermal output of 2 700 MW may produce about 900 MW of electricity (i.e. around 33% efficient).
Mineral Resource	Category from the JORC Code. A 'Mineral Resource' is a concentration or

	occurrence of material of intrinsic economic interest in or on the Earth’s crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, geological characteristics and continuity of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge. Mineral Resources are sub-divided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories.
Mixed Oxide Fuel (MOX)	A fuel fabricated from plutonium and depleted ora natural uranium oxide which can be used in standard light water rectors.
Natural uranium	Uranium with an isotopic composition found in nature, containing 99.28% U-238, 0.71% U-235 and 0.01% U-234. Can be used as fuel in heavy water-moderated nuclear reactors.
NEA / IAEA (uranium resources) classification scheme	The OECD Nuclear Energy Agency (OECD-NEA) and the International Atomic Energy Agency (IAEA) classification scheme for uranium resources. The scheme has been adopted internationally and divides resource estimates into categories that reflect the level of confidence in the quantities of recoverable uranium against the cost of production. Resources are divided into two major classifications of Identified and Undiscovered resources. Identified Resources are further classified into Reasonably Assured Resources (RAR) and Inferred Resources (IR). The cost categories are defined as <US$40/kgU, <US$80/kgU, and <US$130/kgU. Resource estimates in this classification scheme are expressed in terms of tonnes of recoverable uranium (rather than uranium oxide) after losses due to mining and milling have been deducted. These categories are broadly equivalent to the national classification scheme used by Geoscience Australia. For example, RAR recoverable at less than US$40/kg U is equivalent to Economic Demonstrated Resources (EDR) in the Australian classification scheme. The OECD-NEA and IAEA resource estimates are published biennially in *Uranium Resources, Production and Demand*, which is commonly known as the ‘Red Book’.
Net U_3O_8	U_3O_8 contained in the UOC or uranium peroxide.
Nuclear weapon state(s) (NWS)	The five states recognised by the *Treaty on the Non-Proliferation of Nuclear Weapons* as having nuclear weapons at 1 January 1967 when the Treaty was negotiated, namely the United States, Russia, the United Kingdom, France and China.
Nuclide	Nuclear species characterised by the number of protons (atomic number) and the number of neutrons. The total number of protons and neutrons is called the mass number of the nuclide.
Nuclear (or uranium) fuel cycle	The sequence of processes, from uranium mining through to the final disposal of waste materials, associated with the production of electricity from nuclear reactions. There are two common types of fuel cycle: closed and open (or once-through) fuel cycles. The main stages in the closed fuel cycle are: mining and milling of uranium ore; conversion and enrichment of uranium; fuel fabrication; fission in a reactor for the generation of power, or production of radioisotopes (for medical, industrial or research purposes); reprocessing of the used fuel elements; and disposal and storage of wastes. The open fuel cycle excludes reprocessing.
Nuclear power reactor	A nuclear reactor produces and controls the release of energy from splitting (fissioning) the atoms of certain elements (e.g. uranium-235). The energy released is used as heat to make steam to generate electricity. The principles for using nuclear power to produce electricity are the same for most types of reactor. The energy released from continuous fission of the atoms of the fuel is harnessed as heat in either a gas or water, and is used to produce steam. The steam is used to drive the turbines which produce electricity (as in most fossil fuel plants). Several generations of nuclear reactors are commonly distinguished: Generation I reactors were developed in the 1950–60s and, outside the UK, none are still operating today; Generation II reactors are typified by the

	present US fleet and most elsewhere; Generation III (and III+) designs are known as ‘Advanced Reactors’ and are now being deployed, with the first in operation in Japan since 1996 and once each currently being built in France and Finland. Six Generation IV reactor technologies are currently being developed, with some at an advanced stage. Prior to being deployed, reactor designs must be licensed (along with the siting, construction, operations and decommissioning of each reactor) by the relevant regulatory authority (e.g. the Nuclear Regulatory Commission in the United States).
Ore	Any metalliferous mineral from which the metal may be profitably extracted. An orebody is soil or rock containing minerals of economic value.
Ore Reserve	Category from the JORC Code. An ‘Ore Reserve’ is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified. Ore Reserves are sub-divided in order of increasing confidence into Probable Ore Reserves and Proved Ore Reserves.
Overburden	Useless soil and rock which overlies a bed of useful material.
Palaeochannel	Ancient river or stream channels that have been preserved in sedimentary rocks.
pH	A measure of hydrogen ions in solution; it indicates acidity (pH 1 to 7) or alkalinity (pH 8 to 14) of an aqueous solution.
Plutonium (Pu)	A heavy, fissionable, radioactive metallic element with atomic number 94. Plutonium is not naturally occurring, but is produced as a by-product of the fission reaction in a uranium fuelled nuclear reactor and is recovered from irradiated fuel. It is used in preparing commercial nuclear fuel and in manufacturing nuclear weapons.
Radiation	The emission and propagation of energy by means of electromagnetic waves or particles.
Radiation dose	A measure of the amount of radiation absorbed by the body and the damage this radiation causes the person. This is determined by the type and energy of the radiation (alpha, beta, gamma), and the exposure scenario. Units of dose are measured in Sieverts (Sv).
Radioactivity	The spontaneous decay of an unstable atomic nucleus giving rise to the emission of radiation.
Reasonably Assured Resources (RAR)	Category from the NEA / IAEA uranium resource classification scheme which refers to uranium that occurs in known mineral deposits of delineated size, grade and configuration such that the quantities which could be recovered within the given production cost ranges with currently proven mining and processing technology, can be specified.
Reprocessing	The chemical separation of uranium and plutonium from used fuel. It allows the recycling of valuable fuel material and minimises the volume of high level waste material.
Separative Work Unit (SWU)	The capacity of an enrichment plants is measured in terms of ‘separative work units’ or SWU. The SWU is a function of the amount of uranium processed and the degree to which it is enriched (i.e. the extent of increase in the concentration of the U-235 isotope relative to the remainder) and the level of depletion of the remainder. About 100-120 000 SWU is required to enrich the annual fuel loading for a typical 1 000 MWe light water reactor.
Sievert (Sv)	Unit indicating the biological damage caused by radiation. One Joule of beta or gamma radiation absorbed per kilogram of tissue has 1 Sv of biological effect; 1 J/kg of alpha radiation has 20 Sv effect and 1 J/kg of neutrons has 10 Sv effect.
Tails (or	The relatively depleted fissile uranium (U-235) which is the waste stream

enrichment tails)	from the uranium enrichment process.
Tailings	The remaining portion of a metal-bearing ore consisting of finely ground rock and process liquids after some or all of the metal, such as uranium, has been extracted.
Tailings dam	Facility where tailings / mill residues are stored after treatment.
Transuranics	Very heavy elements formed artificially by neutron capture and possibly subsequent beta decay(s). Has a higher atomic number than uranium (92). All are radioactive. Neptunium, plutonium, americium and curium are the best-known.
Uranium deposit	A mass of naturally occurring mineral from which uranium could be exploited at present or in the future.
Uranium oxide concentrate (UOC)	The mixture of uranium oxides produced after milling uranium ore from a mine. UOC is khaki in colour and is usually represented by the empirical formula U_3O_8. Uranium is sold in this form (or as hydrated uranium peroxide, $UO_4.2H_2O$, which is the product of in-situ leach uranium mining). The concentrate usually contains some impurities such as sulphur, silicon and zircon. The quantity of U_3O_8 equivalent is determined by assay after drumming of the concentrate. UOC is sometimes loosely, but mistakenly, referred to as ‘yellowcake’ .
U-233 (or U^{233})	Isotope 233 of uranium, produced through neutron irradiation of thorium-232.
U-235 (or U^{235})	Isotope 235 of uranium (occurs as 0.711% of natural uranium, comprising 92 protons and 143 neutrons.
U-238 (or U^{238})	Isotope 238 of uranium (occurs as about 99.3% of natural uranium), comprising 92 protons and 146 neutrons.
UF_6	Uranium hexafluoride, a gaseous compound of uranium and fluorine used as feedstock for most enrichment processes.
UO_2	Uranium dioxide, a chemical form of uranium commonly used in power reactors.
U_3O_8	Triuranium octaoxide (commonly referred to as uranium oxide), produced as a result of uranium mining and milling.
Watt (W)	International System of Units standard unit of power, which is the rate of conversion (or transfer) of energy per unit time. One watt is the equivalent of one joule per second. One kilowatt (kW) is equal to one thousand watts, one megawatt (MW) is equal to one million watts, one gigawatt (GW) is equal to one billion watts, and one terawatt (TW) is equal to one trillion watts.
Weapons of mass destruction (WMD)	Refers to nuclear, chemical, biological and occasionally radiological weapons.
Yellowcake	A name originally given to the bright yellow substance ammonium diuranate, which is the penultimate uranium compound in U_3O_8 production.

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List of recommendations

3 Australia’s uranium resources, production and exploration

Recommendation 1

The Committee recommends that the Australian Government introduce a flow-through share scheme for companies conducting eligible minerals and petroleum exploration activities in Australia.

Recommendation 2

The Committee recommends that Geoscience Australia be granted additional funding to develop and deploy new techniques, including airborne electromagnetics, to provide precompetitive geoscience of prospective areas, in order to assist in the discovery of new world-class uranium and other mineral deposits located under cover and at depth.

6 The safety of the nuclear fuel cycle

Recommendation 3

To provide greater assurance to workers and the public at large, and also to definitively answer claims—which the Committee is confident are entirely mistaken—that current radiation exposures are harming workers, the Committee recommends that the Australian Government, in conjunction with state governments and industry, establish:

- a national radiation dose register for occupationally exposed workers; and
- a system of long-term monitoring of the health outcomes for workers occupationally exposed to radiation in uranium mining, associated industries and nuclear facilities.

The Committee further recommends that the Australian Government:

- jointly fund the health monitoring program with industry; and
- periodically publish the monitoring data, indicating any link between radiation exposures and health outcomes for these workers.

7 The global non-proliferation regime

Recommendation 4

The Committee recommends that the Minister for Foreign Affairs:

- seek, through all relevant fora, to impress on other countries the central importance of the non-proliferation aspects of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and the security benefits of the NPT for all countries;
- redouble efforts to encourage adoption by other countries of an Additional Protocol to their safeguards agreements with the International Atomic Energy Agency (IAEA);
- advocate strengthening the verification regime so that the IAEA is empowered to more thoroughly investigate possible parallel weaponisation activities;
- seek the development of criteria for assessing the international acceptability of proposed sensitive projects, particularly in regions of tension, and advocate the development of a more rigorous verification regime for countries that either possess or choose to develop sensitive facilities;
- support proposals for nuclear fuel supply guarantees for those countries who waive the right to develop enrichment and reprocessing technologies; and
- come to a considered view about the adequacy of the resources currently allocated to the IAEA’s safeguards program and, if deemed necessary, advocate within the IAEA Board of Governors for an increased allocation of resources to verification activities and recommend increased contributions from member states.

10 Uranium industry regulation and impacts on Aboriginal communities

Recommendation 5

The Committee recommends that the Australian Government provide adequate funding to ensure the rehabilitation of former uranium mine sites, and for towns and similar facilities, rehabilitation to meet the expectations of the local community.

Recommendation 6

The Committee recommends that the Australian Government examine expanding the role performed by the Office of Supervising Scientist (OSS) in relation to the monitoring and approvals for uranium mines. As an example, the OSS could be given a formal role in advising the Minister for the Environment and Heritage in relation to all uranium mine assessments and approvals under the *Environment Protection and Biodiversity Conservation Act* and the Minister for Industry, Tourism and Resources in relation to the conditions for granting uranium export licenses.

Given the proposed expanded role for the OSS, the Committee further recommends that the Environmental Research Institute of the Supervising Scientist (ERISS) be provided with additional resources, potentially in partnership with a suitable university, so as to provide a national research function. The OSS should continue to be able to refer matters to ERISS for research, but ERISS's autonomy should be preserved in terms of the conduct of research and the release of its findings.

Recommendation 7

The Committee recommends that the Australian Government work with industry, Indigenous groups and state/territory governments to develop strategies to improve Indigenous training and employment outcomes at uranium mines, with consideration given to studying and, if possible, emulating the strategies employed by Cameco Corporation and governments in Canada. The Committee further recommends that, where appropriate, mining companies consider employing Aboriginal liaison officers with direct access to management.

To ensure adequate local community consultation, the Committee further recommends that a process be established whereby it and its successor committees be formally given access to new uranium mine sites, with customary powers of inquiry and report to the Parliament. This process should formally provide for affected local governments to nominate a person to liaise with the Committee about any community concerns.

11 Impediments to the uranium industry's development

Recommendation 8

The Committee recommends that the Australian Government Minister for Industry, Tourism and Resources, through the Council of Australian Governments and other means, encourage state governments to reconsider their opposition to uranium mining and abolish legislative restrictions on uranium (and thorium) mining and exploration, where these exist.

Recommendation 9

The Committee recommends that the Australian Government, through the Council of Australian Governments, seek to remedy the impediments to the development of the uranium industry identified in this report and, specifically:

- develop uniform and minimum effective regulation for uranium exploration and mining across all states and territories;
- ensure that processes associated with issues including land access, Native

Title, assessment and approvals, and reporting are streamlined;

- where possible, minimise duplication of regulation across levels of government;
- address labour shortages, training and skills deficits relevant to the industry; and
- address transportation impediments, and particularly issues associated with denial of shipping services.

Recommendation 10

The Committee recommends that the Australian Government, through the Council of Australian Governments, examine incident reporting requirements imposed on uranium mining companies with a view to aiding public understanding of the real impacts of incidents that may occur at uranium mines. Specifically, the Committee recommends that companies continue to meet existing reporting thresholds, but that regulators be required to issue a brief assessment of each incident informing the public of the gravity of the incident and its likely impacts on the environment and human health. To this end, a simple and accurate incident impact classification system could be devised.

Recommendation 11

The Committee recommends that the Australian Government:

- identify and fund an authoritative scientific organisation to prepare and publish objective information relating to uranium mining, the nuclear fuel cycle and nuclear power, including radiation hazards and radioactive waste management;
- support the scientific organisation identified above to develop a communication strategy to provide information to the public, media and political leaders to address concerns these groups may have in relation to uranium mining, uranium exports and nuclear power;
- seek to rectify any inaccuracies or lack of balance in school and university curricula pertaining to uranium mining and nuclear power;
- encourage industry bodies, including state chambers of mines, to conduct or augment programs to educate teachers, media and political leaders about the uranium industry;
- encourage companies to conduct programs of visits to uranium mines for teachers, school groups, media representatives and political leaders; and
- encourage industry to be forthright in engaging in public debate, where this may assist in providing a more balanced perspective on the industry and its impacts.

12 Value adding — fuel cycle services industries, nuclear power, skills and training in Australia

Recommendation 12

The Committee recommends that the Australian and state governments, through the Council of Australian Governments:

- examine how Australia might seek greater beneficiation of its uranium resources prior to export and encourage such a development, while meeting non-proliferation objectives proposed in initiatives such as the US Global Nuclear Energy Partnership (GNEP) and the International Atomic Energy Agency's (IAEA) proposed multilateral approaches to the nuclear fuel cycle;

- examine the possible establishment of fuel cycle facilities (for example, uranium conversion and enrichment plants) which, in accordance with the IAEA's recommendation for such facilities to be operated on a multilateral basis, could be operated on a joint ownership, co-management or drawing rights basis with countries in the region intending to use nuclear energy in the future;
- examine whether, in light of the advances in spent fuel management proposed in the GNEP initiative, there is in fact a potential role for Australia in the back-end of the fuel cycle;
- in the event these proposals are adopted, develop a licensing and regulatory framework, that meets world's best practice, to provide for the possible establishment of fuel cycle services industries and facilities in Australia; and
- having established an appropriate regulatory regime, remove legislative impediments to the establishment of nuclear fuel cycle facilities in Australia and, specifically, repeal or amend:

    Section 140A of the *Environment Protection and Biodiversity Conservation Act 1999*, and

    Section 10 of the *Australian Radiation Protection and Nuclear Safety Act 1998.*

The Committee further recommends that such examination take account of full life cycle costs and benefits of the proposed facilities.

Recommendation 13

The Committee recommends that the Australian Government take steps to rebuild Australia's nuclear skills base and expertise by:

- broadening the Australian Nuclear Science and Technology Organisation's (ANSTO) research and development mandate, so that it is able to undertake physical laboratory studies of aspects of the nuclear fuel cycle and nuclear energy that may be of future benefit to Australia and Australian industry;
- developing a program whereby Australian nuclear scientists and engineers are assisted to study at overseas universities and/or to be placed with companies where relevant expertise resides, in order to expand Australia's knowledge base;
- increasing engagement by Australian nuclear scientists and engineers at a technical level with the International Atomic Energy Agency, for example through a program of secondments and placements;
- examining the possibility of re-establishing at least one Australian University School of Nuclear Engineering and an Australian Research Council Research Network or Centre(s) of Excellence in the relevant fields;
- encouraging industry to increase its collaborations with and support of ANSTO's proposed expanded research activities and any school of nuclear engineering that may be established; and
- encouraging greater university research into aspects of nuclear energy and the nuclear fuel cycle through the allocation of research grants awarded by the

Australian Institute of Nuclear Science and Engineering.

Recommendation 14

The Committee recommends that the Australian Government:

- negotiate an appropriate subscription for Australia to the International Thermonuclear Experimental Reactor project on a whole-of-Government basis;
- support the establishment of a national research centre to consolidate and coordinate Australia's efforts in fusion related research; and
- examine the merits of establishing fusion science as a national research priority.

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Executive summary

Introduction

The terms of reference for the case study were to inquire into and report on the strategic importance of Australia's uranium resources. The Committee was asked to give particular attention to the: global demand for Australia's uranium resources and associated supply issues; potential implications for global greenhouse emission reductions from the further development and export of Australia's uranium resources; and the current regulatory environment of the uranium mining sector.

The Committee indicated in its letters inviting submissions that it would also welcome comments in relation to six additional issues, relating to: whole of life cycle waste management; adequacy of social impact assessment, consultation and approval processes with traditional owners; health risks to workers and to the public from exposure to radiation; adequacy of regulation of uranium mining by the Commonwealth; the extent of federal subsidies and other mechanisms to facilitate uranium mining; and the effectiveness of safeguards regimes in addressing proliferation.

These matters are addressed in the Committee's report, which consists of 12 chapters. The contents, findings and recommendations of each chapter are summarised as follows.

The Committee's conclusions and recommendations are also summarised in a *key messages* section at the beginning of each chapter and in the *conclusions* section at the end of each chapter.

Chapter one: Introduction

The chapter outlines the referral of the inquiry to the Committee, the conduct of the inquiry, and the structure of the report and its principal findings.

Chapter two: Uranium: Demand and Supply

The Committee commences the report by considering the global demand and supply of uranium in the context of world electricity consumption trends and nuclear power's share in the electricity generation mix. The Committee provides a summary of forecasts for world nuclear generating capacity and associated uranium requirements. Competing views on the outlook for new nuclear power plant construction are then considered, followed by an assessment of the role of existing plant performance in influencing the demand for uranium.

The chapter commences with an overview of the nuclear fuel cycle, which establishes a context for the discussion in subsequent chapters of matters including greenhouse gas emissions, waste, safety and proliferation risks associated with nuclear power generation.

Demand for uranium is a function of nuclear generating capacity in operation worldwide, combined with the operational characteristics of reactors and fuel management policies of utilities.

There are currently 441 commercial nuclear power reactors operating in 31 countries. In 2005, nuclear reactors generated 2 626 billion kilowatt-hours of electricity, representing approximately 16 per cent of world electricity production. Some 27 nuclear reactors are currently under construction and a further 38 are planned or on order worldwide.

Expectations of increased world nuclear generating capacity and demand for uranium are underpinned by:

- forecasts for growth in world electricity demand, particularly in China and India;
- improved performance of existing nuclear power plants and operating life extensions;
- plans for significant new nuclear build in several countries and renewed interest in nuclear energy among some industrialised nations; and
- the desire for security of fuel supplies and heightened concerns about greenhouse gas emissions from the electricity sector.

New reactor construction combined with capacity upgrades and life extensions of existing reactors are projected to outweigh reactor shutdowns over the next two decades, so that world nuclear capacity will continue to increase and thereby increase projected uranium requirements.

Several forecasts for world nuclear generating capacity and uranium requirements have been published. A conservative forecast by the International Atomic Energy Agency (IAEA) and OECD Nuclear Energy Agency (OECD-NEA) predicts that nuclear generating capacity will grow to 448 gigawatts electrical by 2025, representing a 22 per cent increase on current capacity. This would see annual uranium requirements rise to 82 275 tonnes by 2025, also representing a 22 per cent increase on the 2004 requirements of 67 430 tonnes.

Uranium mine production currently meets only 65 per cent of world reactor requirements. The balance of requirements are met by secondary sources of supply, notably inventories held by utilities and ex-military material. Secondary supplies are expected to decline over coming years and the anticipated tightness in supply has been reflected in a seven-fold increase in the uranium spot market price since December 2000.

The Committee concludes that new nuclear build combined with improved reactor performance and operating life extensions are likely to outweigh reactor retirements in the years ahead, thereby increasing projected uranium requirements. Importantly, secondary supplies are also declining, leading to an increased requirement for uranium mine production. The dramatic increases in the uranium spot price are stimulating new uranium exploration activity.

The Committee notes that Australia possesses some 36 per cent of the world’s Reasonably Assured Resources of uranium recoverable at low cost. However, Australia only accounts for 23 per cent of world production and lags behind Canada (which has less than half Australia’s resources in this category). The Committee concludes that provided the impediments to the industry’s growth are eliminated, there is great potential for Australia to expand production and become the world’s premier supplier of uranium.

Notwithstanding the current tightness in the uranium market, the Committee notes that sufficient uranium resources exist and are likely to be discovered to support significant growth in nuclear capacity in the longer-term.

Chapter three: Australia ’s uranium resources, production and exploration

The chapter provides a detailed overview of Australia’s uranium resources, mine production and exploration for uranium.

The Committee notes that Australia possesses 38 per cent of the world’s total Identified

Resources of uranium, recoverable at low cost (less than US$40 per kilogram). According to company reports, Australia’s known uranium deposits currently contain a total of over 2 million tonnes of uranium oxide in in-ground resources. The in-situ value of this resource at spot market prices prevailing in June 2006 was over A$270 billion.

Some 75 per cent of Australia’s total Identified Resources of uranium are located in South Australia, but significant deposits are also located in the Northern Territory, Western Australia and Queensland.

Seven of the world’s 20 largest uranium deposits are in Australia—Olympic Dam (SA), Jabiluka (NT), Ranger (NT), Yeelirrie (WA), Valhalla (Queensland), Kintyre (WA) and Beverley (SA).

In addition to its uranium resources, Australia also possesses the world’s largest quantity of economically recoverable thorium resources—300 000 tonnes—more than Canada and the US combined. Like uranium, thorium can be used as a nuclear fuel, although the thorium fuel cycle is not yet commercialised.

In 2005, Australia achieved record national production of 11 222 tonnes of uranium oxide from three operational mines—Ranger, Olympic Dam and Beverley. Beverley is the world’s largest uranium mine employing the in-situ leach (ISL) mining method and a fourth uranium mine (also employing the ISL method), Honeymoon, is anticipated to commence production during 2008.

A proposal to expand Olympic Dam would see uranium production from the mine treble to 15 000 tonnes of uranium oxide per year, which would make Olympic Dam and its owners, BHP Billiton, by far the world’s largest producer. The expanded mine would account for more than 20 per cent of world uranium mine production and Australia would become the world’s largest supplier of uranium with a doubling of national production.

Australia exported a record 12 360 tonnes of uranium oxide in 2005. This quantity of uranium was sufficient for the annual fuel requirements of more than 50 reactors (each of 1 000 megawatt electrical capacity), producing some 380 terawatt-hours of electricity in total—some one and a half times Australia’s total electricity production. The value of uranium exports reached a record high of $573 million in 2005. The outlook for further increases in production and export earnings is positive.

The increase in uranium price and the anticipated decline in secondary supplies have stimulated a resurgence in exploration activity and expenditure in Australia. In 2005, total exploration expenditure for uranium was $41.09 million, which was almost a three-fold increase on 2004 expenditure.

While there has been a trend of increasing exploration expenditure since early 2003, there has been relatively little exploration for uranium over the past two decades and Australia’s known uranium resources generally reflect exploration efforts that took place 30 years ago. The size of Australia’s known uranium resources significantly understates the potential resource base and there is great potential for new and significant discoveries.

In its previous report, which addressed impediments to exploration, the Committee accepted that future world-class uranium deposits are likely to be located at greater depths than those hitherto discovered. It was concluded that this will require large injections of exploration investment capital to overcome the technical challenges of locating bedrock deposits. These observations reinforce the need to ensure that juniors, which are generally efficient explorers, are appropriately assisted to discover Australia’s future world-class uranium and other mineral deposits. The Committee is convinced of the merits of flow-through share schemes and repeats the recommendation contained in its previous report **[Recommendation 1]**.

To assist in the discovery of new world-class uranium deposits the Committee recommends that Geoscience Australia be provided with additional funding to develop and deploy techniques to provide precompetitive geoscience of prospective areas, in order to assist in the discovery of new world-class uranium and other mineral deposits located under cover and at depth **[Recommendation 2]**.

Chapter four: Greenhouse gas emissions and nuclear power

The chapter addresses the greenhouse gas emissions avoided by the use of nuclear power, emissions across the whole nuclear fuel cycle, the contribution from renewable energy sources, and the relative economic attractiveness of nuclear power for baseload power generation.

The Committee notes that electricity generation is the largest and fastest growing contributor to global carbon dioxide (CO_2) emissions, responsible for 40 per cent of global emissions in 2003—10 billion tonnes of CO_2. Emissions from electricity are projected to contribute approximately 50 per cent of the increase in global CO_2 emissions to 2030.

The Committee concludes that nuclear power unquestionably makes a significant contribution to the mitigation of greenhouse gas (GHG) emissions—nuclear power plants currently save some 10 per cent of total CO_2 emissions from world energy use. This represents an immense saving of GHG emissions that would otherwise be contributing to global warming. If the world were not using nuclear power plants, emissions of CO_2 would be some 2.5 billion tonnes higher per year.

Australia’s uranium exports displace some 395 million tonnes of CO_2 each year, relative to black coal generation, and this represents some 70 per cent of Australia’s total GHG emissions for 2003. Evidence suggested that the cumulative carbon savings from nuclear power over the three decades to 2030 will exceed 25 billion tonnes.

In addition to its GHG mitigation benefits, nuclear power also offsets the vast emissions of sulphur dioxide, nitrous oxide and particulates which are produced by fossil fuelled plants.

The Committee notes the support shown for nuclear power by several foundational figures of the environment movement. These individuals now perceive that the risks associated with the expanded use of nuclear power are insignificant in comparison to the threat posed by the enhanced greenhouse effect and global warming. The Committee also notes calls by some in industry that, in view of the energy demands from heavily populated developing nations, Australia in fact has a moral responsibility to contribute to reducing global GHG emissions through the increased production and supply of uranium.

It was claimed that nuclear power will not solve climate change because it only reduces emissions from the electricity sector, which is only one source of anthropogenic GHG emissions. The Committee notes, however, that no representative of the uranium industry ever claimed that nuclear power alone could ‘solve’ climate change. In fact, it was repeatedly stated that nuclear power is one—albeit significant—part of the solution to global warming.

Although nuclear power has the potential to reduce emissions in the transport sector through the production of hydrogen, nuclear’s greenhouse mitigation contribution is currently limited to the electricity sector. However, electricity generation, which is already the largest contributor of CO_2 emissions at 40 per cent of the global total, is also the fastest growing. It is imperative that emissions from this sector be reduced.

The Committee finds that over its whole fuel cycle nuclear power emits very small quantities of CO_2 (2–6 grams of carbon per kilowatt-hour of electricity produced). This is two orders of magnitude less than coal, oil and natural gas, and is comparable to emissions from wind and solar power.

Evidence suggested that renewables and energy efficiency measures *alone* have no prospect of meeting rapidly growing demands for energy and abating greenhouse emissions to the degree required. The weight of evidence points to the need for a mix of low-emission energy sources and technologies, in which nuclear power will continue to play a significant part.

In the context of rapidly growing energy demand, particularly from developing nations, nuclear power represents the only means of limiting increased emissions while meeting the world’s voracious appetite for energy. While the Committee recognises that there is a role for renewables, and certainly for greater use of efficiency measures, renewables are limited in their application by being intermittent, diffuse and pose significant energy storage problems. Renewables also require substantial backup generation, which needs to be provided by conventional baseload power sources. Promised baseload contributions from geothermal, which will be welcome, are yet to be developed on any scale.

The Committee believes that the ‘nuclear versus renewables’ dichotomy, which was explicit in some submissions, is a false debate and misses the point: while renewables have a contribution to make, other than hydro and (potentially) geothermal, they are simply not capable of providing baseload power on a large scale. The relevant comparison, if one needs to be made, is between baseload alternatives. On this issue the evidence is clear—nuclear power is the only proven technology for baseload power supply which does not release substantial amounts of CO_2.

The Committee also recognises that given its comparative advantage in fossil fuels and the world’s projected continued reliance on fossil fuels, Australia has a strong economic interest in supporting technologies that reduce the greenhouse intensity of these fuels. The Committee agrees that nuclear power should not be seen as competing with or substituting for clean coal technologies, and indeed renewables such as photovoltaics in which Australia has expertise.

A vital consideration in assessing nuclear power’s viability as a GHG emission mitigation option relates to the economic competitiveness of nuclear power relative to other baseload alternatives. Evidence suggests that nuclear power plants have higher capital/construction costs than either coal or gas plants, which are characterised by mid-range and low capital costs respectively. However, nuclear plants have low fuel, operating and maintenance costs relative to the fossil fuel alternatives.

A range of recent studies have concluded that, in many industrialised countries, nuclear power is competitive with gas and coal-fired electricity generation, even without incorporating an additional cost for the carbon emissions from the fossil fuelled plants. Factors that influence the suitability of deploying nuclear plants in a particular situation include the projected prices of natural gas and coal, the discount rate employed, proximity and access to fuel sources such as low cost fossil fuels, and the quality of fuel sources.

Although nuclear plants generally have higher capital costs, the Committee notes there are developments which promise to reduce the construction costs and construction times for new plants, including possible regulatory reforms in the US and new plant designs. It seems clear that replicating several reactors of one design, or standardising reactors, reduces levelised generating costs considerably.

Although again the Committee does not wish to enter into a nuclear versus renewables debate, evidence suggests that renewables, particularly wind, have consistently higher generating costs than nuclear plants. These costs are even higher if the necessity for standby generation is included.

The Committee concludes that, in addition to security of energy supply and near-zero GHG emissions, nuclear power offers at least three economic advantages relative to other baseload energy sources: price stability, very low operating costs and internalisation of costs that are not incorporated in the cost of other sources of electricity, notably waste management.

Chapter five: Radioactive waste

The chapter addresses the management of radioactive waste generated across the nuclear fuel cycle, from uranium mining to the decommissioning of nuclear power plants. This is the first of three issues which critics of uranium mining and nuclear power claim are fatal for the civil nuclear power industry. The other two issues relate to safety and proliferation, which are addressed in the following three chapters.

While some radioactive waste is produced at each stage of the nuclear fuel cycle, the volumes of high level waste (HLW) are extremely small, contained and have hitherto been safely managed.

The Committee finds that HLW has several features which lends itself to ease of management: very small volumes; the radioactivity is contained in the spent fuel assemblies; it decays at a predictable rate; and is amenable to separation, encapsulation and isolation. Moreover, the nuclear power industry significantly contributes to the cost of its waste management through levies imposed on utilities. That is, the cost of managing radioactive waste is internalised in the price of the electricity generated.

In short, nuclear power deals with its waste more explicitly and transparently than many other sources of energy.

The generation of electricity from a typical 1 000 megawatt (MWe) nuclear power station, which would supply the needs of a city the size of Amsterdam, produces approximately 25–30 tonnes of spent fuel each year. This equates to only three cubic metres of vitrified waste if the spent fuel is reprocessed. By way of comparison, a 1 000 MWe coal-fired power station produces some 300 000 tonnes of ash alone per year.

HLW is accumulating at 12 000 tonnes per year worldwide. The International Atomic Energy Agency (IAEA) states that this volume of spent fuel, produced by all of the world’s nuclear reactors in a year, would fit into a structure the size of a soccer field and 1.5 metres high—even without any being reprocessed for re-use. This contrasts with the 25 billion tonnes of carbon waste released directly into the atmosphere each year from the use of fossil fuels.

To date, there has been no practical need and no urgency for the construction of HLW repositories. This has been due to the small volumes of waste involved and the benefit of allowing interim storage for up to several decades to allow radioactivity to diminish so as to make handling the spent fuel easier.

There is an international scientific consensus that disposal in geologic repositories can safely and securely store HLW for the periods of time required for the long-lived waste to decay to background levels.

While plans for geologic repositories are now well advanced in several countries, finding sites for repositories has been problematic. This has been due in large part to a lack of public acceptance. ‘Not in my backyard’ arguments about the siting of repositories have been fuelled by misperceptions of the level of risk involved in radioactive waste management and the operation of repositories. However, some countries, notably Finland and Sweden, have managed this process successfully and with a high degree of public involvement and support.

Transport of radioactive waste is undertaken safely and securely—in sharp contrast to other energy industries. Since 1971, there have been more than 20 000 shipments of spent fuel and HLW over more than 30 million kilometres. There has never been any accident in which a container with highly radioactive material has been breached or leaked. In contrast, in OECD countries over the past 30 years more than 2 000 people have been killed in accidents involving the transport of LPG.

Advanced nuclear reactors and spent fuel reprocessing technologies are now being developed which will significantly reduce the quantity and toxicity of nuclear waste, potentially reducing the required isolation period to just a few hundred years and further reducing the disposal/storage space required. These technological advances could potentially obviate the need for geologic repositories altogether.

Nuclear power utilities are charged levies to provide funds for the management of the industry’s waste and for the eventual decommissioning of plants. In the US, the Nuclear Waste Fund now amounts to over US$28 billion, while more than US$23 billion has been set aside for decommissioning. These costs are factored into the cost of the electricity generated and the prices paid by consumers.

In contrast, wastes from fossil fuel power are not contained or managed, involve enormous volumes and a range of toxic pollutants that do not decay. Moreover, the cost of the environmental externalities these energy sources create are generally not factored into the price of the electricity produced.

The Committee concludes that claims that the generation of radioactive waste, its management and transportation pose unacceptable risks simply do not reflect the realities. Some submitters misperceive the risks involved and either misunderstand or ignore the historical record. The facts indicate that the radioactive wastes generated at the various stages of the nuclear fuel cycle continue to be safely and effectively managed. Indeed, the way in which the nuclear power industry manages its waste is an example for other energy industries to follow.

Chapter six: The safety of the nuclear fuel cycle

The chapter examines the second key concern raised in opposition to the civil nuclear power industry—the safety of nuclear fuel cycle facilities, and particularly the health risks to workers and to the public from exposure to radiation from uranium mining and nuclear power plants.

The Committee concludes that nuclear power, like all other major energy industries, is not and nor could it ever be entirely risk free. However, notwithstanding the Chernobyl accident, which has been the only accident to a commercial nuclear power plant that has resulted in loss of life in over 50 years of civil nuclear power generation (over 12 000 cumulative reactor years of commercial operation in 32 countries), nuclear power’s safety record surpasses that of all other major energy industries.

While the Chernobyl accident could lead, over the lifetime of the most exposed populations, to several thousand excess cancer deaths, other energy sources are responsible for killing thousands of workers and members of the public every year. For example, in addition to catastrophic events (e.g. 3 000 immediate fatalities in an oil transport accident in 1987 and 2 500 immediate fatalities in a hydro accident in 1979), more than 6 000 coal miners die each year in China alone. Evidence suggests that coal mining worldwide causes the deaths of 12 000 to 15 000 miners each year. Even in Australia , 112 coal miners have died in NSW mines alone since 1979.

Moreover, the numbers of fatalities cited do not include the deaths and other health impacts likely to be caused by the release of toxic gases and particulates from burning fossil fuels. Neither do these considerations consider the possible health impacts and other risks associated with climate change arising from fossil fuel use.

In any case, the Committee notes that the multi UN agency Chernobyl Forum report found that the most pressing health problem for areas most affected by the Chernobyl accident is *not* radiation exposure but poor life style factors associated with alcohol and tobacco use, as well as poverty. The largest public health problem has been the mental health impact of the accident. The Forum concluded that persistent ‘misconceptions and myths’ about the threat of radiation have promoted a ‘paralysing fatalism’ among residents.

The Chernobyl accident resulted from a flawed Soviet reactor design which would never have been certified for operation under regulatory regimes of western nations. The reactor was operated with inadequately trained personnel and without proper regard for safety. In addition, the Chernobyl plant did not have a containment structure common to most nuclear plants elsewhere in the world.

In terms of the health hazards from the routine operations of nuclear fuel cycle facilities, evidence suggests that occupational radiation exposures are low. In fact, the average annual effective radiation dose to monitored nuclear industry workers is less than the exposure of air crew in civil aviation, and is also less than the radon exposure in some above-ground workplaces.

Globally, exposure by the general public to radiation from the whole fuel cycle is negligible. The average annual natural background radiation exposure is 2.4 millisieverts (mSv). In comparison, the average dose received by the public from nuclear power production is 0.0002 mSv and, hence, corresponds to less than one ten thousandth the total yearly dose received from natural background.

Radiation exposure for workers at Australian uranium mines is well below (less than half) the prescribed average annual limit for workers of 20 mSv. The radiation exposure for the public in the vicinity of the mines is also far below the prescribed level of 1 mSv for members of the public. Indeed, at Beverley in South Australia, the nearest members of the public received a dose less than one hundredth the prescribed limit in 2005.

The Committee acknowledges there have been incidents at the Ranger mine in the Northern Territory, for which the mining company has been prosecuted. This is evidence of a willingness by regulators to pursue the company where necessary, contrary to the claims by the industry’s opponents. The Committee notes that the company itself acknowledges that its performance in 2004 was not adequate and has taken steps to improve. The Australian Government is satisfied that the company has met the conditions required of it.

The Committee is persuaded that uranium industry workers in Australia are not being exposed to unsafe doses of radiation. However, to provide greater assurance to workers and the public at large, and also to definitively answer claims—which the Committee is confident are entirely mistaken—that current radiation exposures are harming workers, the Committee recommends the establishment of:

a national radiation dose register for selected occupationally exposed workers; and

a system of long-term monitoring of the health outcomes for workers occupationally exposed to radiation in uranium mining, associated industries and nuclear facilities **[Recommendation 3]**.

In the Committee’s view, some critics of uranium mining and nuclear power misconceive or exaggerate the health risks from the industry’s operations, for example, by wildly inaccurate assessments of the deaths attributable to the routine operations of the industry and dismissing the Chernobyl Forum as a ‘whitewash’. Such views have however influenced wider public opinion and public policy in a way detrimental to the industry, and have reduced the potential community and global benefits from use of nuclear power.

The Committee concludes that there is a clear need for improved public understanding of the nature of radiation and the effects of the actual exposures to the public from the nuclear industry’s operations.

Chapter seven: The global non-proliferation regime

In this and the following chapter the Committee addresses the third objection to the use of nuclear power—nuclear proliferation and the effectiveness of safeguards regimes.

Chapter seven first introduces the concept of proliferation and explains how some technologies required in the civil nuclear fuel cycle also have military uses. The Committee describes the current global non-proliferation regime, the key elements of which are the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and the safeguards activities of the IAEA.

While submitters acknowledged that improvements have been made to IAEA safeguards in recent years, it was argued that a number of deficiencies remain. These alleged deficiencies and a response to each claim from the Australian Safeguards and Non-Proliferation Office (ASNO) are summarised in turn. Finally, the chapter presents an overview of measures recently proposed to address perceived vulnerabilities in the non-proliferation regime.

The Committee concludes that the global safeguards regime has indeed been remarkably successful in limiting the proliferation of nuclear weapons. Today, in addition to the five nuclear-armed states that existed prior to the NPT’s entry into force in 1970, there are only four states that have or are believed to have nuclear weapons: the three non-NPT parties—Israel, India and Pakistan—and North Korea. This is clearly a tremendous achievement, particularly in light of predictions that by the end of the 20 th century there would be some 25 to 30 nuclear armed states.

In response to the discovery of a clandestine weapons program in Iraq, which had a comprehensive safeguards agreement in force with the IAEA at the time, a range of safeguards strengthening measures have now been introduced. These measures enable the IAEA to draw conclusions about the absence of *undeclared* nuclear materials and activities in countries, in addition to the assurance provided under traditional safeguards about the non-diversion of *declared* nuclear material and activities. The Committee considers that these measures are clearly a great advance.

Central to the safeguards strengthening measures has been the adoption by states of an Additional Protocol (AP) to their safeguards agreements with the IAEA. APs require states to provide the IAEA with broader information, allow the IAEA wider access rights and enable it to use the most advanced verification technologies. The Committee is pleased to note the Australian Government’s strong support for the AP, its prominent role in the AP’s formulation and that Australia was the first country to sign and ratify an AP. The Committee also welcomes the Government’s decision to make the AP a condition for the supply of uranium to non-nuclear weapons states (NNWS).

However, the Committee is concerned that the uptake of APs remains slow. As of July 2006, only 77 countries had APs in force. The Committee notes with concern the IAEA Director General's comment that the Agency's verification efforts will not be judged fully effective on a global scale as long as its access rights remain uneven. The AP must become the universal standard for verifying nuclear non-proliferation commitments. The Committee urges the Australian Government to redouble its efforts to encourage adoption of APs by other countries.

Submitters alleged that there are a range of deficiencies and limitations to the NPT/IAEA safeguards regime. While the Committee believes that most of these alleged deficiencies are without substance, it notes that the non-proliferation regime is now facing several challenges. The Committee concurs with the Minister for Foreign Affairs that these challenges must be met so that the public can be confident that an expansion of nuclear power (and of uranium exports) will not represent a risk to international security.

Among these challenges is the weakening of political support for the non-proliferation regime and the problem now presented by Iran, which claims the right to develop the *full* nuclear fuel cycle, ostensibly on the grounds of security of nuclear fuel supply. This raises the possibility that, having made full use of the alleged 'right' to acquire proliferation-sensitive technologies under Article IV of the Treaty, states could then withdraw from the NPT and pursue weapons programs.

The Committee notes that the claim of a right to pursue proliferation-sensitive technologies may indeed be a serious misreading of the Treaty, which speaks of the right of all parties to use *nuclear energy* for peaceful purposes and that this was never intended to mean development of *any* nuclear technology. It is clear that when the NPT was first negotiated it was envisaged that the nuclear weapons states (NWS) would provide these fuel cycle services to the NNWS. Moreover, the Committee notes that the right to use of nuclear energy is subject to the other provisions of the Treaty, notably the corresponding duties to comply with NPT and safeguards commitments—factors that seem to have been ignored by Iran and its supporters.

Nonetheless, the Committee is pleased to note that this dilemma is receiving considerable attention and that there are a range of proposals now being considered that will increase control over proliferation-sensitive technologies and limit their spread.

The Committee recommends that the Australian Government take steps to strengthen the non-proliferation regime, including seeking through all relevant fora to impress on other countries the central importance of the non-proliferation aspects of the NPT; redoubling efforts to encourage adoption by other countries of an AP to their safeguards agreements with the IAEA; supporting proposals for nuclear fuel supply guarantees for those countries that forego developing sensitive facilities; and reviewing the adequacy of the resources allocated to the IAEA's safeguards program **[Recommendation 4]**.

While the Committee acknowledges that technical measures to prevent proliferation are unlikely to be successful in the absence of political commitment, the Committee is encouraged to note that proliferation-resistant technologies are continuing to be developed. In particular, the Committee was informed about efforts to develop a nuclear fuel cycle that does not require enrichment and currently-established reprocessing technologies (which separate out plutonium that could potentially be diverted for weapons), and the development of reactor types that incorporate proliferation resistance into their designs.

Finally, the Committee welcomes the commendable range of efforts the Australian Government is undertaking to advance non-proliferation objectives. As a major uranium exporter and, potentially, as the world's largest uranium producer, Australia has a strong interest in ensuring that the material and technologies required for peaceful use of nuclear energy are not diverted for any military purpose.

Chapter eight: Australia 's bilateral safeguards

The chapter considers the adequacy and effectiveness of Australia's safeguards policy and the bilateral safeguards agreements it enters into with countries wishing to purchase Australian uranium.

In addition to IAEA safeguards described in the previous chapter, Australia superimposes additional safeguards requirements through a network of bilateral safeguards agreements. The objectives of Australia’s safeguards policy are to ensure that Australian Obligated Nuclear Material (AONM) is: appropriately accounted for as it moves through the fuel cycle; is used only for peaceful purposes; and in no way contributes to any military purpose.

Australia’s policy also establishes criteria for the selection of countries eligible to receive AONM. The Committee notes that of the five cases where the IAEA has found countries in non-compliance with their safeguards agreements and reported the non-compliance to the UN Security Council, none of these cases involved countries eligible to use Australian uranium.

While the Committee notes that it simply cannot be absolutely guaranteed that diversion of AONM for use in weapons could never occur at some point in the future, nevertheless the Committee is satisfied that Australia’s safeguards policy has been effective to date. The Committee concludes that the requirements in safeguards agreements are adequate and can see no reason for imposing additional requirements at this time.

The Committee rejects arguments that Australia’s safeguards policy has been eroded and stripped of its potency over time. In particular, the Committee believes that the principles of equivalence and proportionality, which underlie nuclear fuel trade, simply reflect that, other than by establishing the entire nuclear fuel cycle in Australia and leasing fuel elements, it is impossible to track ‘national atoms’ once uranium from different sources is mixed together (e.g. in enrichment and fuel fabrication processes). It is for this reason that international practice is to designate an equivalent quantity as (Australian) obligated nuclear material. In this way, even if at some point AONM is co-mingled with unsafeguarded material, a proportion of the resulting material will be regarded as AONM corresponding to the same proportion of AONM initially. Thus, even if a stream of material is taken from a process for military purposes (e.g. from a conversion facility), the presence of the AONM will in no way benefit or contribute to the quantity or quality of the unobligated material. In any case, the facilities where AONM can be processed, including in the NWS, must be safeguarded and are eligible for IAEA monitoring and inspections.

The Committee notes the strong objection by some submitters to the reprocessing of spent fuel containing Australian-obligated plutonium. While the Committee agrees that the existence of stocks of separated plutonium does represent a possible proliferation danger, it notes that reprocessing used fuel has a number of important advantages that must also be considered. Specifically, reprocessing and plutonium recycling enables a far more efficient use of the uranium fuel, extending by about one third the amount of energy a country can obtain from the uranium they purchase. Furthermore, reprocessing and use of mixed oxide fuel significantly reduces the amount of waste that must be disposed of.

The Committee concludes that there is little or no potential for the diversion of AONM for use by terrorists, or for AONM and other Australian radioactive materials to be used in ‘dirty bombs’. In particular, the Committee notes that Australia’s conditions for supply of AONM include an assurance that internationally agreed standards of physical security will be applied to nuclear materials in the country concerned.

The Committee was informed of the recent strengthening, under the IAEA’s auspices, of several conventions and guidelines to protect against acts of nuclear terrorism, including significant amendments to the *Convention on the Physical Protection of Nuclear Materials* and the Code of Conduct for Safety and Security of Radioactive Sources.

The Committee is pleased to note that Australia has again been at the forefront in negotiating these outcomes, as well as contributing to nuclear security initiatives in the region, such as leading a project to ensure the security of radioactive sources.

The Committee supports the Australian Government’s decision to permit exports of uranium to China.

The Committee belives that the US-India nuclear cooperation agreement will have a number of important non-proliferation benefits, including that it will expand the application of IAEA safeguards in India and allow the IAEA enhanced access rights. However, while there are sound reasons to allow an exception to Australia’s exports policy in order to permit uranium sales to India, including its record as a non-proliferator, the Committee does not wish to make a recommendation on the matter. Maintaining the integrity of the non-proliferation regime must remain the top priority and guiding principle for Australia’s uranium exports policy and the Committee hopes that a bipartisan position on this issue can be developed.

Chapter nine: Strategic importance of Australia ’s uranium resources

In addition to its greenhouse gas emission benefits, which were discussed in chapter four, evidence presented to the Committee suggested that the strategic importance of Australia’s uranium resources also derives from the:

- significance of the resource as one of Australia’s major energy exports;
- energy security benefits that uranium can provide those countries that choose to adopt nuclear power;
- potential for Australia’s uranium exports to assist in addressing the global energy imbalance;
- economic benefits that may be obtained from uranium mining, particularly for state economies and regional communities;
- economic significance of Australia’s undeveloped uranium resources; and
- Australia’s role as a major uranium exporter in the global nuclear fuel cycle.

The chapter considers each of these points in turn.

The Committee finds that uranium is Australia’s second largest energy export in thermal terms, which is of great importance given predictions for an increase in energy demand over the coming decades, particularly in developing countries. Uranium is an immensely concentrated source of energy—one tonne of uranium oxide generates the same amount of energy as 20 000 tonnes of black coal. The uranium produced from just one of Australia’s mines each year—Ranger, in the Northern Territory—contains sufficient energy to provide for 80 per cent of Australia’s total annual electricity requirements, or all of Taiwan’s electricity needs for a year. Olympic Dam in South Australia contains uranium equivalent in energy content to 4.5 times the energy contained in the entire North-West Shelf gas field—25 billion tonnes of steaming coal.

The Committee concludes that nuclear power represents a significant means of addressing the global energy imbalance. It is an important component of the global energy mix, which can provide developing countries with access to the energy required to fuel their industrialisation and particularly their electricity requirements.

Uranium production currently generates considerable economic benefits and has the potential to make such contributions in states that currently prohibit uranium mining. In recognising the economic benefits of the industry, the Committee is conscious that failure to permit the development of the industry has corresponding costs. Such costs include loss of the industry’s current and potential contribution to the national and state economies, regional development, services and employment in Aboriginal communities, and further promotion of Australia’s role in the international nuclear community.

For example, it is estimated that the proposed expansion of Olympic Dam will increase South Australia’s Gross State Product by about $1.4 billion and the number of jobs associated with the mine will increase by about 8 400.

The Committee notes that while precise estimates of the value of undeveloped uranium resources varies, one conservative estimate suggests that the locked up uranium in Australia could earn revenues in excess of A$32 billion (at prices prevailing in November 2005). Other estimates suggest that sales of uranium from WA alone could generate revenues of $1.6 billion per year.

The Committee notes that the further expansion of the nuclear power industry worldwide will not be dependent on Australian uranium and will proceed irrespective of whether or not Australia supplies uranium. If Australia fails to supply then marginally higher cost overseas resources will be supplied to meet global demand, and these resources may not be provided to the market with the same safeguards and other regulatory requirements imposed on Australian exports. However, Australia can contribute to international energy security by being a reliable and stable supplier of uranium.

In view of the strategic importance of Australia’s uranium resources, the potential benefits from the further development of these resources, and following consideration of the alleged risks summarised in the previous four chapters, the Committee concludes that development of new uranium deposits should be permitted and encouraged.

Chapter ten: Uranium industry regulation and impacts on Aboriginal communities

The chapter examines the current structure and regulatory environment of the uranium mining sector (noting the work that has been undertaken by other inquiries and reviews on these issues), and consultation with Traditional Owners and the social impacts of uranium mining on Aboriginal communities.

While the regulation of uranium mining is principally a state and territory government responsibility, the Australian Government’s interests and responsibilities in this area include:

- environmental assessment and approval of new uranium mines and significant expansion of existing mines;
- ownership of uranium in the NT; and
- oversight of uranium mining operations in the Alligator Rivers Region (ARR) of the NT through the Supervising Scientist Division of the Department of the Environment and Heritage.

Industry is generally supportive of state and territory governments regulating uranium mining, and is confident that the current regulatory regime is sufficiently stringent. Industry is concerned, however, with some of the complexity involved and perceived reporting regulations that exceed those of other minerals industries.

Criticisms of existing regulatory arrangements were largely directed to the adequacy of provisions for environmental protection from the impacts of uranium mining in the Kakadu National Park and the ARR. Criticisms were also made of the performance of the Office of Supervising Scientist (OSS), which, among a number of allegations, was said to have been ‘captured’ by Energy Resources of Australia (ERA), owners of the Ranger mine. However, the OSS provided convincing rebuttals to each of these allegations, as well as to arguments relating to the adequacy of tailings and water management at Ranger.

The Committee rejects the claim that the regulation of uranium mining in the ARR is inadequate. There is extensive formal oversight of the Ranger operation and ERA meet some of the most rigorous reporting regimes in Australia. Ranger is monitored and regulated by a range of independent bodies including Australian Government agencies (OSS, ASNO and the Department of Industry, Tourism and Resources), NT Government agencies and independent review bodies, namely the Mine Site Technical Committees, ARR Advisory Committee and ARR Technical Committee.

Moreover, the Committee notes that monitoring and research by the OSS since 1978 has concluded that uranium mining operations at Ranger have had no detrimental impact on the Kakadu National Park. This confirms that the regulatory regime governing uranium mining in the ARR has indeed succeeded in protecting the environment from any harmful impacts caused by uranium mining.

Uranium mining regulation in the ARR has, however, evolved into what appears to be an unduly complex regime, comprised of arrangements underpinned by a range of Commonwealth and Territory legislation. The Committee recognises that the complexity may well have been unavoidable because of the combination of factors, including that: mining is taking place on Aboriginal land; the need to protect the Kakadu National Park; and the special nature of uranium. Nonetheless, if a regulatory framework were to be designed from ‘scratch’ in 2006, it seems unlikely that a similar framework would be developed. The Committee will not recommend specific improvements but suggests that the entire regulatory regime in the NT should be reviewed with a view to consolidation and simplification.

Although the Committee believes there have been clear improvements in environmental regulations relating to mine closure and rehabilitation, some partially rehabilitated former uranium mines continue to present pollution problems. The Australian Government’s recent decision to allocate some additional funding to address this problem is welcome, but the Committee recommends that the Australian Government redouble efforts to completely rehabilitate former uranium mines and provide funding to do so **[Recommendation 5]**.

The Committee recommends that consideration should be given to utilising the expertise of the OSS in assessment and approvals processes for uranium mines generally. Mindful that industry wishes to see any unnecessary duplication across levels of government eliminated, the Committee urges that an expanded role for the OSS not add to what is already a highly regulated industry. The Committee further recommends that the Environmental Research Institute of the Supervising Scientist be provided with additional resources, potentially in partnership with a suitable university, so as to provide a national research function **[Recommendation 6]**.

Despite professing concern that Indigenous groups be consulted, some environmental groups revealed that, should Traditional Owners approve a mining development, they would still oppose uranium mining. This seems to support the observation made by one submitter who remarked that Aboriginal groups are being used by some ‘no development’ groups to support their opposition to uranium mining. Traditional Owners’ views are clearly *not* to be respected if they happen to support resource development.

Notwithstanding this, the Committee believes that care must be taken to ensure that uranium mining does not impact negatively on local Aboriginal communities. The Committee is of the view that the social impacts of mining operations must be adequately monitored, and Aboriginal communities and Traditional Owners should have an opportunity to share in the benefits associated with a vibrant minerals industry.

The Committee is not convinced that social problems are peculiar to uranium mining, or to Jabiru, Ranger and ERA, but rather that the social problems and issues of service provision in Jabiru are common to large Aboriginal communities wherever they are located.

In relation to employment, the Committee notes impediments to increasing Aboriginal engagement in the uranium industry, including the opposition by some Aboriginal groups and low levels of educational attainment. The Committee sees merit, however, in industry seeking to emulate the examples of mining operations that have succeeded in achieving benefits for Indigenous communities. In particular, the Committee was impressed by the successes of Heathgate Resources at Beverley and Cameco Corporation in Saskatchewan. The Committee strongly urges industry, governments and Indigenous communities themselves to continue to strive to ensure Aboriginal people benefit from uranium mining operations through employment, business and training opportunities.

To ensure adequate local community consultation, the Committee further recommends that a process be established whereby it and its successor committees be formally given access to new uranium mine sites, with customary powers of inquiry and report to the Parliament. This process should formally provide for affected local governments to nominate a person to liaise with the Committee about any community concerns **[Recommendation 7]**.

Chapter eleven: Impediments to the uranium industry’s development

The chapter outlines the range of impediments to the uranium industry’s development in Australia, summarising these under the headings of: general impediments to the industry; impediments to existing producers; impediments to junior exploration companies; and public perceptions of the uranium industry and nuclear power.

Industry presented a range of issues to the Committee, including:

- restrictions on uranium mining and exploration in some states;
- regulatory inconsistencies across jurisdictions;
- lack of government assistance;
- sovereign risk;
- inappropriate government scrutiny of sales contracts;
- transportation restrictions;
- labour and skills shortages;
- excessive reporting requirements;
- absence of infrastructure in some prospective mining areas;
- labour and skills shortages;
- geoscientific data;
- access to capital; and
- the opposing influence of other industries.

The Committee urges the Australian Government, through the Council of Australian Governments, seek to remedy these impediments **[Recommendation 9]**.

The Committee concludes that the principal impediment to the growth of the uranium industry in Australia remains the prohibition on uranium mining in some states and the lack of alignment between federal and state policy. The Committee insists that the current restrictions on uranium mining are illogical, inconsistent and anticompetitive. Restrictions have impeded investment in the industry, and have resulted in a loss of regional employment and wealth creation opportunities, royalties and tax receipts. The only beneficiaries of restrictions are the three existing producers and foreign competitors. State policies that prevent development of new uranium mines should be lifted and legislative restrictions on uranium mining and exploration should be repealed **[Recommendation 8]**.

Negative public perceptions of the uranium industry and misconceptions about the nature of the industry’s operations were frequently cited, both by existing producers and by junior exploration companies, as key impediments to the industry’s growth in Australia.

The Committee does not question the sincerity with which those people expressing ‘moral outrage‘ at the very existence of the uranium industry hold their views. However, the Committee believes that these views are not informed by an accurate assessment of the benefits and risks associated with the industry. Misinformation and ignorance of the facts, as presented in evidence to the Committee, included: the failure to appreciate the true greenhouse benefits of nuclear power across the fuel cycle; nuclear power’s safety record, which is far superior to all other major energy sources; massive overstatement of the known number of fatalities associated with the Chernobyl accident; the success of non-proliferation regimes; and the sophisticated management of waste, which is very small in volume compared with fossil fuel alternatives; and the international consensus in support of geologic repositories for disposal of high level waste. There is also a general refusal to acknowledge the immense energy density of uranium and its value in a world where demand for energy may triple by 2050. There is no acknowledgement that uranium is Australia’s second largest energy export in thermal terms, or nuclear’s part in addressing the global energy imbalance. Such views, although held by perhaps a minority of people, do influence policy and this impedes the development of the industry.

The Committee is convinced that while widespread misconceptions about the industry persist, the industry’s growth will be impeded.

Factors that have contributed to negative perceptions of the industry have included the Australian public’s lack of exposure to uranium mining and nuclear power in the past, which has led to a degree of ignorance about the industry and in turn created a climate in which myths and unfounded fears could be propagated. Ignorance and/or bias by sections of the teaching profession, and neglect of uranium and nuclear power from school and tertiary curricula may also have contributed. The opposition to uranium mining by environmental groups and some unions were also cited as factors in generating public antipathy to uranium mining and nuclear power.

The uranium industry consistently emphasised the need for improved public eduction about all aspects associated with uranium mining and nuclear power. The Committee concurs with this view. It is imperative that the benefits and risks associated with uranium mining and use of nuclear power be more widely understood among the Australian public. Any concerns and unfounded fears should be addressed. Moreover, opinion leaders in Australia, particularly members of parliaments and the media, need to be better informed and provided with a more balanced perspective on the industry and its merits.

To this end, accurate and objective information about the industry needs to be made available by a credible and authoritative source or sources. In particular, evidence pointed to the need for information on radiation and radioactive waste management.

The Committee concludes that public education and advocacy needs to be augmented and the Committee believes that both industry and Government must play a part. A communication strategy is therefore justified to address concerns the public may have and address areas of poor understanding. This information should also be provided to political leaders at all levels and the media **[Recommendation 11]**.

The Committee concedes that finding the right balance between transparency versus the right of the industry to have its reputation protected from undue criticism is a difficult balance to strike. The Committee is pleased to note the preparedness of the industry to comply with reporting standards as they currently stand.

The Committee believes that progress could be made if, in addition to maintaining the currently rigorous reporting requirements, regulators issued a brief assessment of the impacts of any incidents that occur. A simple classification system could be devised that states simply whether the incident has ‘no impact’, ‘minimal impact’ and so on. In this way, companies will continue to report incidents and satisfy the public’s desire to be informed about the industry, while regulators’ assessments will better communicate the seriousness of the impacts of any incidents that may occur. In this way, the Committee hopes that public understanding of the real impacts of uranium mining operations will be enhanced and companies will be somewhat protected from unfounded criticism **[Recommendation 10]**.

Chapter twelve: Value adding — fuel cycle services industries in Australia

The Committee’s terms of reference and additional issues did not seek submissions relating to the possible domestic use of nuclear power or the question of establishing domestic fuel cycle services industries. However, a number of submitters volunteered opinions and information in relation to these matters. The Committee concludes its report with an overview of this evidence. The Committee also addresses itself to the skills base and research and development (R&D) activity to support Australia’s current and possible future participation in the nuclear fuel cycle.

The Committee agrees that for Australia to possess such a large proportion of the world’s uranium resources—approximately 40 per cent of the global total—and *not* to have taken up opportunities over the past 35 years to develop uranium enhancement industries is highly regrettable.

There have been several missed opportunities, notably a proposal to develop a commercial uranium enrichment industry in Australia by a consortium of Australian companies, the Uranium Enrichment Group of Australia (EUGA)—BHP, CSR, Peko-Wallsend and WMC—in the early 1980s. This proposal was terminated following a change of Federal Government.

In addition to the foregone export earnings and the missed opportunities to develop sophisticated technologies and an associated domestic knowledge base, the failure to press ahead with the development of fuel cycle services industries in Australia has wasted a significant public R&D investment.

In addition to domestic economic and technological benefits, increased involvement by Australia in the fuel cycle could have non-proliferation and security advantages. Indeed, as argued by some submitters, fuel cycle facilities could well be established in Australia on a multination basis, in accordance with the IAEA’s expert advisory group recommendations outlined in chapter seven, thereby providing a high level of transparency for regional neighbours and the international community generally. Such a development would have clear global non-proliferation benefits, while also allowing Australia the opportunity to extract greater returns from its immense uranium resource endowment, to develop sophisticated technologies and to expand its national skills base.

The Committee urges that state governments re-evaluate the merits of the eventual establishment of such industries within their jurisdictions, particularly in the uranium rich jurisdictions of South Australia, the Northern Territory and Western Australia. Furthermore, the Committee wishes to encourage Australian companies, such as those that participated in the UEGA enrichment industry proposals of the early 1980s, to actively consider the opportunities such developments might present in the future.

The Committee concludes that, by virtue of its highly suitable geology and political stability, Australia could also play an important role at the back-end of the fuel cycle in waste storage and disposal. Again, such a development could be highly profitable, as well as possibly providing global security benefits. However, as noted in chapter five, the US Global Nuclear Energy Partnership initiative proposes to revolutionise spent fuel management and this could obviate the need for geologic repositories altogether.

The Committee has no in-principle objection to the use of nuclear power in Australia and believes that, subject to appropriate regulatory oversight, utilities that choose to construct nuclear power plants in Australia should be permitted to do so. There would be clear greenhouse gas emission and other technological and potential economic benefits from doing so.

Nuclear power may not be immediately competitive in the Australian context, due to the quantity and quality of Australia’s coal resources (and that carbon emissions are currently not priced). However, the Committee believes that if Federal and state governments continue to provide a range of incentives to achieve low carbon emissions, for example by subsidising renewables such as wind, then governments should not discriminate against nuclear power—which will achieve very low emissions but also generate baseload power, unlike the currently subsidised renewable alternatives.

Even if the domestic use of nuclear energy and uranium enhancement industries in Australia are not established in the near future, the Committee recommends that the Australian and state governments commence examining best practice licensing and regulatory frameworks that could be put in place to facilitate the eventual establishment of such facilities **[Recommendation 12]**.

The Committee is concerned that, with the closure in 1988 of Australia’s sole university school of nuclear engineering, Australia no longer has an indigenous source of trained personnel in the nuclear field. The Committee concludes that the Australian Government should seek to progressively rebuild Australia’s nuclear skills base. Among other initiatives, the Government should broaden ANSTO’s research and development mandate, so that it is once again able to undertake physical laboratory studies of aspects of the nuclear fuel cycle that may be of future benefit to Australia and Australian industry. Consideration should also be given to re-establishing at least one university school of nuclear engineering **[Recommendation 13]**.

Finally, the Committee is persuaded of the immense potential benefit that fusion energy represents for the world and, specifically, the potential benefits for Australian science and industry from involvement in the International Thermonuclear Experimental Reactor (ITER) project. The Committee believes that involvement in this experimentation is simply too important for the nation to miss, even if the introduction of fusion power is indeed many decades off. Accordingly, the Committee recommends that Australia secure formal involvement in the ITER project and seek to better coordinate its research for fusion energy across the various fields and disciplines in Australia **[Recommendation 14]**.

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Footnotes

1 The glossary has been compiled from the following sources: OECD Nuclear Energy Agency, *Nuclear Energy Today*, OECD-NEA, Paris, 2003, pp. 91–102; Australian Safeguards and Non-Proliferation Office, *Annual Report 2003–2004*, ASNO, Canberra, 2004, pp. 143–49; Senate Environment, Communications, Information Technology and the Arts References Committee , *Regulating the Ranger, Jabiluka, Beverley and Honeymoon uranium mines*, SECITARC, Canberra, 2003, pp. 321–27; Australian Science and Technology Council, *Australia's Role in the Nuclear Fuel Cycle*, AGPS, Canberra, 1984, pp. 301–12; World Nuclear Association, *Glossary*, WNA, London, 2002, viewed 21 June 2005, <http://www.world-nuclear.org/info/inf51.htm>; Uranium Information Centre, *Glossary: Nuclear Issues Briefing Paper 30*, UIC, Melbourne, 2002, viewed 21 June 2005, <http://www.uic.com.au/nip30.htm>; OECD-NEA/International Atomic Energy Agency, *Uranium 2003: Resources, Production and Demand*, OECD-NEA/IAEA, Paris, 2004, pp. 261–77; OECD-NEA/IAEA, *Uranium 2005: Resources, Production and Demand*, OECD-NEA/IAEA, Paris, 2005, pp. 261–276. Joint Ore Reserves Committee , *The JORC Code*, AusIMM, MCA and AIG, 2004 edn; G Taylor et. al., *Review of Environmental Impacts of the Acid In-Situ Leach Uranium Mining Process*, CSIRO Land and Water, Melbourne , 2004, pp. 56–58; Geoscience Australia, *Australia's Identified Mineral Resources 2005*, GA, Canberra, 2005, p. 88; IAEA, *Analysis of Uranium Supply to 2050*, IAEA, Vienna, 2001, p.101. **Back**

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Last reviewed 14 March 2007 by Committee Secretariat

Australia's uranium — Greenhouse friendly fuel for an energy hungry world

A case study into the strategic importance of Australia 's uranium resources for the Inquiry into developing Australia 's non-fossil fuel energy industry

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Chapter 1 Introduction

Referral of the inquiry

1.1 On 15 March 2005 the Minister for Industry, Tourism and Resources, the Hon Ian Macfarlane MP, wrote to the House of Representatives Standing Committee on Industry and Resources (the Committee) asking it to conduct a case study into the strategic importance of Australia's uranium resources, as part of a broader inquiry into the development of Australia's non-fossil fuel energy industry. The terms of reference for the case study are provided on page xxi of the report.

Conduct of the case study

1.2 A media release announcing the inquiry was issued on 17 March 2005. The Committee's terms of reference were advertised and written submissions invited in the *Australian Financial Review* on 1 April 2005, *The Australian* on 20 April 2005, *Australia's Mining Monthly* in May 2005, *TheAusIMM Bulletin* in May/June 2005, and on-line through *MiningNews.Net* during April 2005.

1.3 The Committee wrote to 180 organisations, companies and individuals inviting them to make submissions to the inquiry. These included major uranium and coal mining companies, junior uranium exploration companies, industry and professional associations, banking and financial institutions, environmental organisations, unions, Aboriginal organisations, and Government scientific agencies. The Committee invited submissions from all state and territory governments.

1.4 In its letters inviting submissions, the Committee also indicated that it would welcome comments in relation to six additional issues, as follows:

- whole of life cycle waste management assessment of the uranium industry, including radioactive waste management at mine sites in Australia, and nuclear waste management overseas consequent to use of Australian exported uranium;
- the adequacy of social impact assessment, consultation and approval processes with traditional owners and affected Aboriginal people in relation to uranium mining resource projects;
- examination of health risks to workers and to the public from exposure to ionising radiation from uranium mining;

- adequacy of regulation of uranium mining by the Commonwealth;
- assessing the extent of federal subsidies, rebates and other mechanisms used to facilitate uranium mining and resource development; and
- the effectiveness of safeguards regimes in addressing the proliferation of fissile material, the potential diversion of Australian obligate fissile materials, and the potential for Australian obligate radioactive materials to be used in ‘dirty bombs’.

1.5 The Committee received 87 written submissions and 19 supplementary submissions, which are listed at Appendix A. The Committee also received 93 exhibits, which included ancillary material provided by witnesses at public hearings and various technical documents. A list of the exhibits is at Appendix B.

1.6 Three petition letters were received from seventeen individuals expressing opposition to further uranium mining. These were received by the Committee as three submissions, with the names of the individuals expressing the views listed under the respective submission in Appendix A.

1.7 Public hearings were conducted by the Committee in Sydney, Melbourne, Perth, Darwin and Canberra from August 2005 to March 2006. In total, 87 witnesses were examined at 13 public hearings. The dates and locations of the hearings, together with the names of witnesses who appeared before the Committee is at Appendix C.

1.8 Inspections were held by the Committee at the three uranium mines that are currently operating—Olympic Dam and Beverley in South Australia and Ranger in the Northern Territory.

1.9 Access to the published submissions to the inquiry, transcripts of evidence taken at public hearings and an electronic copy of the report is available on the internet from the Committee’s web site:
http://www.aph.gov.au/house/committee/isr/uranium/index.htm

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Structure of the report and principal findings

1.10 In addition to this introductory chapter, the report comprises 11 chapters. The contents and principal findings of the chapters are summarised as follows.

1.11 The Committee’s conclusions and recommendations are also summarised in a *key messages* section at the beginning of each chapter and in the *conclusions* section at the end of each chapter.

Chapter two: Uranium: Demand and Supply

1.12 The Committee commences the report by considering the global demand and supply of uranium in the context of world electricity consumption trends and nuclear power’s share in the electricity generation mix. The Committee provides a summary of forecasts for world nuclear generating capacity and associated uranium requirements. Competing views on the outlook for new nuclear power plant construction are then considered, followed by an assessment of the role of existing plant performance in influencing the demand for uranium.

1.13 Uranium supply is provided by a combination of primary (mine) production and secondary sources (e.g. inventories held by utilities and ex-military material). The contribution of each part is discussed. The Committee then considers the argument that world uranium resources are insufficient to support an expansion of nuclear power and, hence, represent only a temporary response to the problem of climate change.

1.14 The Committee concludes the chapter with an assessment of the implications of the supply/demand balance for further mine production and the potential for Australia’s uranium production to expand to meet requirements.

1.15 The Committee concludes that new nuclear build combined with improved reactor performance and operating life extensions are likely to outweigh reactor retirements in the years ahead, thereby increasing projected uranium requirements. Importantly, secondary supplies (which provide some 35 per cent of the market) are also declining, leading to an increased requirement for uranium mine production. Dramatic increases in the uranium spot price are stimulating new uranium exploration activity.

1.16 The chapter commences with an overview of the nuclear fuel cycle, which establishes a context for the discussion in subsequent chapters of matters including greenhouse gas emissions, waste, safety and proliferation risks associated with nuclear power generation.

Chapter three: Australia's uranium resources, production and exploration

1.17 The chapter provides a detailed overview of Australia's uranium resources, mine production and exploration for uranium.

1.18 Australia possesses 38 per cent of the world's total Identified Resources of uranium recoverable at low cost. According to company reports, Australia's known uranium deposits currently contain a total of over 2 million tonnes of uranium oxide in in-ground resources. The in-situ value of this resource at spot market prices prevailing in June 2006 was over A$270 billion.

1.19 The Committee was pleased to note record uranium production and exports for Australia in calendar year 2005. Production across the three operational mines (Ranger, Olympic Dam and Beverley) was 11 222 tonnes of uranium oxide (t U_3O_8) and exports were 12 360 t U_3O_8. Uranium exports also earned a record $573 million in 2005.

1.20 Some 75 per cent of Australia's total Identified Resources of uranium are located in South Australia, but significant deposits are also located in the Northern Territory, Western Australia and Queensland.

1.21 Olympic Dam in South Australia contains 26 per cent of the world's low cost uranium resources and is the world's largest uranium deposit. A proposal to expand Olympic Dam would see uranium production from the mine treble to 15 000 tonnes of uranium oxide per year, which would make Olympic Dam and its owners, BHP Billiton Ltd, by far the world's largest uranium producer.

1.22 The increase in uranium spot price and the anticipated decline in secondary supplies have stimulated a resurgence in exploration activity and expenditure in Australia.

1.23 While there has been a trend of increasing exploration expenditure since early 2003, there has been relatively little exploration for uranium over the past two decades and Australia's known uranium resources generally reflect exploration efforts that took place 30 years ago. It is likely that the size of Australia's known uranium resources significantly understates the potential resource base and there is great potential for new and significant discoveries.

1.24 In its previous report, which addressed impediments to exploration, the Committee accepted that future world-class uranium deposits are likely to be located at greater depths than those hitherto discovered. It was concluded that this will require large injections of exploration investment capital to overcome the technical challenges of locating bedrock deposits. These observations reinforce the need to ensure that junior companies, which are generally efficient explorers, are appropriately assisted to discover Australia's future world-class uranium and other mineral deposits. The Committee is convinced of the merits of flow-through share schemes and repeats the recommendation contained in its previous report.

1.25 To assist in the discovery of new world-class uranium deposits the Committee recommends that Geoscience Australia be provided with additional funding to develop and deploy techniques to provide precompetitive geoscience of prospective areas, in order to assist in the discovery of new world-class uranium and other mineral deposits located under cover and at depth.

Chapter four: Greenhouse gas emissions and nuclear power

1.26 The chapter addresses the greenhouse gas emissions avoided by the use of nuclear power, emissions across the whole nuclear fuel cycle, the contribution from renewable energy sources, and the relative economic attractiveness of nuclear power for baseload power generation.

1.27 The Committee concludes that nuclear power unquestionably makes a significant contribution to the mitigation of greenhouse gas (GHG) emissions—nuclear power plants currently save some 10 per cent of total carbon dioxide (CO_2) emissions from world energy use. This represents an immense saving of GHG emissions that would otherwise be contributing to global warming. If the world were not using nuclear power plants, emissions of CO_2 would be some 2.5 billion tonnes higher per year.

1.28 An important consideration in assessing nuclear power's viability as a GHG emission mitigation option relates to the economic competitiveness of nuclear power relative to other baseload alternatives. Evidence suggests that nuclear power plants have higher capital/construction costs than either coal or gas plants, which are characterised by mid-range and low capital costs respectively. However, nuclear plants have low fuel, operating and maintenance costs relative to the fossil fuel alternatives.

1.29 A range of recent authoritative studies have concluded that, in many industrialised countries, nuclear power is competitive with gas and coal-fired electricity generation, even without incorporating an additional cost for the carbon emissions from the fossil fuelled plants.

Chapter five: Radioactive waste

1.30 It was alleged in evidence that there remain three unresolved issues associated with the nuclear fuel cycle and its industries that, in the view of some submitters, are such as to justify a winding back of uranium mining and an eventual end to the use of nuclear power worldwide. These issues relate to the:

- generation and management of *radioactive waste* across the nuclear fuel cycle, principally waste from the operation of nuclear reactors, but also waste from uranium mines;
- *safety* of the fuel cycle, particularly the operation of nuclear reactors and the risks to health from fuel cycle industries, including uranium mining; and
- risk of *proliferation* of nuclear materials and technologies, and their diversion for use in weapons programs.

1.31 Chapter five and the following three chapters examine the evidence presented to the Committee in relation to each of these three key issues.

1.32 Chapter five addresses the management of radioactive waste generated across the nuclear fuel cycle, from uranium mining to the decommissioning of nuclear power plants.

1.33 The Committee concludes that the radioactive wastes which are produced at each stage of the nuclear fuel cycle have, since the inception of the civil nuclear power industry 50 years ago, been responsibly managed. There are proven technologies for the management of all types of radioactive waste.

1.34 The Committee finds that nuclear power deals with its waste more explicitly and transparently than many other sources of energy. The Committee notes that high level radioactive waste has several features which lends itself to ease of management: very small volumes (12 000 tonnes per year worldwide); the radioactivity is contained in the spent fuel assemblies; it decays at a predictable rate; and is amenable to separation, encapsulation and isolation. Moreover, the nuclear power industry significantly contributes to the cost of its waste management through levies imposed on utilities.

1.35 This is in sharp contrast to the wastes produced by fossil fuels, which are not contained or managed, involve enormous volumes and a range of toxic pollutants that do not decay. Moreover, the cost of the environmental externalities these energy sources create are generally not factored into the price of the electricity generated.

Chapter six: Safety of the nuclear fuel cycle

1.36 The chapter examines the second 'unresolved' issue associated with the civil nuclear power industry—the safety of nuclear fuel cycle facilities, and particularly the health risks to workers and to the public from exposure to radiation from uranium mining and nuclear power plants.

1.37 The chapter presents evidence in relation to the following themes in turn: the health effects from exposure to ionising radiation and the current international standards for control of radiation exposure; regulation for radiation protection in Australia; safety and health issues associated with the uranium mining industry in Australia; radiation exposure from the whole nuclear fuel cycle; nuclear safety; and radiation and public perceptions.

1.38 The Committee concludes that the nuclear power industry has by far the best safety record of all major energy industries, including coal, oil, natural gas, liquefied petroleum gas and hydro. Notwithstanding the tragedy of the Chernobyl accident, which has been the only accident to a commercial nuclear power plant that has resulted in loss of life, nuclear power's safety record is unrivalled by any other major energy source.

1.39 The total average effective radiation dose received by the world population from natural sources of radiation (i.e. 'natural background radiation') is 2.4 millisieverts (mSv) per year. In contrast, the total average effective dose to monitored workers across the whole nuclear fuel cycle (including uranium mining and milling) is 1.75 mSv per year. The maximum average annual radiation dose allowed for a uranium miner is currently set at 20 mSv. The actual dose received by workers at Australian uranium mines is well under half this level. The radiation exposure for the public in the vicinity of the mines is a small fraction of the prescribed limit for members of the public.

1.40 To provide greater assurance to uranium industry workers and the public at large, and also to definitively answer claims—which the Committee is confident are entirely mistaken—that current radiation exposures are harming workers, the Committee recommends the establishment of:

- a national radiation dose register for occupationally exposed workers; and
- a system of long-term monitoring of the health outcomes for workers occupationally exposed to radiation in uranium mining, associated industries and nuclear facilities.

Chapter seven: The global non-proliferation regime

1.41 In this and the following chapter the Committee addresses the third objection to the use of nuclear power—nuclear proliferation and the effectiveness of safeguards regimes.

1.42 The chapter first introduces the concept of proliferation and explains how some technologies required in the civil nuclear fuel cycle also have military uses. The Committee describes the current global non-proliferation regime, the key elements of which are the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and the safeguards activities of the International Atomic Energy Agency (IAEA).

1.43 The Committee concludes that the global safeguards regime has indeed been remarkably successful in limiting the proliferation of nuclear weapons. While the Committee believes that most alleged deficiencies in the regime are without substance, it notes that the regime is now facing several challenges which must be met.

1.44 The Committee welcomes the commendable range of efforts the Australian Government is undertaking to advance non-proliferation objectives but recommends that further action be taken, including, inter alia: redoubling efforts to encourage adoption by other countries of the Additional Protocol to the NPT; seeking the development of criteria for assessing the international acceptability of proposed sensitive projects; and examining the resourcing of the IAEA's safeguards program.

Chapter eight: Australia's bilateral safeguards

1.45 The chapter considers the adequacy and effectiveness of Australia's safeguards policy and the bilateral safeguards agreements it enters into with countries wishing to purchase Australian uranium.

1.46 The chapter commences with an overview of the safeguards policy and the principal conditions for the use of Australian Obligated Nuclear Material (AONM) set out in the bilateral agreements. Four main criticisms were made in evidence of the safeguards policy and agreements, which the Committee considers in turn, along with rebuttals from the Australian Safeguards and Non-Proliferation Office.

1.47 The chapter then considers several other proliferation concerns and allegations raised by submitters, and concludes with a discussion of nuclear security, including the possible malicious use of radioactive sources in so-called 'dirty bombs' and efforts to prevent nuclear terrorism.

1.48 While the Committee notes that it simply cannot be absolutely guaranteed that diversion of AONM for use in weapons could never occur at some point in the future, nevertheless the Committee is satisfied that Australia's safeguards policy has been effective to date. The Committee concludes that the requirements in safeguards agreements are adequate and can see no reason for imposing additional requirements at this time.

1.49 The Committee supports the Australian Government's decision to permit exports of uranium to China.

1.50 The Committee belives that the US-India nuclear cooperation agreement will have a number of important non-proliferation benefits, including that it will expand the application of IAEA safeguards in India and allow the IAEA enhanced access rights. However, while there are sound reasons to allow an exception to Australia's exports policy in order to permit uranium sales to India, including its record as a non-proliferator, the Committee does not wish to make a recommendation on the matter. Maintaining the integrity of the non-proliferation regime must remain the top priority and guiding principle for Australia's uranium exports policy and the Committee hopes that a bipartisan position on this issue can be developed.

Chapter nine: Strategic importance of Australia's uranium resources

1.51 In addition to its greenhouse gas emission benefits, which were discussed in chapter four, evidence presented to the Committee suggested that the strategic importance of Australia's uranium resources derives from the:

- significance of the resource as one of Australia's major energy exports;
- energy security benefits that uranium can provide those countries that choose to adopt nuclear power;
- potential for Australia's uranium exports to assist in addressing the global energy imbalance;
- economic benefits that may be obtained from uranium mining, particularly for state economies and regional communities;
- economic significance of Australia's undeveloped uranium resources; and
- Australia's role as a major uranium exporter in the global nuclear fuel cycle.

The chapter considers each of these points in turn.

1.52 Among other findings, the Committee notes that uranium is Australia's second largest energy export in terms of contained energy content. Uranium is an immensely concentrated source of energy—one tonne of uranium oxide generates the same amount of energy as 20 000 tonnes of black coal. The uranium produced from just one of Australia's mines each year—Ranger, in the Northern Territory—contains sufficient energy to provide for 80 per cent of Australia's total annual electricity requirements, or all of Taiwan's electricity needs for a year.

1.53 In addition, the Committee concludes that while Australia is well endowed with energy resources for its own needs, other countries are not so fortunate. These include developing countries such as China. As a matter of energy justice, the Committee believes that Australia should not deny countries who wish to use nuclear power in a responsible manner the benefits from doing so. Neither should Australia refuse to export its uranium to assist in addressing the global energy imbalance and the disparity in living standards associated with this global inequity.

1.54 Moreover, expanded mining and exports of uranium will have economic and other benefits for the nation, the states that permit uranium resources to be developed and the regional communities supporting the mines.

Chapter ten: Uranium industry regulation and impacts on Aboriginal communities

1.55 The chapter examines the current structure and regulatory environment of the uranium mining sector (noting the work that has been undertaken by other inquiries and reviews on these issues). The chapter commences with a description of the current regulatory environment, focussing on the Australian Government's role. This is followed by sections detailing the industry's assessment of the current regulatory regime, criticisms of the regulatory environment and consultation with Traditional Owners and the social impacts of uranium mining on Aboriginal communities.

1.56 Criticisms of perceived failings of the current regulatory regime by those opposed to uranium mining generally relate to the adequacy of environmental protection from the impacts of uranium mining. However, the Committee concludes that while deficient regulation and poor mining practices in past decades have led to ongoing rehabilitation problems at former uranium mine sites and recommends that further funding be provided to complete this rehabilitation, it concludes that current regulation is entirely adequate.

1.57 The Committee notes, for example, that the Ranger operation in the Northern Territory is required to meet among the most rigorous reporting regimes in the country. Ranger is monitored and regulated by a range of independent bodies. The Committee notes that there has been no harm to the Kakadu National Park from the mining operations at Ranger.

1.58 The Committee concludes that while there are a number of impediments to increasing Aboriginal engagement in uranium mining, industry, governments and Indigenous communities themselves should seek to emulate the examples of mining operations, both in Australia and abroad, that have succeeded in achieving employment, business and training benefits for Indigenous communities.

Chapter eleven: Impediments to the uranium industry's development

1.59 The chapter summarises the impediments to the uranium industry's growth in Australia.

1.60 The Committee finds that the principal impediment to the growth of the uranium industry in Australia remains the prohibition on uranium mining in some states and the lack of alignment between federal and state policy. The Committee urges state governments to reconsider their opposition to uranium mining and to abolish legislative restrictions where these exist. The Committee also recommends that governments address the range of other impediments to the development of the industry.

1.61 In addition, and as described in preceding chapters of the report, the Committee believes that there are widespread misconceptions associated with uranium mining and nuclear power. While these misconceptions persist, the industry's growth is likely to be impeded. The Committee concludes that it is vital that the concerns of the public be responded to. Information should be communicated both to the general public and opinion leaders that eases concerns and addresses areas of poor understanding.

Chapter twelve: Value adding — fuel cycle services industries, nuclear power, skills and training in Australia

1.62 The chapter provides an overview of evidence presented in relation to the possible domestic use of nuclear power and the question of establishing domestic fuel cycle services industries. The Committee also addresses itself to the skills base and research and development (R&D) activity to support Australia's current and possible future participation in the nuclear fuel cycle.

1.63 The Committee regrets that Australia has missed several opportunities to develop industries based on upgrading Australia's uranium resources for export. In addition to the foregone export earnings and the missed opportunities to develop sophisticated technologies and an associated domestic expertise, the failure to press ahead with the development of fuel cycle services industries in Australia has wasted a significant public R&D investment.

1.64 Australia possesses some 40 per cent of the world's uranium, perhaps more. By virtue of this immense resource endowment, Australia has a very strong economic interest in, and justification for, seeking to add value to its uranium resources prior to export. The Committee concludes that such a development would allow Australia the opportunity to extract greater returns from its resource endowment, to develop sophisticated technologies and to expand its national skills base.

1.65 Although the Committee acknowledges that nuclear power may not be immediately competitive in the Australian context, due to the quantity and quality of coal resources (and that carbon emissions are currently not priced), the Committee has no in-principle objection to the use of nuclear power in Australia and believes that, subject to appropriate regulatory oversight, utilities that choose to construct nuclear power plants in Australia should be permitted to do so.

1.66 To facilitate the possible eventual development of domestic fuel cycle facilities, the Committee recommends that steps should now be taken to develop a licensing and regulatory framework to support the possible eventual establishment of such facilities in Australia. The Committee also urges that Government seek to progressively rebuild Australia's nuclear skills base which has been dissipated.

1.67 The chapter concludes with some supplementary remarks from the Opposition members of the Committee in relation to the domestic use of nuclear power and uranium enrichment.

Appreciation

1.68 The Committee wishes to thank those who contributed to the uranium case study, particularly the witnesses who were prepared to travel in order to appear before the Committee. The Committee also thanks the companies that facilitated its inspections of the currently operating uranium mines—BHP Billiton Ltd, Energy Resources of Australia Ltd and Heathgate Resources Pty Ltd. The Committee appreciated the willingness of the Northern Territory Government to have its officials appear before the Committee at its public hearing in Darwin.

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Last reviewed 14 March 2007 by Committee Secretariat

Australia’s uranium — Greenhouse friendly fuel for an energy hungry world

A case study into the strategic importance of Australia ’s uranium resources for the Inquiry into developing Australia ’s non-fossil fuel energy industry

Print *Chapter 2* (PDF 456KB) < - Report Home < - Chapter 1 : Chapter 3 - >

Chapter 2 Uranium: Demand and Supply

The civilian nuclear industry is poised for world-wide expansion. Rapidly growing demand for electricity, the uncertainty of natural gas supply and price, soaring prices for oil, concern for air pollution and the immense challenge of lowering greenhouse emissions, are all driving a fresh look at nuclear power. At the same time, fading memories of Three Mile Island and Chernobyl is increasing confidence in the safety of new reactor designs. So the prospect, after a long hiatus, of new nuclear power construction is real, with new interest stirring in countries throughout the world.[1]

Australia is already a significant supplier of uranium – yet the growing demand is providing an unparalleled opportunity for Australia to be the dominant supplier of a crucial global commodity.[2]

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Key messages —

- **Demand for uranium is a function of nuclear generating capacity in operation worldwide, combined with the operational characteristics of reactors and fuel management policies of utilities.**
- **There are currently 441 commercial nuclear power reactors operating in 31 countries. In 2005, nuclear reactors generated 2 626 billion kilowatt-hours of electricity, representing approximately 16 per cent of world electricity production. Some 27 nuclear reactors are currently under construction and a further 38 are planned or on order worldwide.**
- **Expectations of increased world nuclear generating capacity and demand for uranium are underpinned by:**
- **forecasts for growth in world electricity demand, particularly in China and India;**
- **improved performance of existing nuclear power plants and operating life extensions;**
- **plans for significant new nuclear build in several countries and renewed interest in nuclear energy among**

some industrialised nations; and

- **the desire for security of fuel supplies and heightened concerns about greenhouse gas emissions from the electricity sector.**
- **New reactor construction combined with capacity upgrades and life extensions of existing reactors are projected to outweigh reactor shutdowns over the next two decades, so that world nuclear capacity will continue to increase and thereby increase projected uranium requirements.**
- **Several forecasts for world nuclear generating capacity and uranium requirements have been published. A conservative forecast by the IAEA and OECD-NEA predicts that nuclear generating capacity will grow to 448 gigawatts electrical by 2025, representing a 22 per cent increase on current capacity. This would see annual uranium requirements rise to 82 275 tonnes by 2025, also representing a 22 per cent increase on the 2004 requirements of 67 430 tonnes.**
- **Uranium mine production meets only 65 per cent of world reactor requirements. The balance of requirements are met by secondary sources of supply, notably inventories held by utilities and ex-military material. Secondary supplies are expected to decline over coming years and the anticipated tightness in supply has been reflected in a six-fold increase in the uranium spot market price since December 2000.**
- **A significant source of secondary supply has been provided through the down-blending of highly enriched uranium (HEU) removed from weapons and military stockpiles in both the Russian Federation and the USA. To date, more than 10 460 nuclear warheads have been converted into fuel to generate electricity through a Russia-USA HEU Purchase Agreement. This agreement will run to 2013 and is unlikely to be renewed.**
- **Uranium mine production must expand to meet a larger share of reactor requirements as secondary supplies are exhausted.**
- **Australia possesses 36 per cent the world's low cost uranium resources, twice the resources of Canada. However, Australia accounts for only 23 per cent of world production and lags substantially behind Canada. Provided that impediments to the industry's growth are eliminated, there is great potential for Australia to expand production and become the world's premier supplier of uranium.**
- **Sufficient uranium resources exist and are likely to be discovered to support significant growth in nuclear capacity in the longer-term.**
- **Total Conventional Resources of uranium, amounting to some 14.8 million tonnes of uranium, are sufficient to fuel 270 years of nuclear electricity generation at current rates of consumption. There is considerable potential for the discovery of additional economic resources, particularly as higher uranium prices are now stimulating increased exploration. Utilisation of Unconventional Resources, such as the uranium in phosphates, would extend supply to over 670 years at current rates of consumption.**
- **Wider deployment of advanced reactor technologies, particularly Fast Neutron Reactors, and alternate fuel cycles have the potential to extend the supply of uranium resources for thousands of years.**

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Introduction

2.1 The Committee commences the report of its inquiry into the strategic importance of Australia's uranium resources by considering the global demand and supply of uranium in the context of world electricity consumption trends and nuclear power's share in the electricity generation mix.

2.2 The Committee provides a summary of forecasts for world nuclear generating capacity and associated uranium requirements. Competing views on the outlook for new nuclear power plant construction are then considered, followed by an assessment of the role of existing plant performance in influencing the demand for uranium.

2.3 Uranium supply is provided by a combination of primary (mine) production and secondary sources. The contribution of each part is discussed. The Committee then considers the argument that world uranium resources are insufficient to support an expansion of nuclear power and, hence, represent only a temporary response to the problem of climate change.

2.4 The Committee concludes the chapter with an assessment of the implications of the supply/demand balance for further mine production and the potential for Australia's uranium production to expand to meet requirements.

2.5 The chapter commences with an overview of the nuclear fuel cycle, which establishes a context for the discussion in subsequent chapters of matters including greenhouse gas emissions, waste, safety and proliferation risks associated with nuclear power generation.

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What is uranium?

2.6 Uranium is a radioactive metallic element, naturally occurring in most rocks, soil and in the ocean. In its pure form, uranium is a silvery white metal of very high density—1.7 times more dense than lead. Uranium is found as an oxide or complex salt in minerals such as pitchblende, uraninite and brannerite. Concentrations of uranium also occur in substances such as phosphate rock deposits and minerals such as lignite.[3]

2.7 Uranium is 500 times more abundant in the Earth's crust than gold and as common as tin.[4] While uranium can be found almost everywhere, including in seawater, concentrated uranium ores are found in relatively few places, usually in hard rock or sandstone. Concentrations of uranium that are economic to mine for use as nuclear fuel are considered orebodies.[5] Economically extractable concentrations of uranium occur in more than a dozen different deposit types in a wide range of geological settings.[6]

2.8 Uranium has two major peaceful purposes: as the fuel in nuclear power reactors to generate electricity, and for the manufacture of radioisotopes for medical and other applications.

2.9 Naturally occurring uranium exists as a mix of three isotopes in the following proportions: U-234 (0.01%), U-235 (0.71%) and U-238 (99.28%).[7] Uranium-235 has a unique property in that it is the only naturally-occurring fissionable isotope. That is, the nucleus of the U-235 atom is capable of splitting into two parts when hit by a neutron. As the atom splits, a large amount of energy is released as heat and several new neutrons are emitted. This process is called fission. The neutrons emitted from the split nucleus may then cause other U-235 atoms to split, thus giving rise to a chain reaction if the mass of fissionable material exceeds a certain minimum amount known as the critical mass. The process of fission is harnessed in nuclear power generation, which is described in the following section, and in nuclear weapons.[8]

2.10 Following mining and milling, uranium metal (U) is sold as uranium oxide concentrate (UOC) which is comprised of uranium oxide (U_3O_8) and small quantities of impurities. Until 1970 uranium mine product was sold in the form of 'yellowcake' (ammonium diuranate), which is the penultimate uranium compound in U_3O_8 production. Following mining and milling, uranium enters the remaining stages of the nuclear fuel cycle, which are described below.

2.11 Uranium demand and supply are generally expressed in terms of tonnes U, while uranium mine production, ore reserves, ore grades and prices are commonly described in terms of U3O8. Uranium prices are generally expressed in terms of US dollars per pound U_3O_8. The glossary of this report contains definitions of uranium production and other mining terminology.[9]

2.12 Uranium was first recognised as a potential energy source by Ernest Rutherford in 1904 and first used as nuclear fuel in 1942. The first nuclear reactor to produce electricity was in Idaho , USA in December 1951. In 1954 the world's first nuclear powered electricity generator commenced operation at Obninsk in Russia , with other early generators at Calder Hall , England (1956) and Pennsylvania , USA (1957).[10]

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The nuclear fuel cycle

2.13 The civil nuclear fuel cycle refers to the sequence of processes, from uranium mining through to final disposal of waste materials, associated with the production of electricity from nuclear reactions. The main stages in the fuel cycle are:

- mining and milling of the uranium ore;
- conversion and enrichment of the uranium;
- fuel fabrication to suit the requirements of reactors;
- fission in a reactor for the generation of power, or production of radioisotopes (for medical, industrial or research purposes);
- reprocessing of the used fuel elements; and
- disposal and storage of wastes.

2.14 In Australia, the fuel cycle is undertaken to the stage of uranium milling. A description of each of the stages, submitted by the Uranium Information Centre (UIC), follows.[11]

2.15 There are two common types of nuclear fuel cycle. The 'closed' nuclear fuel cycle, which is illustrated in figure 2.1, includes the reprocessing of used fuel whereby uranium and plutonium are separated and recycled into new fuel elements. The 'open' (or once-through) fuel cycle excludes reprocessing and all the used fuel is treated as waste for disposal.[12]

Uranium mining

2.16 Both excavation and in situ techniques are used to recover uranium. Excavation may involve underground and open pit methods.

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

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

2.19 The decision as to which mining method to use for a particular deposit is governed by the nature of the orebody, safety, environmental and economic considerations. In the case of underground uranium mines, special precautions, consisting primarily of increased ventilation, are required to protect against airborne radiation exposure.

Uranium milling

2.20 Milling, which is generally carried out close to a uranium mine, extracts the uranium from the ore. Most mining facilities include a mill, although where mines are close together, one mill may process the ore from several mines.

2.21 In a mill, uranium is extracted from the crushed and ground-up ore by leaching, in which either a strong acid (usually sulphuric acid) or a strong alkaline solution is used to dissolve the uranium. The uranium is then removed from this solution and precipitated. The bright yellow powder produced by this process is referred to as ‘yellowcake’. The yellowcake is then dried and usually heated to produce a fine black powder containing over 98 per cent U_3O_8, which is then packed in 205-litre drums and shipped as UOC. Typically, 70 to 90 per cent of the uranium metal in the original ore is recovered in the milling process. The original ore itself may contain as little as 0.1 per cent uranium. The UOC usually contains small quantities of impurities such as sulphur, silicon and zircon.

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

2.23 When mining and milling has been completed the tailings are covered with clay and topsoil to allow vegetation to be established and to keep radiation levels to the normal background value experienced near a uranium orebody. Alternatively, tailings may be filtered to a dry state and the solids disposed of in subsurface storage areas.

Conversion

2.24 The product of a uranium mill is not directly usable as a fuel for a nuclear reactor. Additional processing, generally referred to as enrichment, is required for most types of reactors. This process requires uranium to be in gaseous form and this is achieved by converting the UOC into uranium hexafluoride (UF_6), which is a gas at relatively low temperatures.

2.25 At a conversion facility, uranium is first refined to uranium dioxide (UO_2), which can be used as the fuel for those types of reactors that do not require enriched uranium. Most uranium is then converted into UF_6, ready for the enrichment plant.

Enrichment

2.26 As noted above, natural uranium consists, primarily, of a mixture of two isotopes of uranium. Only 0.71 per cent of natural uranium is fissile, or capable of undergoing fission. The fissile isotope of uranium is uranium-235 (U-235), while most of the remainder is uranium-238 (U-238).

2.27 In the most common types of nuclear reactors, a higher than natural concentration of U-235 is required. The enrichment process produces this higher concentration, typically between 3.5 per cent and five per cent U-235, by removing over 85 per cent of the U-238. This is done by separating UF_6 into two streams, one being enriched to the required level and known as low-enriched uranium. The other is depleted in U-235 and is called ‘tails.’

2.28 There are two enrichment processes in large scale commercial use, each of which uses UF_6 as a feedstock—gaseous diffusion and gas centrifuge. Both processes use the physical properties of molecules, specifically the one per cent mass difference, to separate the isotopes. The product of this stage of the nuclear fuel cycle is enriched uranium hexafluoride, which is reconverted to produce enriched UO_2.

Fuel fabrication

2.29 Reactor fuel is generally in the form of ceramic pellets. These are formed from pressed UO_2 which is sintered (baked) at a high temperature (over 1400 degrees celsius). The pellets are then encased in metal tubes to form fuel rods, which are arranged into a fuel assembly ready for introduction into a reactor. The dimensions of the fuel pellets and other components of the fuel assembly are precisely controlled to ensure consistency in the characteristics of fuel bundles.

Power generation

2.30 Inside a nuclear reactor the nuclei of U-235 atoms split (fission) and, in the process, release energy. This energy is used to heat water and turn it into steam. The steam is used to drive a turbine connected to a generator which produces electricity. Some of the U-238 in the fuel is turned into plutonium in the reactor core (plutonium-239, Pu-239, is formed when the U-238 isotope absorbs a neutron), and this yields about one third of the energy in a typical nuclear reactor. The fissioning of uranium is used as a source of heat in a nuclear power station in the same way that the burning of coal, gas or oil is used as a source of heat in a fossil fuel power plant.

2.31 With time, the concentration of fission fragments (such as bromine, caesium and iodine among others, which are produced from the splitting of the U-235 atoms) and heavy elements, formed in the same way as plutonium in a fuel bundle, will increase to the point where it is no longer practical to continue to use the fuel.[13] After 18–24 months the ‘spent fuel’ is removed from the reactor. The amount of energy that is produced from a fuel bundle varies with the type of reactor and the policy of the reactor operator.

2.32 In a typical light water reactor (LWR), which is the most common type of reactor, fuel elements are used over 3–4 operating cycles, each of 12–18 months (i.e. the reactor might be unloaded every 12 months, with a third of the core being replaced each time).[14]

Used fuel storage

2.33 When removed from a reactor, a fuel bundle will be emitting both radiation, principally from the fission fragments, and heat.[15] Used fuel is unloaded into a storage pond immediately adjacent to the reactor to allow the radiation levels to decrease. In the ponds the water shields the radiation and absorbs the heat. Used fuel is held in such pools for several months to several years. Issues associated with waste management are addressed in chapter five and issues associated with radiation and health are addressed further in chapter six.

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

Reprocessing

2.35 In a reprocessing facility the used fuel is separated into its three components: uranium, plutonium and waste (which contains fission products). Reprocessing enables recycling of the uranium and plutonium into fresh fuel, and produces a significantly reduced amount of waste (compared with treating all spent fuel as waste).

2.36 Used fuel is about 95 per cent U-238 but it also contains about one per cent U-235 that has not fissioned, about one per cent plutonium and three per cent fission products, which are highly radioactive, with other transuranic elements formed in the reactor.[16]

Uranium and plutonium recycling

2.37 The uranium from reprocessing, which typically contains a slightly higher concentration of U-235 than occurs in nature, can be reused as fuel after conversion and enrichment, if necessary. The plutonium can be directly made into mixed oxide (MOX) fuel, in which uranium and plutonium oxides are combined. In reactors that use MOX fuel, Pu-239 substitutes for the U-235 in normal uranium oxide fuel.

Used fuel disposal

2.38 The longer that used fuel is stored, the easier it is to manage final disposal, due to the progressive diminution of radioactivity. After 40 to 50 years of storage, the radioactivity level of the fuel falls to 0.1 per cent of its original level. This, and the fact that the volumes of waste involved are not, relatively, large, have meant that final disposal facilities (as opposed to storage facilities) have not been operated since civil nuclear power programs were introduced. There is also a reluctance to dispose of used fuel because it represents a significant energy resource which could be reprocessed at a later date to allow recycling of the uranium and plutonium.

2.39 Technical issues related to disposal have been addressed and a number of countries have determined their own optimum approach to the disposal of used fuel and waste from reprocessing. The most commonly favoured method for disposal is placement into deep geological repositories. The USA is now building a national repository under Yucca Mountain in Nevada, which is scheduled to be operational by 2017. Sweden is proposing to have a deep geological repository in operation by about 2017 and Finland by 2020. Issues associated with the management of the waste produced across the nuclear fuel cycle are addressed in chapter five.

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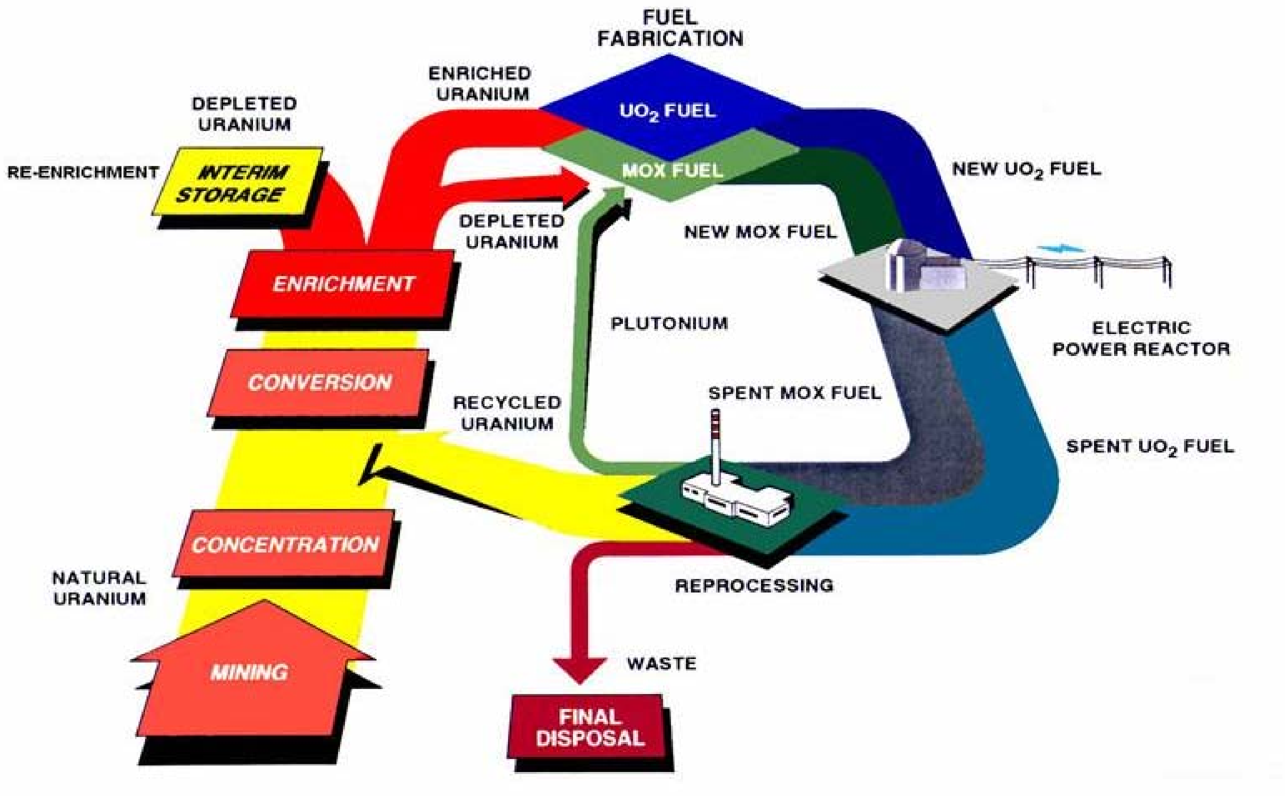
The military fuel cycle

2.40 According to the Australian Safeguards and Non-Proliferation Office (ASNO), the military fuel cycle involves the production of special grades of nuclear material, substantially different to the material used in civil programs, principally plutonium and weapons-grade uranium. While nuclear reactors require uranium enrichment to no more than five per cent, nuclear weapons must have U-235 enriched to about 90 per cent. Weapons-grade plutonium is generally produced in dedicated plutonium production reactors, usually natural uranium fuelled, where irradiated fuel can be removed after short irradiation times. Issues associated with the proliferation of technologies and materials that have military uses, notably uranium enrichment and used fuel reprocessing or plutonium-separation, are addressed in chapter seven.[17]

Figure 2.1 The nuclear fuel cycle



Source Areva

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World electricity production

2.41 As the main civil use for uranium is in generating power, the demand for uranium needs to be assessed in the context of world electricity consumption trends and nuclear power's share of electricity production.

2.42 Global primary energy demand is forecast by the International Energy Agency (IEA) to expand by more than half between 2003 and 2030, reaching 16.5 billion tonnes of oil equivalent by 2030. Energy demand is projected to grow at a rate of 1.6 per cent per year over the period.[18]

2.43 According to the IEA, in 2003 world electricity production was 16 742 terawatt-hours (TWh).[19] As listed in table 2.1, fuel for world electricity production was provided 39.9 per cent by coal, 19.2 per cent by natural gas, 6.9 per cent by oil (for a total of 66 percent from fossil fuels), 16.3 per cent by hydro, 1.2 per cent by combustible renewables (such as biomass), and 0.7 per cent from geothermal, solar and wind combined. Nuclear was the fourth largest fuel source for electricity generation at 15.7 per cent.[20]

Table 2.1 Shares of world electricity production by fuel type in 2003

Fuel type	World production (TWh)	Percentage of world total
Nuclear	2 635.35	15.7
Coal	6 676.24	39.9
Oil	1 151.73	6.9
Natural gas	3 224.70	19.2
Hydro	2 725.82	16.3
Geothermal	53.74	0.3
Solar and wind	68.51	0.4
Combustible renewables	200.70	1.2
Total	**16 741.88**	100

Source IEA, *Electricity Information 2005*, p. I.39.

2.44 Among the fuel types for electricity generation in OECD countries, the strongest growth in the 30 years to 2004 was from solar and wind generation at 17.6 per cent. Aside from renewables, nuclear power experienced the strongest growth, with an average annual growth of electricity generation of 7.8 per cent—larger than the inputs from natural gas (4.2 per cent), [21] coal (2.9 per cent) and hydro (0.8 per cent).

2.45 Electricity generation, which uses some 40 per cent of the world's primary energy supply, is forecast by the IEA to grow at an annual rate of 2.5 per cent between 2002–30, faster than overall energy demand, and rise to 31 657 TWh by 2030. World consumption of electricity is expected to double by 2030.[22]

2.46 Some 1.6 billion people worldwide currently have no access to electricity and demand from developing countries is forecast to more than triple by 2030. In particular, the growth in world demand for electricity is likely to be driven by the industrial modernisation of India and China, with a quarter of the world's projected increase in electricity production to 2030 expected to occur in China. In contrast, growth in electricity demand in the OECD nations will be slower at 1.4 per cent per year.[23]

2.47 According to the IEA, new power plants with a combined capacity of 4 800 gigawatts (GW) are expected to be built worldwide over the period to 2030, with half of these new plants to be built in developing countries. China is expected to require the largest increase, with 860 GW of capacity expected to be added over the period. The IEA estimates that the capacity additions will require investment of over US$4 trillion in new plant construction. Total investment in the electricity sector over the three decades to 2030, including generation, transmission and distribution, is expected to be some $10 trillion.[24]

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Nuclear power in the world's electricity generation mix

2.48 Nuclear power programs, which were launched in the USA in the 1960s and in Europe at the beginning of the 1970s, expanded rapidly in the following two decades. Nuclear power generation rose from 100 TWh in 1970 to 2 000 TWh in 1990, with a total of 399 reactors constructed over the period.[25] The rate of growth slowed in the years following, largely as a reaction to public concern about the safety of nuclear reactors after accidents at Three Mile Island in 1979, Chernobyl in 1986, and Tokaimura in 1999.[26]

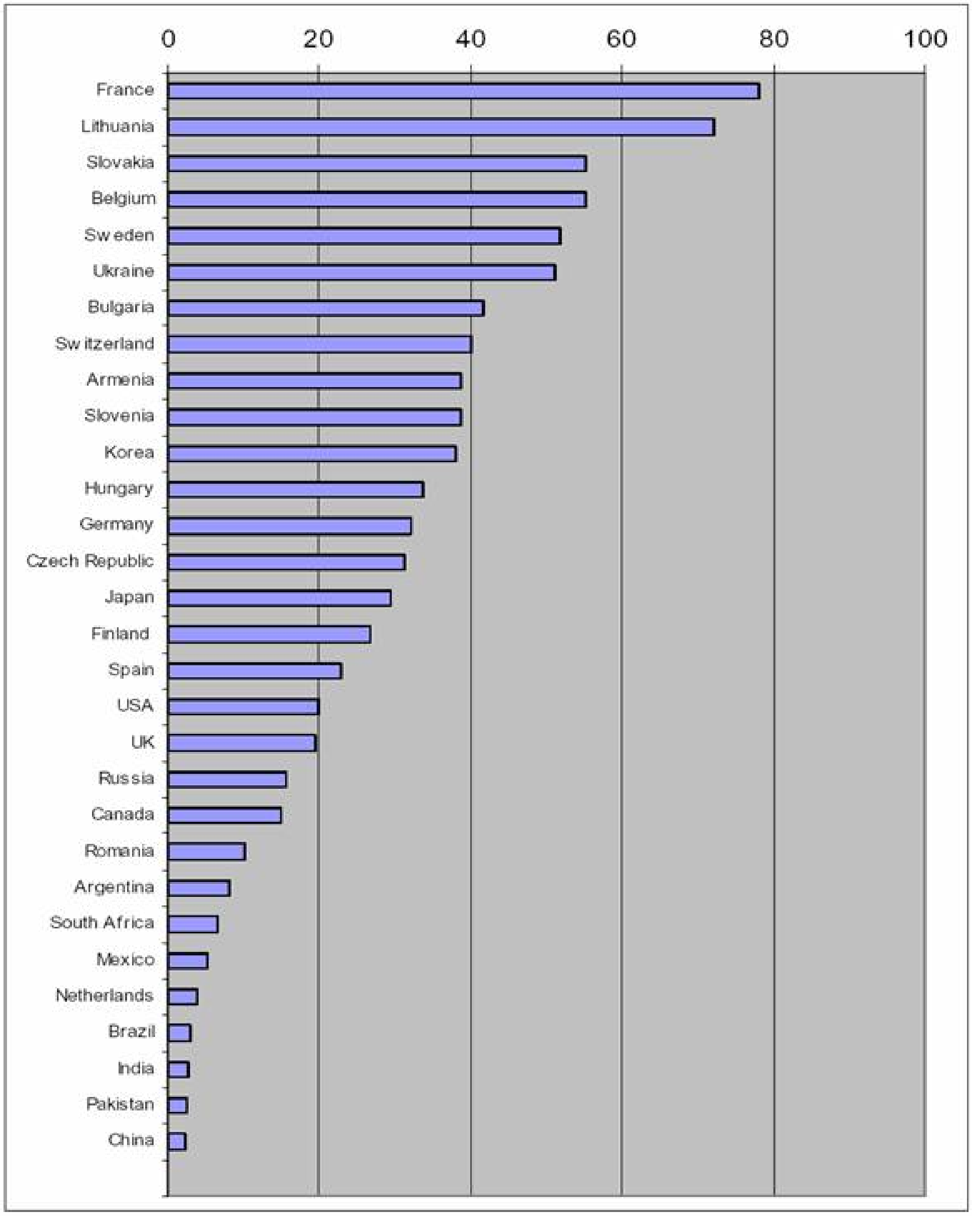
2.49 Information published by the World Nuclear Association (WNA) indicates that there are currently 441 commercial nuclear power reactors operating in 31 countries, with an aggregate installed generating capacity of over 369 gigawatts electrical (GWe).[27] In 2005, nuclear reactors produced 2 626 TWh of electricity which, as noted above, represents approximately 16 per cent of world electricity production.[28] Of the 441 nuclear reactors worldwide, 360 are operated by countries eligible to use Australian uranium under bilateral agreements with Australia, described in chapter eight.[29]

2.50 Uranium requirements to fuel the world's reactors are currently 65 478 tonnes of uranium (tU), or 77 218 t U_3O_8, per year.[30] In 2004, world uranium requirements were accounted for principally by the following regions: North America, which used 20 025 tU (38.6 per cent of the world total); Western Europe, which used 17 775 tU (26.4 per cent); East Asia, which used 12 430 tU (18.4 per cent); and Central and Eastern Europe, which used 9 935 tU (14.7 per cent).[31]

2.51 The share of nuclear power in total electricity generation varies significantly across countries, with some 85 per cent of nuclear electricity produced in 17 OECD countries. Nuclear plants account for more than 22 per cent of electricity production in OECD countries (with 61 per cent from fossil fuel plants), while in non-OECD countries only 6.1 per cent of electricity is generated by nuclear plants (with 72.4 per cent from fossil fuels).[32] Western Europe (33.8 per cent), North America (30.6 per cent) and East Asian countries (19.5 per cent) had the largest shares of world installed nuclear capacity in 2004.[33]

2.52 In many countries nuclear power supplies a substantial proportion of national electricity requirements. Some 15 countries generate more than 25 per cent of their total electricity requirements from nuclear power plants (NPPs). Among these, France generates 79 per cent, Lithuania 70 per cent, Belgium 56 per cent, Sweden 47 per cent, South Korea 45 per cent, and Japan 29 per cent from NPPs. The USA generates 19 per cent and the UK generates 20 percent from nuclear.[34] The nuclear share of electricity in each country operating NPPs is illustrated in figure 2.2.

Figure 2.2 Nuclear share of electricity by country in 2004, per cent of each country's total



Source WNA, *The Global Nuclear Fuel Market —Supply and Demand 2005–2030,* p. 26.

2.53 The world's nuclear reactors, which are commonly classified according to the type of coolant they use, fall into one of three main categories:

- light water reactors (LWR), which represent over 80 per cent of the nuclear capacity installed in the world. There are 362 LWRs currently in operation and these are divided into two groups: pressurised water reactors (PWR), with 268 in operation in 2005, and boiling water reactors (BWR), with 94 in operation;
- pressurised heavy water reactors (PHWR) designed in Canada, known as 'CANDU' technology, with 40 in operation; and
- gas-cooled Magnox and advanced gas-cooled reactors (AGR), with 23 units operating in the UK.[35]

Other reactor types include fast neutron reactors (four in operation) and Russian-designed graphite-moderated light water reactors, of which there are currently 12 in operation.[36]

2.54 In addition to the world's nuclear reactors used to generate electricity, 56 countries operate a total of 280 research rectors and over 220 small reactors are used for naval propulsion.[37]

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The outlook for nuclear power and the demand for uranium

2.55 World demand for uranium, as indicated by the uranium requirements to fuel nuclear reactors, is a function of nuclear electricity generating capacity in operation worldwide, combined with the operating characteristics of individual reactors and the fuel management policies of utilities. Generating capacity is in turn influenced by the outlook for the continued [38] operation of existing NPPs and the prospects for new NPP construction.

2.56 The Committee commences its discussion of these matters by providing an overview of the forecasts for nuclear generating capacity and uranium demand published by the IEA, WNA, International Atomic Energy Agency (IAEA) and the OECD Nuclear Energy Agency (OECD-NEA).

International Energy Agency

2.57 In terms of forecasts for the world electricity generation mix, the IEA predicts that coal and gas-fired generation will provide over 75 per cent of the world's incremental demand for electricity to 2030. Some 40 per cent of new generating capacity is expected to be gas-fired, while coal-fired capacity is expected to account for some 30 per cent of new construction.[39]

2.58 Coal is forecast to remain the predominant fuel for electricity generation, falling slightly to 38 per cent by 2030. However, while coal's market share in the OECD is expected to decline substantially over the projection period (to 33 per cent in 2030), developing countries are expected to increase their use of coal for electricity generation:

> Over the projection period, most new coal-fired power plants will be built in developing countries, especially in developing Asia. Coal will remain the dominant fuel in power generation in those countries because of their large coal reserves and coal's low production costs. Developing countries are projected to account for almost 60% of world coal-based electricity in 2030. China and India together will account for 44% of worldwide coal-based electricity generation.[40]

2.59 The share of oil in world electricity generation is expected to fall to 4 per cent while natural gas and non-hydro renewables (biomass, wind, geothermal, solar, tidal and wave energy) are predicted to increase their market share. Largely driven by government action in the OECD countries to reduce carbon dioxide emissions, non-hydro renewable sources are forecast to increase from 2 per cent in 2002 to 6 per cent in 2030. Of these, wind power's market share is projected to increase the most, with a tenfold increase from 0.3 per cent of global electricity in 2002. Hydropower's share is forecast to fall to 13 per cent in 2030.[41]

2.60 In both the 2004 and 2005 editions of *World Energy Outlook*, the IEA presents a subdued forecast for nuclear power. The IEA predicts that while nuclear generating capacity will increase in absolute terms, its share of world electricity generation will nearly halve—from 17 per cent in 2004 to 9 per cent in 2030. In its reference scenario, the IEA predicts that world nuclear capacity will increase only slightly to 376 GWe in 2030. While new nuclear plants with a combined capacity of 150 GWe are expected to be added by 2030, these will simply replace older reactors being retired in France. The IEA predicts that three quarters of existing nuclear capacity in OECD Europe will be retired by 2030 and over one third of existing plants will be shut down across the entire OECD.[42]

2.61 The IEA notes that three European countries have policies in place to phase out nuclear power (Germany, Belgium and Sweden). The Slovak Republic and the Spanish Government have also canvassed phasing out nuclear power. However, the IEA notes that four OECD countries (France, Finland, Japan and Korea) plan to increase their use of nuclear power.[43]

2.62 While the IEA expects large declines in nuclear production in Europe and an increase in nuclear output in only a few Asian countries, it nonetheless qualifies these predictions by noting that:

> These projections remain very uncertain. Shifts in government policies and public attitudes towards nuclear power could mean that this energy source plays a much more important role than projected here.[44]

2.63 In its *World Energy Outlook* for 2006, the IEA presents a more optimistic forecast for world nuclear generating capacity, concluding that, if public confidence is regained, nuclear power could make a "major contribution" to curbing carbon dioxide emissions, reducing dependence on imported gas and providing baseload electricity supply.[45] In its latest Reference Scenario, the IEA predicts nuclear generating capacity will increase from 368 GW in 2005 to 416 GW in 2030. In its Alternative Policy Scenario, more favourable nuclear policies raise nuclear generating capacity to 519 GW by 2030, so nuclear's share in the world energy mix rises. The IEA also notes that interest in building nuclear reactors has increased as a result of rising fossil fuel prices, which have made nuclear power relatively more competitive. It is concluded that new nuclear plants could produce electricity at less than five US cents per kWh.

2.64 In line with forecasts of increased nuclear generation of electricity, the IEA predicts annual demand for uranium will increase from 68 000 tonnes in 2005 to between 80 000 and 100 000 tonnes by 2030. This demand is expected to be met mainly by new mine production.[46]

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World Nuclear Association

2.65 In its 2005 analysis of *The Global Nuclear Fuel Market*, the WNA develops three scenarios for nuclear power to 2030 (lower, reference and upper scenarios), ranging from a slow decline in nuclear generating capacity to a substantial revival over the period.[47]

2.66 In the reference scenario, the WNA assumes continued improvements in the relative economics of nuclear power generation against coal and gas alternatives, public acceptance problems for nuclear begin to diminish, but the concerns about global warming fail to translate into a major shift in the electricity generation mix. In the reference scenario, the WNA predicts that nuclear generating capacity will rise to 378 GWe by 2010 and then grow to 446 GWe by 2020 and to 524 GWe by 2030. This represents an annual average growth rate in nuclear generating capacity of 1.4 per cent over the period. Given that world electricity demand growth is forecast, as noted above, to be substantially greater than this at 2.5 per cent, the WNA accepts that the nuclear share of total generation is likely to decrease substantially to around 13 per cent of the world total in 2030.[48]

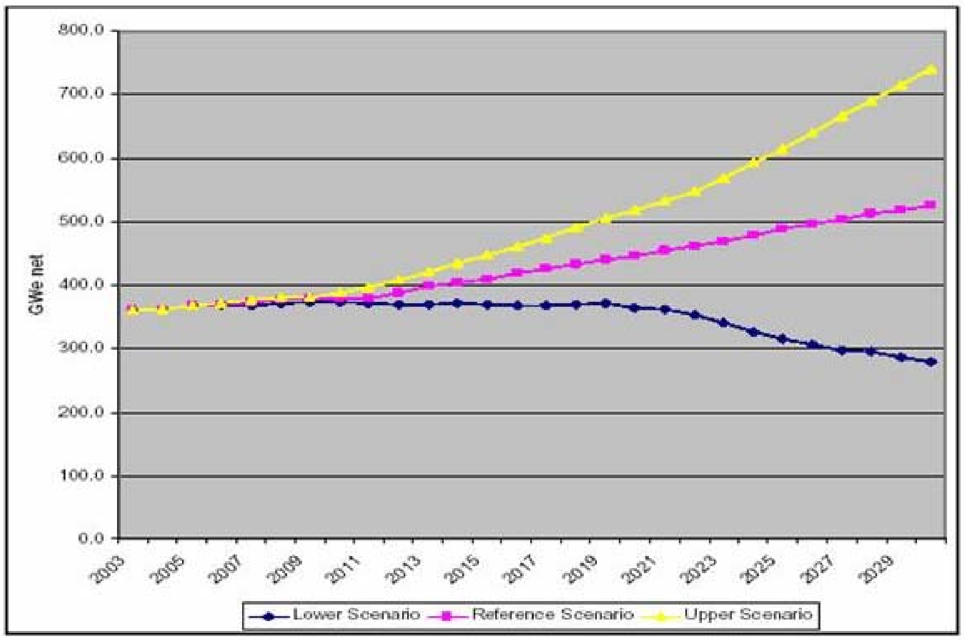
2.67 In contrast to the IEA's virtually static outlook for nuclear generating capacity, the WNA's reference case predicts nuclear capacity will rise by 157 GWe in the period to 2030. The WNA argues that:

> The IEA assessment of nuclear shutdown capacity of 150 GW by 2030 looks very high, given recent experience. Although smaller and older reactors will shut down in many countries and politically-inspired closures may take place in others, the current stock of reactors is generally performing very well in economic terms and operating lives are being extended … Other features to note include the extent of actual and planned capacity increases and the widespread development of life extension programs for existing reactors as they are refurbished (Belgium, France, Netherlands, Spain, Sweden, USA).[49]

2.68 The IEA's reactor retirement schedule is also said to assume that nuclear's economic position and public acceptance deteriorates, so existing reactors are retired earlier.[50]

2.69 In the WNA's upper scenario, world nuclear capacity is forecast to be 740 GWe in 2030, which would maintain nuclear's share of world electricity at the current levels of 16–17 per cent. In the lower scenario, nuclear generating capacity still rises slightly to 372 GWe by 2010, but then falls away to 279 GWe in 2030.[51] Figure 2.3 illustrates world nuclear generating capacity to 2030 in the three WNA scenarios.

Figure 2.3 World nuclear generating capacity to 2030

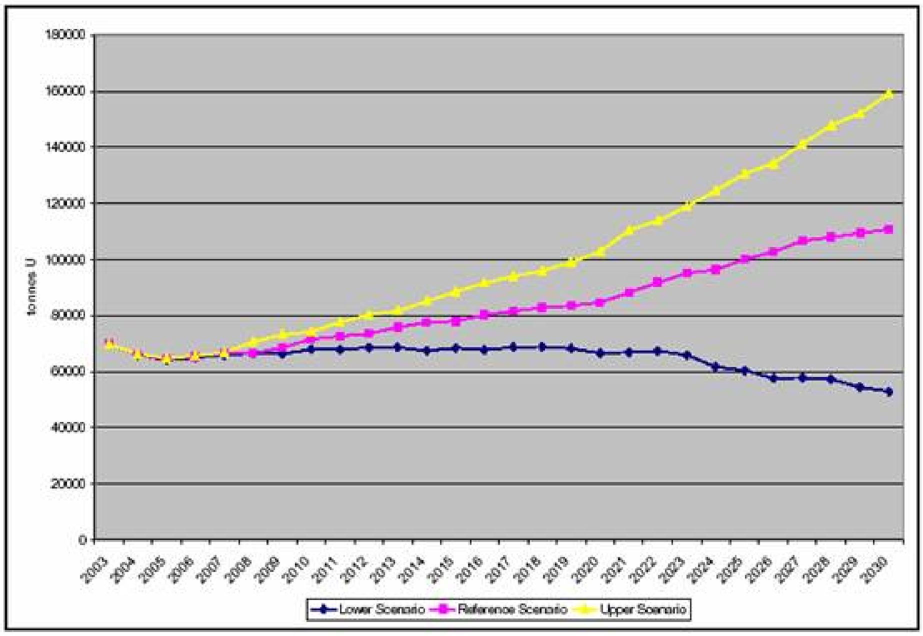


Source WNA, *The Global Nuclear Fuel Market—Supply and Demand 2005–2030,* p. 64

2.70 Based on its scenarios for nuclear generating capacity, the WNA has developed demand forecasts for uranium, which take into account a range of factors including the life of existing reactors and prospects for construction of new NPPs. In the reference scenario, reactor uranium requirements are expected to rise from 66 000 tU in 2004 to 71 500 tU in 2010, 84 700 tU in 2020 and to 110 800 tU in 2030, with an annual growth rate of 2 per cent over the period.[52] The prospects for new plant construction are discussed further in the section commencing on page 36.

2.71 In the upper scenario, uranium requirements are forecast to be 159 200 tU in 2030, while in the lower scenario they are 52 800 tU in 2030.[53] Figure 2.4 depicts the WNA's forecasts for uranium requirements in the three scenarios to 2030.

Figure 2.4 Uranium requirements to fuel nuclear reactors to 2030



Source WNA, *The Global Nuclear Fuel Market—Supply and Demand 2005–2030,* p.82.

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International Atomic Energy Agency and OECD Nuclear Energy Agency

2.72 In the joint IAEA and OECD-NEA publication *Uranium 2005: Resources, Production and Demand,* which is widely cited as an authoritative study and commonly referred to as the 'Red Book', the agencies provide 'low' and 'high' estimates for future nuclear power deployment to 2025.

2.73 The low projection assumes that the present barriers to nuclear deployment continue to prevail in most countries, including low electricity demand growth, continued public opposition to nuclear power and inadequate mechanisms for nuclear technology transfer and project funding in developing countries. The low projection assumes no new nuclear power plants are built beyond what is currently under construction or firmly planned, and old NPPs are retired on schedule.[54] Similar to the IEA reference scenario described above, the agencies' low projection assumes expansion for nuclear power in East and South Asia, contraction in Western Europe and stability in North America.[55]

2.74 In contrast, the high projection assumes a moderate revival of nuclear deployment taking into account global concerns over climate change and implementation of some policy measure to facilitate deployment such as enhancing technology transfer to developing countries.[56]

2.75 The agencies forecast that by 2025 world nuclear capacity will grow to 449 GWe in the low demand case and 533 GWe in the high demand case. The low case represents growth of 22 per cent and the high case represents an increase of 44 per cent from current capacity. Accordingly, uranium requirements are projected to rise to between 82 275 tU and 100 760 tU by 2025, representing 22 per cent and 50 per cent increases respectively, compared to the 2004 total.[57]

2.76 The Red Book qualifies its projections for nuclear capacity and uranium demand, noting that there are 'great uncertainties in these projections as there is an ongoing debate on the role that nuclear energy will play in meeting future energy requirements.'[58]

2.77 In general, the IAEA notes 'a sense of rising expectations for nuclear power' and states that its current projections are markedly different from even four years ago.[59] The IAEA explains that its revised forecasts have been driven by :

> … nuclear power's performance record, by growing energy needs around the world coupled with rising oil and natural gas prices, by new environmental constraints including entry-into-force of the Kyoto Protocol, by concerns about energy supply security in a number of countries, and by ambitious expansion plans in several key countries .[60]

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The prospects for nuclear power and new plant construction

2.78 Evidence to the Committee was sharply divided on the prospects for future nuclear capacity and particularly on the outlook for new NPP construction.

2.79 The IAEA and OECD-NEA state that the key factors that will influence future nuclear electricity capacity and construction include:

- projected growth of base load electricity demand;
- the cost-competitiveness of new NPPs and fuel compared to other energy sources, particularly with deregulation of electricity markets;

- concerns about security of fuel supplies;
- public attitudes and acceptance towards the safety of nuclear energy and proposed waste management strategies;
- concerns about the connection between the civil nuclear fuel cycle and military uses; and
- environmental considerations, in particular consideration of the role nuclear energy can play in reducing air pollution and greenhouse gas emissions.[61]

2.80 For the IAEA and OECD-NEA, 'evidence suggests that many nations have decided that the balance of these factors supports construction of new nuclear power plants', with significant building programs now underway in China, India, Japan and the Russian Federation.[62]

2.81 The installation of new nuclear capacity will increase uranium requirements where new construction outweighs reactors retirements. According to information published by the WNA, at the end of May 2006 there were 27 nuclear reactors under construction in 11 countries (which will have a generating capacity of 21 GWe), with a further 38 planned or on order (40.7 GWe) and another 115 reactors are proposed (65.4 GWe).[63] During 2003 and 2004 seven new reactors commenced to produce electricity, while 11 reactors were permanently shut down (eight in the UK).[64] The world's nuclear power reactors, reactors being constructed, planned and proposed, and their uranium requirements are listed by country in appendix D.

2.82 While existing NPPs are clustered in Europe, the US and Japan, submitters observed that new construction is currently centred in the Asian region, notably China, India and South Korea, with 18 plants (or 66 per cent of the total) currently under construction.[65]

2.83 The IAEA notes that 'current expansion, as well as near-term and long-term growth prospects, is centred in Asia', and that 20 of the last 30 reactors to have been connected to the grid were in Asian countries.[66] The WNA also predicts that over the next few years nuclear construction will be concentrated in Asia (China, South Korea and India), and to some extent in Russia and other Eastern European countries.[67]

2.84 China currently has four reactors under construction and is planning a fivefold increase in nuclear capacity from 6.6 GWe to 40 GWe by 2020.[68] The expansion will require the construction of two reactors every year over the period.[69] India is currently constructing eight reactors and intends to triple nuclear generating capacity to 20 GWe by 2020. India also plans that by 2050 nuclear power will contribute 25 per cent of the country's electricity generation—a hundredfold increase on 2002 nuclear generating capacity.[70] Japan currently has one plant under construction and plans to build another 12 reactors. Japan also plans to expand nuclear's contribution to 41 per cent of total electricity generation by 2014, up from 29 per cent currently.[71] Indonesia will commence construction of its first NPP in 2010, to be completed by 2016, with plans for a further three NPPs to be constructed by 2025.[72] Plants are also being considered in Vietnam, Malaysia, Poland, Belarus, Turkey, Serbia and Egypt.[73]

2.85 Elsewhere, the Russian Federation plans to raise nuclear capacity from 22 GWe to 40–45 GWe by 2020, and has four reactors currently under construction.[74] Finland has commenced construction on a new plant—the first new nuclear construction in Western Europe since 1991, and France plans to commence construction of a new reactor (the European Pressurised Water Reactor) in 2007.[75]

2.86 Several submitters expressed 'optimism and enthusiasm about the opportunities for nuclear energy', pointing variously to the:

- growing world demand for electricity;
- life extensions and refurbishments of existing reactors;
- increasing concern about greenhouse gas emissions and security of fuel supply; and
- plans for significant new NPP construction in several countries and renewed interest in some industrialised nations.[76]

For Cameco, these favourable trends are expected to result in 470 nuclear reactors being in operation by 2015.[77]

2.87 Compass Resources argued that:

> … driven partly by high fossil fuel costs and the greenhouse gas reduction imperative … it seems likely that nuclear energy will play an increasing role in meeting the growth in world energy demand.[78]

2.88 The MCA cited a number of recent developments it claims indicates that nuclear electricity generation will continue to grow:

- during 2004 seven new reactors were connected to electricity grids overseas and another was restarted after major refurbishment;
- Japan's newest and largest Advanced Boiling Water Reactor has commenced commercial operation bringing the country's number of reactors in commercial operation to 54. In addition, grid connection of the first unit of a further nuclear power plant is expected with commercial operation in October 2005. At least three more units are expected to be built or are planned to be built at this site;

- the 20th nuclear power reactor in the Republic of Korea (and sixth Korean Standard Nuclear Power Plant) was connected to the grid in December 2004 and a further four plants are due to come on line over the period 2010–2013;
- the Republic of Korea is also establishing a joint venture in Kazakhstan to mine uranium;
- in a speech given by the President of the United States to the April 2005 National Small Business Conference, President Bush said:
- … the first essential step toward greater energy independence is to apply technology to increase domestic production from existing energy resources. And one of the most promising sources of energy [for the USA] is nuclear power;
- public sentiment in Sweden and to an extent in the UK, among others, appears to be changing in favour of nuclear power according to various polls. In Sweden, which has faced the prospect of phasing out nuclear power, public opinion is now 80 per cent favourable. The change reflects public concern and media coverage related to energy security and environmental concerns, particularly regarding climate change;
- various nuclear generators in Europe and the USA are implementing capacity upgrades and extending operating licenses—one third of the current 103 US plants have had 20 year licence extensions; and
- the chief executives of 20 European Union energy companies recently called upon governments to make nuclear power a central part of their energy policies on the basis of energy security and environmental protection.[79]

2.89 Mr Lance Joseph, Australian Governor on the Board of the IAEA from 1997 to 2000, asserted that:

> The civilian nuclear industry is poised for world-wide expansion. Rapidly growing demand for electricity, the uncertainty of natural gas supply and price, soaring prices for oil, concern for air pollution and the immense challenge of lowering greenhouse emissions, are all driving a fresh look at nuclear power. At the same time, fading memories of Three Mile Island and Chernobyl is increasing confidence in the safety of new reactor designs. So the prospect, after a long hiatus, of new nuclear power construction is real, with new interest stirring in countries throughout the world.[80]

2.90 Similarly, the Australian Nuclear Forum (ANF) proposed that use of nuclear power will expand and demand for reactor fuel will increase as:

> … the fear of more 'Chernobyl's' recedes and it becomes clearer that fossil fuel plants cannot be made sufficiently environmentally friendly and that the 'alternative' methods of generating electricity prove to be incapable of meeting demand.[81]

2.91 ANSTO argued that given the expansion plans announced by several countries and nuclear's improved economic competitiveness due to fuel cost increases and emission constraints impacting upon fossil fuels:

> It seems clear … that the proportion of the world's electricity that is derived from nuclear power will increase from present levels during the next two or three decades, and the demand for uranium will increase correspondingly.[82]

2.92 The UIC cited forecasts prepared by International Nuclear Inc (iNi), an independent consulting organisation which specialises in uranium supply-demand-price trends, which broadly supports the WNA's conclusions summarised above. iNi forecasts that uranium oxide requirements will rise to nearly 84 000 tonnes per year by 2010 and to almost 91 900 tonnes by 2020. These forecasts are said to be conservative in that they make no allowance for a potential increase in nuclear generation arising from concerns over greenhouse gas emissions from other forms of electricity generation.[83]

2.93 ANSTO also noted that, to date, plans for new nuclear build have been driven primarily by energy demand and not by greenhouse gas mitigation concerns.[84] The Department of the Environment and Heritage (DEH) also noted that, in addition to the 'massive growth in energy demand' in India and China, countries expanding the use of nuclear power are doing so for reasons of energy security.[85]

2.94 Energy Resources of Australia Ltd (ERA) also emphasised the role of energy security, arguing that 'market behaviour has fundamentally changed, with security and stability of fuel supply becoming the most important issues for nuclear utilities.'[86] ERA noted that utilities are increasing plant output and operating efficiencies, which are in turn increasing uranium demand. Power plant construction is also being seen as an important option in responding to greenhouse gas emissions.[87]

2.95 ERA also pointed to new NPP construction around the world. It was argued that while no new orders have yet been placed in North America, significant pre-order work is being undertaken by utilities, including applications for early site permits and the streamlining of regulatory processes. In addition, countries such as Chile, which were previously opposed to nuclear power, are now considering the nuclear option.[88]

2.96 In 2002 the US Government launched Nuclear Power 2010 (NP 2010), a public-private partnership to identify new sites for plants, develop advanced reactor technologies and test new regulatory processes. NP 2010 assumes that the first new power plant order will be placed in 2009 and construction will be completed by 2014. Ten energy companies or consortia in the US have indicated that they will apply to build 16 new NPPs.[89]

2.97 In contrast to these assessments, groups critical of nuclear power argued that construction of new reactors is unlikely to keep pace with retirements. The Australian Conservation Foundation (ACF) argued that there is likely to be no significant expansion of global nuclear power or total uranium demand. ACF predicted that the number of nuclear power plants across the western world will decline over the next 25 years:

> The number of reactors across the USA and western Europe peaked some 15 years ago and is highly likely to continue to decline with the scheduled closure of some 50 nuclear power plants in western Europe across a range of countries, given government legislation, government policy and government schedules of closure based on ageing and unsuitability for extension of life for existing reactors.[90]

2.98 Specifically, the ACF argued that:

- across the EU-15 countries in the last 25 years only two NPPs have been ordered and started construction (France in 1991 and Finland in 2004);
- in the expanded EU-25 group of countries, Finland has the only new plant under construction and there is one other at a planning stage, in France;
- the number of reactors in the EU-25 will continue to decline with legislative nuclear power phase outs in Germany and Belgium, to see 25 NPPs close by 2025;
- nuclear phase out policies exist in Spain, the Netherlands and Sweden, which will see a further 21 NPPs close by 2030;
- in the UK, nine NPPs are set to close from 2007 to 2020 due to the ageing of plants that are unsuited to life extensions; and
- in the USA, despite Presidential support for nuclear power, there has not yet been an order for a new reactor.[91]

2.99 It was argued that the only prospects for significant expansion of nuclear power are in India and China. ACF noted that in China the nuclear share of electricity generation will 'only increase from the present 2% toward some 6–10% by 2025'.[92] While it was conceded that this represents a significant increase in nuclear generating capacity, it was argued that this 'shows that nuclear is not a major answer to electricity supply in China in the foreseeable future'.[93]

2.100 Friends of the Earth (FOE) also stated that the future of nuclear power is uncertain. It was argued that, assuming a reactor life of 40 years, a total of 280 reactors will need to be built over the next 20 years to offset reactor shutdowns. FOE claimed that 'even if lifetime extensions significantly increase the average reactor lifespan, it is doubtful whether new reactors will keep pace with shut downs.'[94]

2.101 Consistent with the IEA view, ABARE also argued that despite a substantial amount of capacity expected to be added in Japan, China, India, the Russian Federation and South Korea, 'total growth in nuclear capacity will be largely offset by reactor retirements, particularly in Europe.'[95] ABARE predicted that world demand for uranium will rise by one per cent over 2005 and 2006.

2.102 More broadly, the Uniting Church (Synod of Victoria and Tasmania) claimed that demand for uranium will fall over time due to: legislative phase outs of nuclear power in some countries; investment in nuclear power being overly risky; 'unresolved' waste storage issues; safety and health problems; and security concerns associated with use of nuclear power.[96]

2.103 ACF also noted that the IAEA has predicted that nuclear's share of world electricity supply will drop to 12 per cent in its low forecast by 2030. Cameco agreed that there may be a decline in the proportion of the world's energy supplied by nuclear, given the predicted overall growth in energy demand. However, it was argued that total nuclear capacity will still increase, as was concluded in the forecasts summarised above.[97]

2.104 Mr Ian Hore-Lacy, General Manager of the UIC, observed that there is a renewal of interest in nuclear power in Europe, beyond the new plants announced for Finland and France:

> I do not see any reduction in nuclear capacity or interest in Europe. I note the policies of the German government, I note the policies of the Swedish government and I note that those policies are timed, as it were, to possibly take effect way into the future, several changes of government away. In other words, for Germany it will be about 2010 before their current policies matter, if they last that long. In fact, they might not last till Christmas.[98]

2.105 The UIC argued that it is now well understood that German policies to phase out nuclear power, while simultaneously increasing renewables to 20 per cent of total electricity, will be impossible without also adding significant new capacity from fossil fuel plants. However, this will make the country's carbon dioxide reduction target under the Kyoto Protocol simply unattainable.[99] More generally, Nova Energy argued that in both Germany and the UK there is opposition to nuclear phase outs as renewables cannot provide baseload power requirements. The Committee addresses these matters further in chapter four.

2.106 ABARE noted that, rather than shutting down reactors, some European countries are now reconsidering nuclear energy and others are looking to extend the life of existing reactors by up to 20 years.[100] Claims of renewed public support for nuclear power in Europe were also supported by a range of opinion polls conducted in countries including Sweden, Germany and the Netherlands.[101]

2.107 In general, BHP Billiton expressed confidence that:

> … all credible projections of world energy demand and supply options indicate that uranium does have an important role to play in meeting the world's energy needs. We believe … that the meeting of these needs will require a mix of fuels, fossil fuels, uranium and renewable energy sources.[102]

2.108 Specifically, BHP Billiton estimated that, as a proportion of all energy sources, nuclear power will increase. As a consequence, the company predicts a 60 per cent increase in demand for uranium over the next decade.[103]

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Existing plant performance and uranium demand

2.109 As mentioned above, in addition to installed nuclear capacity and the outlook for new plant construction, the demand for uranium is also influenced by the performance and operating characteristics of reactors, and fuel management policies of utilities. Among these is the capacity factor (or 'load factor') of reactors, which is the actual power generated during a period of time expressed as a percentage of the power which would have been generated if the plant had operated at full power continuously throughout the period. The WNA explains that a rise in load factor is a main influence on demand for uranium (and enrichment), with a nearly linear relationship between load factor and fuel requirements.[104]

2.110 In addition to the prospects for new nuclear build, the UIC, ANSTO, Paladin Resources and Areva emphasised the substantial increases in nuclear generating capacity that have been achieved in recent years due to gains in existing NPP availability and productivity. Areva stated that while installed nuclear capacity increased by only 1.2 per cent over the period 1989 to 2004, following the Chernobyl accident, nuclear power generation continued to grow at an average annual rate of 2.1 per cent over the period due to efficiency improvements at existing reactors. Thus, the average reactor capacity factor rose from 67 per cent in 1989 to over 80 per cent by the end of 2004.[105]

2.111 Similarly, Dr Mohamed ElBaradei, Director General of the IAEA, has observed that in 1990 nuclear plants on average were generating electricity 71 per cent of the time, but by 2003 availability had increased to 81 per cent. This represented 'an improvement in productivity equal to adding more than 25 new 1 000 megawatt nuclear plants—all at relatively minimal cost.'[106] Furthermore, Professor Leslie Kemeny noted that by 2005 reactor capacity reached a record average of 91.5 per cent in the USA.[107]

2.112 The UIC noted that the increase in output from existing plants over the past five years has amounted to 235 TWh, which is equal to the output from 33 large new nuclear plants.[108] The increased productivity and availability of NPPs lead to the gains in output mentioned, which in turn leads to an increased demand for uranium.

2.113 A significant increase in output has also been attained through 'up-rating' the capacity (i.e. increasing the power levels) of some plants, by up to 15–20 per cent. According to the WNA this has been a particular focus in the USA, Sweden and Eastern European countries.[109]

2.114 The UIC also noted that a considerable number of reactors are being granted life extensions. For example, in the USA, the Nuclear Regulatory Commission has now approved license extensions for 30 NPPs, adding 20 years to the originally licensed plant life of 40 years. Some 85 NPPs in the USA are eventually expected to be granted licence renewals.[110] The IAEA has reported that approximately three quarters of the USA's 104 NPPs have either received, applied for, or stated their intention to apply for a license extension.[111] Furthermore, ANSTO noted that 60 years is now seen as the minimum operating lifetime for reactors in Japan.[112]

2.115 While reactors are being operated more productively, with higher capacity factors and power levels mentioned above, efficiencies are dampening demand for uranium. For example, increased burn up of nuclear fuel has reduced uranium requirements and increased enrichment requirements. Many utilities are increasing the initial enrichment of their fuel (e.g. from 3.3 per cent to more than 4 per cent U-235) and then burning the fuel longer or harder to leave only 0.5 percent U-235. Over the 20 years from 1970, there was a 25 per cent reduction in uranium demand per kWh output in Europe.[113]

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Supply of uranium

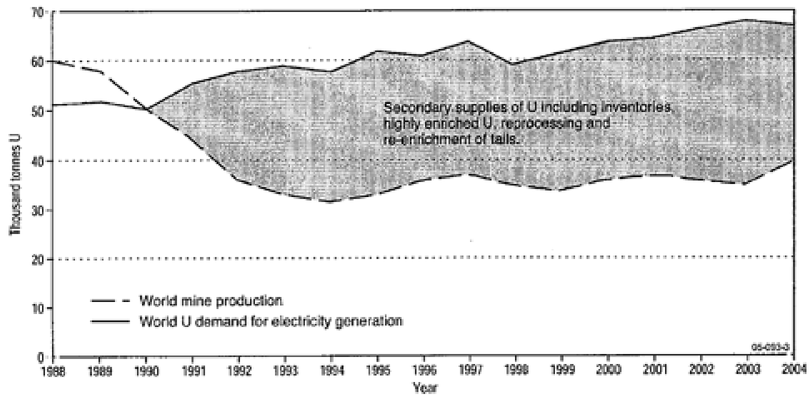
2.116 At the end of 2004 commercial nuclear reactors in operation worldwide required 67 320 tU (or 79 390 t U_3O_8), of which world uranium mine production supplied 40 263 tU, or approximately 60 per cent of requirements.[114] This was an improvement on the previous year, in which world mine production (35 772 tU) provided only 52 per cent of world demand (68 435 tU).[115]

2.117 Coverage of annual uranium requirements by mine production rose to an estimated 64.9 per cent in 2005 due to an increase in production levels to 41 869 tU, coupled with a slight decline in global uranium requirements to 64 600 tU.[116]

2.118 World uranium mine production (also referred to as primary production) is insufficient to meet uranium requirements, meeting an average of only 57 per cent of annual requirements over the past 14 years. The shortfall has been met by secondary sources of supply since the late 1980s. Secondary supplies are essentially inventories, stockpiles and recycled materials of various types. These supplies can be regarded as previous uranium production held off the commercial nuclear fuel market for an extended period.[117]

2.119 Figure 2.5 shows the relationship between world mine production and uranium requirements for electricity generation (including the former Soviet Union and Eastern bloc countries). The continuous line shows world demand for uranium and the dashed line shows mine production. The shaded region between demand and primary production illustrates the balance of supply provided by secondary sources.

Figure 2.5 Comparison of world uranium mine production and world uranium demand for electricity generation, 1988–2004



Source Geoscience Australia , *Submission no. 42* , p. 12.

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Secondary sources of supply

2.120 While secondary supply sources are a common feature in commodity markets, Geoscience Australia (GA) noted that 'uranium is unique among energy fuel resources in that a significant portion of demand is supplied from secondary sources rather than mine production.'[118] Fuel requirements in excess of world mine production are currently met from the following secondary sources, in decreasing order of importance:

- stockpiles of natural and low-enriched uranium (LEU), held by electricity utilities and conversion plants—up to 30 per cent of total world demand;
- down-blending of highly enriched uranium (HEU) removed from decommissioned weapons and military stockpiles in both the Russian Federation and the USA—10 to 13 per cent of world demand. Current arrangements run up to 2013, covering the period of Moscow Treaty reductions, described below;
- re-enrichment of depleted uranium tails, which involves recovering the residual fissile material from depleted uranium tails at enrichment plants—3 to 4 per cent of world demand. This is only commercially viable if there are enrichment plants with low operating costs and available excess capacity; and
- uranium from reprocessing used reactor fuel (known as reprocessed uranium or 'RepU')—approximately 1 per cent of world demand.[119]

In addition, some 2–3 per cent of the demand for reactor fuel is met by the use of recycled plutonium in the form of MOX.[120]

2.121 In February 1993 the Russian Federation and US Governments entered into an HEU Purchase Agreement for the disposition of HEU extracted from nuclear weapons (the so-called 'Megatons to Megawatts' program).[121] The Agreement committed Russia to convert (down-blend) 500 tonnes of HEU from its dismantled nuclear warheads into LEU for civilian use. Under the Agreement, the US Enrichment Corporation receives deliveries of LEU from the Russian Federation for sale to commercial NPPs. ABARE noted that this quantity of HEU is equivalent to approximately 150 000 tonnes of natural uranium, or twice annual world demand.[122] The HEU Purchase Agreement will run for 20 years until 2013 and is supplying the equivalent of some 9 000 tonnes of natural uranium per year on average.[123]

2.122 Silex observed that the Russian HEU material sold to the US has meant that: 'More than 10 000 Russian nuclear warheads have been converted to electricity through this path.'[124] The MAPW (WA Branch) cited research by the Nuclear Energy Institute which found that former Russian warheads were powering one in ten US homes in 2004.[125] A smaller amount of ex-military uranium from US sources is also beginning to become available.

2.123 While it is anticipated that secondary supplies will continue to play a major role in supplying commercial markets, GA and other submitters observed that there is now considerable uncertainty about the quantities of secondary supplies likely to be available for the market in the future. One source of uncertainty is that many countries are unable to provide detailed information on government (i.e. ex-military) and utility stockpiles due to confidentiality concerns.[126]

2.124 ASNO observed that of the secondary sources of supply listed above, only re-enrichment of depleted uranium tails can be increased to maintain supply in the event of a major drawdown of utility inventories. It is expected that the stockpiles accumulated by utilities in the 1970s and 1980s will be exhausted over the next decade and the supply of HEU retired from weapons will also fall away, unless more is released from weapons stockpiles.[127]

2.125 Submitters commented that the supply of Russian HEU is gradually coming to an end. The Russian Federation is now choosing to retain HEU to meet its own demand for electricity generation, which cannot be met by its own mine production, and hence no follow-on HEU purchase agreement is expected.[128] Summit Resources argued that while secondary sources, particularly the downblending of weapons grade material 'will continue for some time … it is diminishing in its contribution and the industry is expanding. So a large shortfall of uranium is coming.'[129]

2.126 Evidence suggested however that there may be additional secondary supplies released on to the market. For instance, ABARE noted that the US and Russian Federation are each committed to holding stockpiles of some 26 000 tonnes of U

3O 8 until 2009, which could then be released to the market. The availability or unavailability of these secondary supplies could significantly influence the uranium spot market, although ABARE commented that should the US decide to release its stockpiles it is expected that it would do so in a manner that would minimise market impact.[130]

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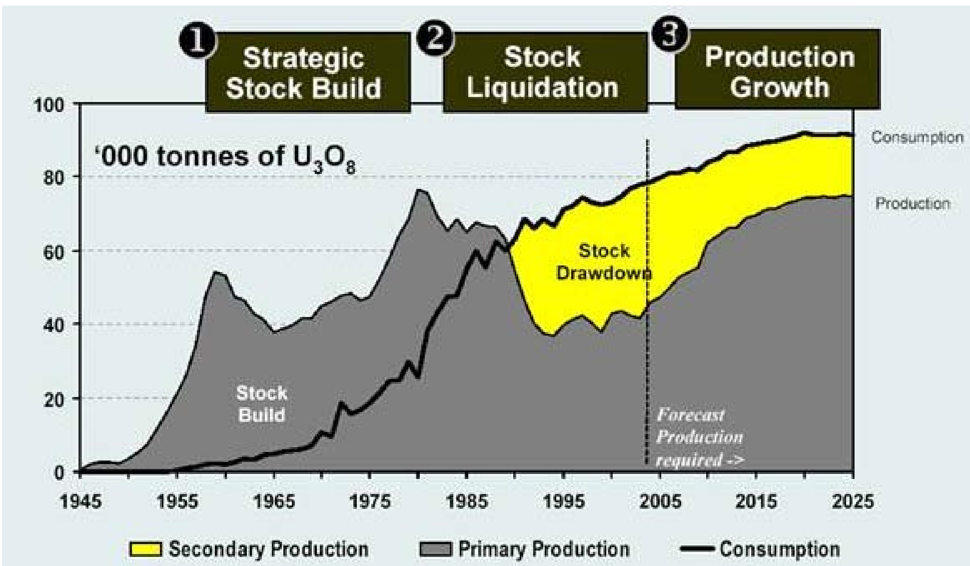
Primary production

2.127 The WNA describes four key periods in the history of uranium mine production:

- a military era, from 1945 to the late 1960s, in which production rose rapidly to satisfy military requirements for HEU and plutonium. Demand from this source fell away sharply from 1960 onwards and production halved by the mid 1960s;
- a period of rapidly expanding civil nuclear power, lasting from the late 1960s to the mid 1980s, in which uranium production rose again as reactors were ordered. Production peaked in 1980 and stayed above annual reactor requirements until 1985;
- a period dominated by inventory over-hang, extended by supply from the Newly Independent States, lasting from the mid 1980s up to 2002; and
- the current period, which commenced in 2003, in which the market has reacted strongly to the perception that secondary supplies are beginning to run out and that primary production needs to rise sharply to fill more of the gap still evident with reactor requirements.[131]

2.128 Figure 2.6 depicts uranium oxide consumption and production from 1945 to the present and includes a forecast developed by WMC Resources (acquired by BHP Billiton in July 2005) to 2025. The periods of production history listed above are evident in the diagram.

Figure 2.6 Uranium oxide consumption and production from 1945 and forecast to 2025



Source WMC Resources Ltd, *Olympic Dam's Position in the World Uranium Industry* , Presentation by Mr Andrew Michelmore , December 2004, p. 12.

2.129 The WNA's assessment was corroborated in evidence which argued that the industry anticipates that secondary supplies are beginning to run out and that primary production must now rise to meet demand. Specifically, the UIC stated that the proportion of uranium demand met by secondary supplies is expected to fall from 41 per cent in 2004 to about 17 per cent in 2025, and hence 'additional primary production will be needed to meet uranium demand.'[132]

2.130 Similarly, GA argued that:

> … there is an emerging consensus that, by about 2020, there will be a considerably greater requirement for primary uranium from mine production. Given the long lead times for environmental clearances and permitting of new uranium mines, new discoveries will be needed in the short to medium term.[133]

2.131 Areva also argued that the decline in secondary supplies will require the discovery of more uranium resources and additional production:

> There is no doubt that the weapons grade material coming on stream to be used as fuel was equivalent to several new world-class uranium deposits … When that stops— and the world's energy needs will continue to increase—that part of the supply will basically diminish and it will gradually disappear over a few years. Therefore, we will have to find significantly more resources and reserves to mine in order to fill that gap.

> Every year, the uranium usage in power plants is increasing reasonably significantly. The number of power plants being [constructed] or on order at this point in time is certainly quite high compared with what it has been over the previous 10 years. The requirement for uranium will become very significant over time and suddenly this supply will not be there any more.[134]

2.132 Paladin Resources argued that:

> World demand for uranium to provide fuel for existing and new plants now under construction exceeds world uranium production twofold … There is ample evidence that the inventory disposals are coming to an end and the industry must now elicit new uranium supplies to meet present demand and to underwrite future nuclear power expansion.[135]

2.133 Heathgate Resources, owners of the Beverley uranium mine in South Australia, submitted that:

> For the first time in 30 years, the uranium business is moving towards primary production. The need to resume uranium exploration is required in order to find and develop more low cost uranium reserves and resources.[136]

2.134 ASNO argued that because of diminishing secondary supplies:

> Clearly expansion of the international uranium mining industry will be required to meet future demand even if there is no significant expansion of the nuclear power industry.[137]

2.135 Drawing on analysis by iNi, the UIC argued that because of the decline in secondary supply, between 2004 and 2020, annual primary production of uranium oxide will have to rise by nearly 28 000 tonnes, or 60 percent, to 74 500 tonnes in order to meet demand.[138]

2.136 The view that primary production must rise to meet future requirements was supported by the WNA, which concludes that:

> The ending of the HEU deal between Russia and the United States in 2013 may prove to be a major watershed, and it is clear that primary production must rise substantially to make up the loss of this source of supply.[139]

2.137 Moreover, in its forecasts of world uranium requirements and supply to 2030, the WNA argues:

> It is clear … that, in addition to current uranium reserves, there is a requirement for the discovery of new uranium deposits to meet demand in the longer term future.[140]

2.138 Similarly, the IAEA and OECD-NEA state that projected primary production capability to 2025 indicates that secondary sources will continue to be needed to meet projected requirements. The 2005 Red Book states that after 2015 secondary sources are expected to decline in availability and that reactor requirements will have to be increasingly met by expanding production from existing mines, developing new mines or introducing alternate fuel cycles:

> A sustained near-term strong demand for uranium will be needed to stimulate the timely development of needed Identified Resources. Because of the long lead-times required to identify new resources and to bring them into production (typically in the order of 10 years or more), there exists the potential for the development of uranium supply shortfalls and continued upward pressure on uranium prices as secondary sources are exhausted. The long lead times required to bring resources into production continues to underscore the importance of making timely decisions to increase production capability well in advance of any supply shortfall.[141]

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Uranium price

2.139 Nova Energy stated that the relative availability of primary and secondary sources of supply of uranium, combined with the level of demand from military and civilian users have determined the market price for mined uranium since the 1940s. Nova Energy cited research which identifies three distinct periods of uranium price history:

- a weapons procurement era (1940–1969);
- an inventory accumulation era (1970–1984); and
- an inventory liquidation period (1985–2004).[142]

2.140 During the weapons procurement and inventory accumulation periods uranium was supplied almost entirely from mine production and the average spot market price was US$54.18/lb U_3O_8 (in 2005 dollars), with a peak of $110/lb U_3O_8 in 1976. During the inventory liquidation era, spot prices fell to an average US$14.57/lb U_3O_8 as secondary sources became available for sale on the market. Nova Energy argued that the effect of the inventory liquidation was to artificially depress the price of uranium in a period when mine supply was declining and demand increasing.[143]

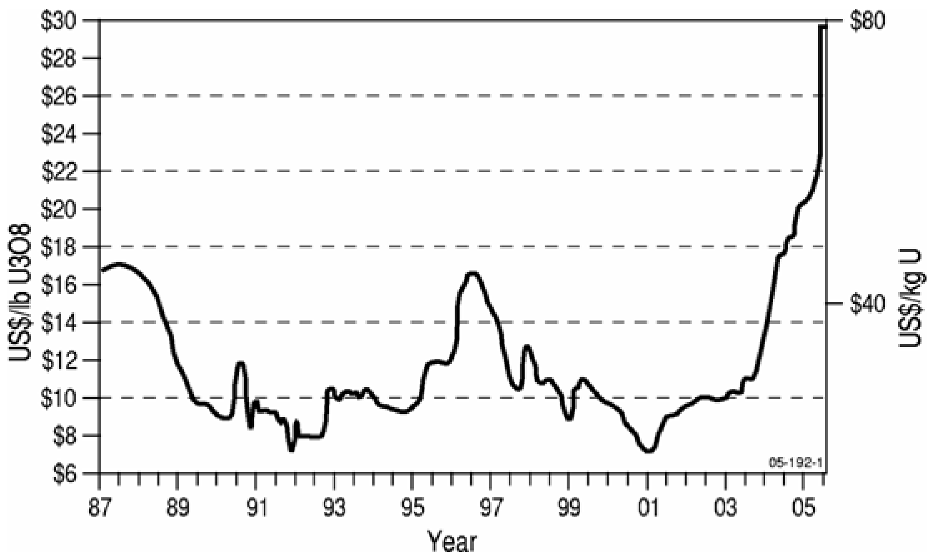
2.141 Market perceptions of diminishing secondary supplies are now a significant influence on the uranium price. Areva stated that the gradual depletion of secondary supplies is now placing considerable upward pressure on spot prices for uranium, which doubled from year-end 2002 to year-end 2004. In the period since, the uranium spot price has more than doubled again.[144]

2.142 GA noted that, in addition to a decrease in the availability of HEU from the Russian Federation, the price increase has been due to very high world oil prices, temporary reductions in mine supply due to the flooding of the McArthur River mine in Canada, and damage to the metallurgical plant at Olympic Dam caused by fires in 2003.[145]

2.143 ASNO observed that because the demand for uranium is relatively inelastic with respect to the price of natural uranium supply, there is expected to be a major increase in price as the inventory drawdown process comes to an end. Reprocessing capacity limitations would also prevent recycled uranium or plutonium from substantially affecting such price rises.[146]

2.144 During the course of the Committee's inquiry, the spot price for uranium oxide doubled from approximately US$22 per pound U_3O_8 to US$44/lb U_3O_8.[147] The spot market prices for uranium since 1988, in both US$/kg U and US$/lb U_3O_8, are shown in figure 2.7.

Figure 2.7 Spot market prices for uranium



Source Geoscience Australia , *Exhibit no. 61* , *Australia 's uranium resources and exploration* , p. 8 (Ux Consulting Company, LLC).

2.145 The IAEA and OECD-NEA explain that the over-production of uranium to 1990, combined with availability of secondary sources, resulted in prices trending downwards from the early 1980s until 1994 when they reached their lowest point in 20 years. Between 1990 and 1994 the decrease in supply, including exploration and production, saw prices rise modestly. This trend reversed as better knowledge of the state of inventories maintained downward pressure on uranium prices. Beginning in 2001, the price of uranium has rebounded from historic lows to levels not seen since the 1980s.

2.146 Although most uranium is sold under long-term contract rather than on to the spot market, the spot market prices give an indication of the state of the world uranium market in which future contracts will be written. ERA noted that market prices for long-term contracts increased at a faster rate than spot prices during 2003 and 2004 and by December 2004 the long-term indicators had risen to US$25/lb U_3O_8. In the first half of 2005 prices rose even higher, with long-term prices reaching US$30 per pound.[148]

2.147 Nova Energy argued that the tightness in secondary supplies, combined with the long lead times required to discover, gain regulatory approvals and develop new mines or to expand existing facilities means that 'the stage is set for a significant increase in spot and contract prices, perhaps matching or exceeding the highs of 1976.'[149]

2.148 The price of natural uranium is unlikely to significantly affect the cost of nuclear fuel or the overall cost of the electricity generated because the mined cost represents only a quarter of the cost of the fuel loaded into a reactor.[150] The economics of nuclear power are discussed further in chapter four.

2.149 The substantial increase in the uranium price can be expected to stimulate expansion of existing mines as well as exploration for uranium. The rise in price will also mean that the economics of known, but economically less attractive, orebodies will improve, leading to development of new mines.[151]

2.150 Dr Donald Perkin explained the relationship between the uranium price, exploration activity and production as follows:

> … a real increase in commodity price results in an increase in exploration activity; increases in exploration expenditure begin almost immediately the price starts to rise and exploration activity tends to reach its maximum about two years after the commodity price peaks. Increases in prices and in levels of exploration expenditure over time leads to a significant increase in the level of known economic resources because of the higher rate of discovery of new ore deposits … as well as through the addition of some previously known sub-economic resources reclassified into the economically viable category … Production of U_3O_8 increases about a year after commodity prices start to rise and the increases in production lasts well after prices peak, an apparent 'momentum' effect which continues several years into the downturn section of the cycle, due largely to contractual sales arrangements containing fixed … spot prices written into agreements.[152]

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World uranium production and resources

Uranium resources and production by country

2.151 In 2005, uranium was mined in 17 countries with the top 12 countries producing 99 per cent of the total output.[153] The quantity produced in each of these countries and the share of the world total for 2002–05 are listed in table 2.2.

2.152 Australia and Canada combined accounted for 50.5 per cent of world uranium production in 2005. Canada produced 11 628 tU, while Australian mines produced 9 522 tU.[154]

2.153 Production in 2005 represented a three per cent increase on the previous year's total. ABARE have forecast that world mine production will again rise modestly in 2006, as increases in Canada and China will be partly offset by the expected closure of a mine in the Czech Republic.[155]

2.154 GA and other submitters noted that the Athabasca Basin in northern Saskatchewan, Canada contains a number of extremely high-grade deposits, such as Macarthur River and Cigar Lake, with ore grades up to 20 per cent uranium. In contrast, the average ore grade at Olympic Dam in South Australia is 0.04 per cent uranium.[156]

2.155 Kazakhstan also contains significant uranium deposits and while the logistics are thought to be difficult, the deposits are now being developed through joint ventures with foreign companies. Several deposits in Kazakhstan are amenable to ISL mining. Mongolia also contains significant known mineralisation and exploration and mining activity is taking place in Niger and Namibia.[157]

Table 2.2 World uranium production by country, 2002–2005

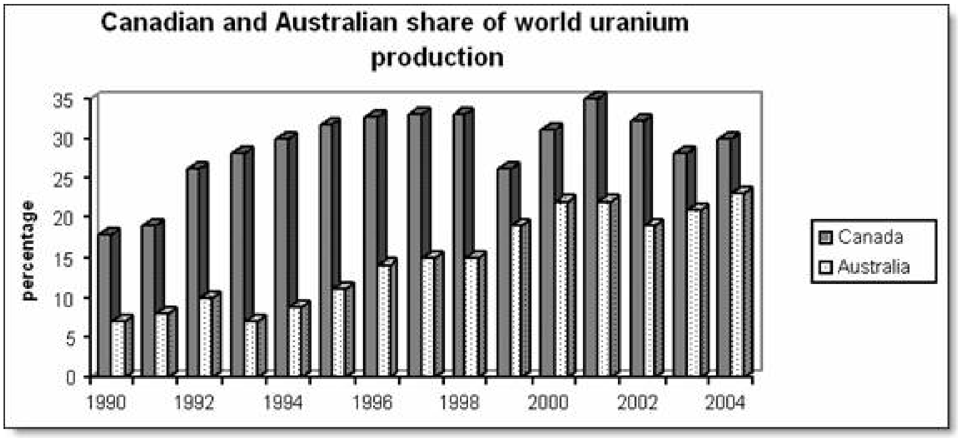
Country	**2002**		**2003**		**2004**		**2005**	
	tonnes U	Share of total (%)	tonnes U	Share of total (%)	tonnes U	Share of total (%)	tonnes U	Share of total (%)
Canada	11 607	32.0	10 446	29.4	11 596	28.5	11 628	27.8
Australia	6 854	18.9	7 595	21.4	9 406	23.1	9 522	22.7
Kazakhstan	2 834	7.8	3 150	8.9	3 719	9.1	4 357	10.4
Russia	3 000	8.3	3 158	8.9	3 200	7.9	3 431	8.9
Namibia	2 333	6.5	2 036	5.7	3 038	7.5	3 147	8.2
Niger	3 076	8.5	3 095	8.7	3 282	8.1	3 093	7.4
Uzbekistan	1 860	5.1	1 545	4.4	2 050	5.0	2 300	5.5
United States	883	2.4	779	2.2	877	2.2	1 039	2.5
Ukraine	1 100	3.0	1 000	2.8	800	2.0	800	1.9
China	500	1.4	750	2.1	750	1.8	750	1.8
South Africa	824	2.3	758	2.1	754	1.8	673	1.6
Czech Republic	465	1.3	346	1.0	412	1.0	108	1.0
Subtotal	*35 336*	*97.6*	*34 863*	*97.7*	*34 863*	*98.1*	*41 490*	*99.0*
Others*	859	2.4	835	2.3	773	1.9	380	1.0
TOTAL	**36 232**	**100.0**	**35 688**	**100.0**	**40 657**	**100.0**	**41 870**	**100.0**

Source RWE NUKEM , *NUKEM Market Report*, May 2006, p. 14.
* Other producing countries include: Brazil , Germany , India , Pakistan and Romania .

2.156 Australia produces less uranium than its proportional share based on its resources. Australia has the world's largest resources in what the IAEA and OECD-NEA classify as Reasonably Assured Resources (RAR) recoverable at less than US$40/kg U, or 'low cost'. In December 2005, Australia's resources were estimated to be 716 000 tU, which represents 36 per cent of world resources in this category. Other countries with large resources include Canada (15 per cent), Kazakhstan (14 per cent), Niger (9 per cent), Brazil (7 per cent), South Africa (5 per cent), Uzbekistan (4 per cent), Namibia (3 per cent) and Russian Federation (3 per cent).[158] Thus, while Australia possesses some 36 per cent of the world's uranium resources, it currently produces only 23 per cent of world mine output.[159]

2.157 Canada has less than half of the uranium resources of Australia but its annual production has been substantially higher, as depicted in figure 2.8.[160]

Figure 2.8 Canadian and Australian shares of world uranium production (1990–2004)



Source UIC, *Submission no. 12* , p. 9.

Uranium production by company

2.158 The world's three largest producers of uranium in 2005 were, in decreasing order of production, Cameco, Rio Tinto/ERA and Areva. WMC Resources, now owned by BHP Billiton, was the fifth largest producer in 2005, with 8.8 per cent of world production. Uranium production by company is listed in table 2.3.

2.159 The three largest producers each account for between 12–20 per cent of total uranium production worldwide. Combined, the ten largest producers represent approximately 75 per cent of world production.[161]

2.160 Cameco is the world's largest producer of uranium and accounts for almost 20 per cent of world production, with four operating mines in Canada and the US. Cameco owns the world's largest high-grade uranium deposit at McArthur River, Saskatchewan, along with mines at Key Lake and Rabbit Lake. In 2004, the McArthur River mine produced 7 200 tU, or almost 18 per cent of world production. Cameco has a 50 per cent interest in the world's second largest high-grade uranium deposit at Cigar Lake in Saskatchewan, which is expected to commence production in late 2007.[162]

Table 2.3 World uranium production according to shareholder, 2004–2005

Company	**2004**		**2005**	
	tonnes U	Share of total (%)	tonnes U	Share of total (%)
Cameco	8 310	20.4	8 275	19.8
Rio Tinto	5 335	13.1	5 583	13.3
Areva	5 666	13.9	5 174	12.4
KazAtomProm	3 582	8.8	4 032	9.6
BHP Billiton (WMC Resources)	3 735	9.2	3 688	8.8
TVEL	3 200	7.9	3 431	8.2
Navoi	2 050	5.0	2 300	5.5
ONAREM (Niger)	1 089	2.0	1 032	2.5
General Atomics	919	2.3	875	2.1
NPV Vostok	800	2.0	800	1.9
CNNC	750	1.8	750	1.8
Anglo Gold	754	1.9	673	1.6
Denison	520	1.3	475	1.1
Subtotal	*36 710*	*90.3*	*37 089*	*88.6*
Others	3 947	9.7	4 781	11.4
TOTAL	**40 657**	**100.0**	**41 870**	**100.00**

Source RWE NUKEM , *NUKEM Market Report*, May 2006, p. 19.

2.161 ABARE informed the Committee that Cameco planned to increase production at its three Canadian mines by over three per cent in 2005 and that this increase could be larger if proposed capacity increases at McArthur River and Key Lake were approved. Cameco has applied for a licence to increase combined annual production at these mines by 18 per cent. However, the *RWE NUKEM Market Report* of May 2006 indicates that the review process was not progressing as rapidly as the company had hoped and consequently the proposed expansion may not be in place until 2007 or 2008.[163] The expected level of Cameco's total production capacity has also been boosted by an extension of the Rabbit Lake mine life to 2007 after additional reserves were identified.[164]

2.162 Rio Tinto, through its shareholdings in ERA (68 per cent) and Rössing Uranium in Namibia (69 per cent), was the second largest producer in 2005, with an estimated 5 583 tU. ERA's Ranger mine in the Northern Territory produced 5 006 tU, which represented 12 per cent of world production in 2005. Ranger was the world's second largest mine by production in 2005 and the world largest uranium mines are listed in table 2.4.[165]

Table 2.4 The world's largest uranium mines 2004–2005, by production

Mine	Country	Main owner	2004		2005	
			tonnes U	Share of total (%)	tonnes U	Share of total (%)
McArthur River	Canada	Cameco	7 200	17.7	7 200	17.2
Ranger	Australia	ERA (Rio Tinto 68%)	4 753	11.7	5 006	12.0
Olympic Dam	Australia	BHP Billiton	3 735	9.2	3 688	8.8
Krasnokamensk	Russia	TVEL	3 000	7.4	3 300	7.9
Rössing	Namibia	Rössing Uranium (Rio Tinto 69%)	3 038	7.5	3 147	7.5
Rabbit Lake	Canada	Cameco	2 087	5.1	2 316	5.5
McClean Lake	Canada	Areva	2 310	7.9	2 112	5.0
Akouta	Niger	Areva/Onarem	2 005	4.9	1 778	4.2
Arlit	Niger	Areva/Onarem	1 277	3.1	1 315	3.1
Beverley	Australia	Heathgate Resources (General Atomics)	919	2.3	875	2.1
Vaal River	South Africa	Anglogold	754	1.9	673	1.6

Source RWE NUKEM , *NUKEM Market Report*, May 2006, pp. 17, 19; UIC, *World Uranium Mining* , Nuclear Issues Briefing Paper No. 41.

2.163 Areva is the only Group active in all stages of the nuclear fuel cycle and in 2004 was the world's second largest producer of uranium, with a market share of 12 470 tU sold and an output of 6 125 tU in 2004. Areva owns 142 000 tU in uranium reserves, which are equal to 20 times its 2004 production. The company's total underground mineral resources, including reserves, amount to approximately 490 000 tU. Areva also has access to the equivalent of 26 000 tU during the 2004 to 2013 timeframe of the HEU Purchase Agreement.[166]

2.164 Areva submitted that it owns uranium resources and conducts operations in Canada, Niger and Kazakhstan and the company expects to benefit from the renewed demand for primary production. From 2010 Areva intends to achieve combined annual production of some 4 000 tU per year from its deposits in Kazakhstan and Cigar Lake in Canada. The company explained that for each deposit it takes some 10–15 years from the first phases of exploration to the commencement of mining, with an average cost of €50 million per deposit. In 2004, Areva's exploration and mine development expenditure amounted to €16 million.[167]

2.165 The ten largest uranium mines in the world produced over 73 per cent of world output in 2005. These facts support the WNA's conclusion that:

> Firstly, uranium production is becoming increasingly concentrated in a small number of large mines in a limited number of countries, particularly Canada and Australia. Secondly, ownership of the major mines is becoming concentrated in a smaller number of companies...[168]

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Adequacy of world uranium resources to meet long-term growth in nuclear capacity

2.166 Several submitters argued that world uranium resources are insufficient to support an expansion of nuclear capacity and, hence, that nuclear power represents at best a 'temporary response' to addressing climate change.[169] For example, FOE argued that:

> Relatively high-grade, low-cost uranium ores are limited and will be exhausted in about 50 years at the current rate of consumption. The estimated total of all conventional uranium reserves is estimated to be sufficient for about 200 years at the current rate of consumption. These resources will of course be depleted more rapidly in a scenario of nuclear expansion. It is far from certain that uranium contained in 'unconventional sources' such as granite, sedimentary rock or seawater can be recovered economically.[170]

2.167 Similarly, Mr Justin Tutty argued that:

> At the current rate of consumption, low cost uranium reserves will be exhausted in around 50 years. To maintain nuclear's share of the energy market, these reserves would be exhausted faster, as global energy demand is continuing to grow. If nuclear is actually meant to displace *future* fossil fuel use, then these reserves will be exhausted faster still. If nuclear is also intended to displace *current* fossil fuel use, then these reserves clearly won't stretch far into the future.[171]

2.168 The ACF likewise argued that if all electricity currently generated by fossil fuels were replaced by nuclear power, 'there would be enough economically viable uranium to fuel reactors for between 3 and 4 years.'[172]

2.169 Other evidence rejected arguments of scarcity of world uranium supply in the longer-term. For example, Compass Resources argued that: 'Uranium is not, nor is likely to be, in short supply in the long term' and Mr Andrew Crooks asserted that: 'The reality is there is plenty of proven and probable uranium resources to last the world for several thousand years.'[173]

2.170 Mr Keith Alder, former General Manger and Commissioner of the Australian Atomic Energy Commission, argued that concerns about the future supply of uranium were first raised in the mid 1950s and have proved false. Concerns about an impending uranium shortage encouraged research into fast breeder reactors (FBRs) which can extend the energy extractable from a given quantity of uranium by up to a factor of 50. However, Mr Alder noted that:

> … it turned out that there was plenty of uranium … The antinuclear people often say, 'It's a stopgap exercise because we will run out of uranium.' That is absolute rubbish. There is an awful lot of uranium still to be discovered, particularly in Australia. I draw your attention to the Northern Territory … nobody has really had an extensive look very deep underground in the Northern Territory, and that is just one part of Australia.[174]

2.171 Mr Andrew Parker also argued that estimates of reserves lasting only a few decades are misleading because until recently there has been relatively little new exploration:

> It is not known how long the reserves will last because the funding of uranium exploration is many years and billions of dollars behind and no where near as comprehensive and complete as exploration for oil and gas. Indeed some of richest uranium deposits have only recently been discovered whereas all the really big oil fields were discovered over 40 years ago. It is likely that many more high-grade uranium deposits will be found and it has been estimated that the ultimate resource base is far larger.[175]

2.172 The ANF also observed that:

> Of course more reserves are certain to be discovered albeit at higher recovery costs, but fuel costs are not a large contributor to generating costs so the basic 50 year figure is probably conservative.[176]

2.173 BHP Billiton also noted that the price of nuclear generated electricity is not sensitive to uranium price, so the requirement to mine uranium recoverable at higher costs is not a major issue:

> … the cost of fuel in nuclear power generation is not a very high proportion of the total cost, and the generators are not particularly sensitive to the actual cost of uranium in their calculations. That means that a decade ago they were quite prepared to sign long-term contracts at significantly above the spot price, because they were more interested in security of supply than they were in the price. The price was not really driving the economics of nuclear power generation.
>
> In the meantime, demand has grown and mine output has not grown all that much, so the spot is now above the long-term contract price, and again the generators are not particularly worried about paying a high spot, because even now, at $30 a pound on the spot, it is not a very high proportion of the total cost of operating nuclear power stations.[177]

2.174 Similarly, Mr Alistair Stephens of Arafura Resources argued that the effect of a rise in uranium price is to make previously uneconomic resources viable for commercial use and to encourage greater exploration:

> The calculation that there are only 50 years of uranium resources left is made on the basis of the supply and demand relationship, so the grade of concentration of uranium in currently known resources that could be economically extracted would last 50 years. If the price of uranium were to increase, the amount of resources that are known would increase, so our supply of product would increase. That calculation also does not account for the fact that exploration will, in all probability, find new sources of uranium that could be used for injection into the supply relationship.[178]

2.175 The 2005 Red Book states that total Identified Resources (which includes RAR and Inferred Resources recoverable at costs of less than US$130/kg U) amounts to 4.7 million tU. The IAEA and OECD-NEA state that these resources are sufficient to supply the current once-through fuel cycle for 85 years at 2004 rates of consumption. [179]

2.176 Total Conventional Resources (which includes all cost categories of Identified Resources plus Prognosticated and Speculative Resources) amounts to some 14.8 million tU. With the once-through fuel cycle, these resources are estimated to be sufficient for 270 years at current rates of consumption.[180]

2.177 Unconventional Resources, which includes uranium that can be recovered from phosphate deposits, seawater and black shale, would add another 22 million tU, bringing total uranium available for exploitation to over 35 million tU. Combining Conventional Resources with the uranium in phosphates would provide sufficient uranium to fuel 675 years of electricity generation at current rates of consumption. The IAEA and OECD-NEA thus conclude that 'sufficient nuclear fuel resources exist to meet energy demands at current and increased demand well into the future.'[181]

2.178 Mr Alder pointed out that the Japanese Government previously studied the extraction of uranium from seawater and while the cost was about eight to ten times the cost of mined uranium at the time of the study, 'they calculated that there is 4,000 million tonnes of uranium in the sea. I cannot see this world running out of uranium fuel.'[182] Moreover, as noted by BHP Billiton and Arafura Resources above, because the cost of uranium is a small proportion of the overall price of nuclear generated electricity, Mr Alder argued that:

> Even if it did cost five to 10 times the [current] price of uranium, if you look at the cost of the uranium that goes into the production of a kilowatt hour you see that it is negligible. If you multiplied the cost of uranium in the kilowatt hour by 10, the householder or the small industrial user would face a very small increase in power price.[183]

2.179 The IAEA and OECD-NEA reinforce the observations of submitters cited above, that exploration is highly likely to find new discoveries and expand the uranium resource base. Indeed, the 2005 Red Book reports that the rise in spot price has stimulated major new exploration activity, with worldwide exploration expenditure in 2004 totalling over US$130 million, a 40 per cent increase on the 2002 figure. Exploration expenditure in 2005 is expected to approach $200 million.[184]

2.180 The WNA, which has published a position statement on future uranium supplies, lists additional sources of nuclear fuel, including:

- reprocessing used nuclear fuel to recover unburned fissile material, which can increase the efficiency of uranium utilisation by up to 30 per cent (as noted above, reprocessing currently provides only 3 per cent of world nuclear fuel supply);
- increasing the enrichment level of fuel, which can save uranium use in reactors;
- using thorium, which is four times more abundant than uranium in the Earth's crust[185];
- greater fuel efficiency in advanced reactor designs, currently being developed in multinational research programs, which may be deployed beyond 2030; and
- using fast neutron reactors (FNRs) (of which FBRs are one sub-type), which utilise the U-238 component of natural uranium, as well as the existing stock of depleted uranium, by converting non-fissile U-238 to ('breed') fissile plutonium.[186]

2.181 ASNO explained that the development of the fast neutron fuel cycle will allow the most efficient use of uranium resources. Currently, the 'thermal' nuclear fuel cycle, typified by the LWR, is an extremely inefficient use of uranium resources, generating energy from the fissile isotope U-235 which comprises only 1/140 th of natural uranium (i.e. 0.71 per cent of natural uranium is U-235). The once-through cycle will consume available supplies of uranium far more quickly because all used fuel is treated as waste for disposal. In contrast, the basis of the fast neutron cycle is the use of fast (unmoderated) neutrons to convert the predominant uranium isotope U-238 to plutonium as reactor fuel.[187] Theoretically, this could extend the energy value of uranium by up to a factor of 140, thereby making existing uranium reserves sufficient for several thousand years.

2.182 The 2005 Red Book reports that use of fast reactor technology, which is already proven, offers the prospects of multiplying uranium resources 50-fold. In this way, use of nuclear energy at current consumption levels may be extended by over 2 500 years based on Identified Resources, to over
8 000 years with currently known Conventional Resources and to almost 20 000 years with total Conventional Resources and phosphates.[188]

2.183 Similarly, the ANF also argued that if FBRs became widely adopted the market demand for uranium may reduce because:

> Breeder reactors will extend uranium utilisation by about a factor of 60; in other words, rather than 50 years, the quantity of world reserves … will last for another 3 000 years. Also, if the 2.1 million tonnes of uranium already mined are taken into account (most of the U238 still remains) then the total rises to nearly 5 000 years.[189]

2.184 Despite the promise of breeder reactors in extending uranium utilisation, FOE argued that most FBR programs have been abandoned:

> Accepting that low-cost uranium resources are limited, nuclear advocates frequently argue that the use (and production) of plutonium in 'fast breeder' reactors will allow uranium resources to be extended almost indefinitely. However, most plutonium breeder programs have been abandoned because of technical, economic and safety problems.[190]

2.185 The ACF also argued that FBRs have been a 'technological and economic failure', but conceded that 'with use of fast breeder reactors a closed cycle could be reached that would end the dependency on limited uranium resources.'[191]

2.186 ASNO previously acknowledged that that despite the energy (and waste management) advantages of the fast neutron cycle, the development of FNRs has been slow for economic reasons, engineering complications and public concerns about the safety of conventional FBRs.[192]

2.187 However, evidence indicated that there is now renewed interest in plutonium recycling. ASNO informed that Committee that, having been committed to the once-through fuel cycle since the Carter Administration, the US is now embracing plutonium recycling because of its more efficient utilisation of uranium.

2.188 Through its recently announced Global Nuclear Energy Partnership (GNEP) initiative, the US intends that so-called 'fuel supplier' nations will use FNRs and advanced spent fuel separation, which will recycle plutonium and transmute longer-lived radioactive materials. These technologies will recycle plutonium *without* requiring plutonium separation, which will meet the concern of some submitters that FBRs add to proliferation risks. Current plans by the US Government are to deploy commercial fast reactors in 2040.[193]

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Potential for Australia's uranium production to expand

2.189 Evidence to the inquiry emphasised that if policies which are preventing the development of much of the nation's resource base are reversed, Australia will be well placed to expand production and meet the expected growth in uranium demand:

> Australia is well positioned in terms of its identified resources to take advantage of the expected growth in

demand for uranium and expected increase in uranium prices. Australia has about one third of the world's low cost uranium. Seven of the top 20 known uranium deposits in the world are in Australia.[194]

2.190 Examples of observations by submitters making this argument include:

- ' Australia is already a significant supplier of uranium – yet the growing demand is providing an unparalleled opportunity for Australia to be the dominant supplier of a crucial global commodity.'[195]
- ' Australia is extremely well placed to take advantage of this situation, both in the immediate future and in the long term.'[196]
- 'With reserves twice those of Canada, despite little exploration over the last fifteen years, Australia is in the position of being capable of significantly increasing its uranium production and exports in direct competition with Canada … Additional low-cost mines in Australia would supply a substantial proportion of the needed increase in world output.'[197]
- ' Australia is, and should be, well positioned to capture a large part of this burgeoning market. We have the largest proportion of economic demonstrated resources of any country in the world. Moreover, our resources are the lowest cost uranium resources in the world, being almost entirely recoverable at less than $US29 a pound of U_3O_8.'[198]

2.191 CSIRO also commented that if Australia could source new deposits of uranium and obtain higher levels of recovery from known deposits, it could position itself as the global leader in the industry.[199]

2.192 Compass Resources suggested that Australia's considerable uranium resources potentially places the domestic industry in a similar position to iron ore or alumina:

> Australia is … in afortunate position that, along with Canada and certain African countries it has substantial high grade resources of uranium that can be produced at relatively low cash costs. In this regard Australia's position for uranium places it with similar advantages to iron ore or alumina, that is it can become one of a limited number of countries that supply a significant proportion of annual world uranium consumption.[200]

2.193 It was also argued that production from other countries may not attract the safeguards and regulatory controls imposed on Australian exports. Nova Energy also argued that the two other countries with major resources, Canada and Kazakhstan, are either not as well regulated or not as well placed to meet the growing demands in the Asian region. Australia was said to be 'uniquely placed – it is geographically well located close to the major growth areas.'[201]

2.194 Similarly, the UIC argued that while Canada has achieved greater annual production than Australia to date and Kazakhstan (which has larger reserves than Canada in the category of RAR recoverable at less than US$80/kg U) is aiming for a fourfold increase in mine production, nonetheless:

> … Australia has good relations with the most rapidly growing markets for uranium, those in East Asia, and is a preferred supplier into those markets.[202]

2.195 AMEC also submitted that with forecast growth in nuclear capacity in East and South East Asia:

> Australia's abundance of uranium reserves will further ensure its future position as a leading world supplier to these markets, provided a politically and economically favourable environment in Australia is maintained.[203]

2.196 While Australia has some 36 per cent of the world's resources of uranium, it was submitted that the key question remains:

> … whether Australian companies … can expand their production to meet this expected increasing demand and also whether they can export uranium to rapidly developing markets in China and India.[204]

2.197 Paladin Resources argued that sustained higher prices will be required to stimulate production because of the 'extreme tightness of supply extending for up to twenty years', but that:

> Australia will be the prime beneficiary of this new investment, if our uranium policies and regulations are brought into alignment with the realities of the world's civil nuclear power industry.[205]

2.198 Similarly, ANSTO submitted that:

> Prima facie, ANSTO believes that Australia is well placed to respond to increases in demand, given the size of our reserves. ANSTO notes, however, that current policy in some states precludes the development of new mines from known resources, and other states have legislation that prohibits the prospecting for, or the mining of, uranium. It is therefore possible that Australia will not be able to maximise the benefits that could be obtained from its uranium resources.[206]

2.199 Jindalee Resources argued that while ' Australia should be the world leader in the production of uranium', the:

> … current regulatory environment dissuades investment in uranium exploration, favours the entrenched position of three existing producers and leaves limited opportunity for the development of other mines by new entrants. This environment is clearly anti-competitive and has sterilised the majority of Australia's uranium

deposits. It is in the National Interest that this environment is changed.[207]

2.200 The following chapter assesses Australia's uranium resources, production and exploration, while the impediments to the development of Australia's uranium resources are addressed in chapter eleven.

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Conclusions

2.201 Nuclear power generates some 16 per cent of the world's electricity. While nuclear's contribution varies, it provides a substantial proportion of national electricity requirements in many countries.

2.202 The Committee notes that forecasts for nuclear capacity and uranium requirements vary, but there are a number of positive demand side trends which indicate that growth in nuclear capacity is probable:

- forecasts for a doubling in world electricity demand in the period to 2030, with a tripling of demand forecast for developing countries;
- plans for significant new nuclear build in several countries and renewed interest in nuclear energy among some industrialised nations;
- improved performance of existing nuclear power plants and operating life extensions; and
- the desire for security of fuel supplies, electricity price stability and heightened concerns about greenhouse gas emissions from the electricity sector.

2.203 In a recent development, the Committee notes the announcement by the British Government in July 2006 that, in view of the potential benefits for its public policy goals of reducing carbon dioxide emissions while delivering secure energy at affordable prices, the British Government proposes to support new nuclear build and to address potential barriers to the construction of NPPs.[208]

2.204 The Committee notes that as of June 2006 there were 27 reactors under construction in 11 countries, with a further 38 planned or on order. New plant construction is centred in the Asian region, with China, Japan and India all having plans for a significant expansion of nuclear capacity.

2.205 While new reactor construction to date has been subdued, the Committee notes that dramatic improvements in plant availability and productivity over recent years have had the effect of significantly increasing nuclear capacity and, consequently, the demand for uranium. The Committee notes that the IAEA and OECD-NEA have concluded that new nuclear build combined with the improved performance of existing NPPs and operating life extensions will outweigh reactor retirements in the years to 2025, thereby increasing projected uranium requirements.

2.206 The IAEA and OECD-NEA 'low demand' scenario forecasts that world nuclear capacity will rise to 449 GWe by 2025, which would see annual uranium requirement rise to 82 275 tonnes U by 2025, representing a 22 per cent increase on the 2004 requirements of 67 430 tonnes.

2.207 Uranium is unique among fuel sources in that a significant portion of demand is met by so-called secondary sources, which are essentially inventories and stockpiles. Currently, primary production from mines only supplies some 65 per cent of uranium requirements. Evidence strongly indicates that secondary supplies are diminishing, particularly with the termination of an HEU Purchase Agreement between Russia and the US in 2013. The Committee concludes that primary production must increase to meet requirements.

2.208 The Committee rejects the argument that the world's uranium resources are insufficient to support an expansion of nuclear power in the decades ahead. Total Conventional Resources are sufficient for some 270 years of nuclear electricity generation at 2004 rates of consumption. The resource base is almost certain to expand as higher uranium prices stimulate new exploration. Furthermore, additional sources of supply can eventually be utilised, including reprocessing used nuclear fuel and wider deployment of advanced reactor technologies. Fast Neutron Reactors are capable of extracting far more energy from uranium and can extend the usable fuel from known uranium resources by a factor of 60. The Committee concurs with the IAEA that there are no resource constraints on the expansion of nuclear power.[209]

2.209 Australia possesses some 36 per cent of the world's low cost uranium resources and on this basis the Committee agrees with submitters that, subject to the elimination of impediments to the industry's growth, Australia is well placed to expand production and meet global demand. Moreover, the Committee concludes that Australia is uniquely placed to supply markets in the Asian region, where nuclear growth is currently centred.

2.210 The Committee believes that it is entirely unsatisfactory for the nation, which possesses more than double the low cost uranium resources of its nearest rival, to consistently lag behind in terms of production and exports. In the following chapter the Committee examines Australia's uranium resources more closely and discusses the nation's potential to occupy a key position in world uranium supply.

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Footnotes

1 Mr Lance Joseph (Australian Governor on the Board of the International Atomic Energy Agency 1997–2000), *Submission no. 71*, p. 1. **Back**

2 Nova Energy Ltd, *Submission no. 50*, p. 8. **Back**

3 e-CBD Pty Ltd, *Australian Uranium*, 'About Uranium', viewed 16 December 2005 , <http://www.australianuranium.com.au/about-uranium.html>. Back

4 Uranium's average abundance in the Earth's crust is 2.7 parts per million (ppm) while the concentration in sea water is 0.003 ppm. Back

5 According to the Uranium Information Centre (UIC), the typical concentration of uranium in high-grade ore is 20 000 ppm, or 2 per cent uranium. Low grade ores are 1 000 ppm, or 0.1 per cent uranium. See: UIC, *Supply of Uranium*, Nuclear Issues Briefing Paper No. 75, viewed 7 June 2006 , <http://www.uic.com.au/nip75.htm>. Back

6 World Nuclear Association (WNA), *Can Uranium Supplies Sustain the Global Nuclear Renaissance?*, WNA, London , 2005, p. 3. Back

7 An atom, which is the smallest particle into which an element can be divided chemically, consists of a nucleus of protons and neutrons, surrounded by a cloud of electrons. The number of protons in the nucleus determines what element the atom represents (92 in the case of uranium). Isotopes occur where atoms of the same element have different numbers of neutrons. That is, isotopes are nuclides (or 'nuclear species' of the same element) with the same number of protons, but different numbers of neutrons. For example, U-235 has 92 protons and 143 neutrons, while U-238 has 92 protons and 146 neutrons. Back

8 UIC, *Submission no. 12*, pp. 18–22; Minerals Council of Australia (MCA), *Commodity Information Sheets: Uranium*, Australian Atlas of Mineral Resources, Mines and Processing Centres, Geoscience Australia (GA), MCA and the Australian Government Department of Industry, Tourism and Resources, Canberra, 2003, viewed 30 May 2005, <www.australianminesatlas.gov.au/info/factsheets/uranium.jsp>. Back

9 Dr Donald Perkin , *Exhibit no. 3, The significance of uranium deposits through time*. Back

10 WNA, *Outline History of Nuclear Energy*, WNA, London , 2005, viewed 31 March 2006 , <http://world-nuclear.org/info/inf54.htm>. Back

11 UIC, *loc. cit*. Back

12 International Atomic Energy Agency (IAEA), *Country Nuclear Fuel Cycle Profiles*, IAEA, Vienna, 2001, p. 1. Back

13 Fission fragments (or 'products') are daughter nuclei resulting either from the fission of heavy elements such as uranium, or the radioactive decay of those primary daughters. Important fission product isotopes (in terms of their relative abundance and high radioactivity) are bromine, caesium, iodine, krypton, rubidium, strontium and xenon. They and their decay products form a significant component of nuclear waste. Back

14 Australian Safeguards and Non-Proliferation Office (ASNO), *Annual Report 2003–2004*, Commonwealth of Australia , Canberra , 2004, p. 105. Back

15 Radiation may be defined as energy travelling through space, which can be transmitted in the form of electromagnetic waves, or it can be carried by energetic sub-atomic particles. Light and heat from the sun are examples of natural forms of radiation. Radioactivity refers to the spontaneous decay of an unstable atomic nucleus, giving rise to the emission of radiation. See: UIC, *Radiation and the Nuclear Fuel Cycle*, UIC, Melbourne , 2004, viewed 20 June 2005 , <www.uic.com.au/nip17.htm>. Back

16 Transuranics are very heavy elements formed artificially by neutron capture and possibly subsequent beta decay(s). Transuranics have a higher atomic number than uranium (92) and all are radioactive. The best known are neptunium, plutonium, americium and curium. Back

17 ASNO, *Annual Report 2003–2004, op. cit.*, p. 107. Back

18 IEA, *World Energy Outlook 2005*, OECD/IEA, Paris, 2005, p. 80. Back

19 One terawatt-hour equals one billion kilowatt-hours of electricity. Back

20 IEA, *Electricity Information 2005*, OECD/IEA, Paris , 2005, pp. I.39. Back

21 *ibid.*, p. I.22. See also: Cameco Corporation, *Submission no. 43*, p. 7. Back

22 IEA, *World Energy Outlook 2004*, OECD/IEA, Paris , 2004, pp. 192–193; Nova Energy Ltd, *Submission no. 50*, p. 3; Heathgate Resources Pty Ltd, *Exhibit no. 57, Energy for the World—Why uranium?,* p. 2. Back

23 IEA, *World Energy Outlook 2004*, *op. cit.,* pp. 193, 196–197. See also: Dr Michael Goldsworthy (Silex Systems Ltd), *Transcript of Evidence*, 9 February 2006 , p. 2; Mr James Brough (Australian Nuclear Forum), *Transcript of Evidence*, 16 September 2005 , p. 42. Back

24 IEA, *World Energy Outlook 2004*, *op. cit.,* p. 208. Back

25 Australian Bureau of Agricultural and Resource Economics (ABARE), *Submission no. 14*, p. 4; Areva, *Submission no. 39*, p. 4. Back

26 *ibid*. Back

27 Installed capacity is the measure of a power station's electric generating capacity at full production, usually measured in megawatts (MW) or gigawatts (GW). Back

28 2 626 TWh is 2 626 billion kilowatt-hours. Back

29 The Hon Alexander Downer MP , *Submission no. 33*, p. 4. Back

30 WNA, *World Nuclear Power Reactors 2004-06 and Uranium Requirements* , WNA, London, 2006, viewed 10 May 2006, <http://www.world-nuclear.org/info/reactors.htm>. Back

31 IAEA and OECD-NEA, *Uranium 2005: Resources, Production and Demand*, OECD, Paris , 2005, p. 43. Back

32 IEA, *World Energy Outlook 2004*, *op. cit.,* p. 200; IEA, *Electricity Information 2005*, *op. cit.*, p. I.3. Back

33 IAEA and OECD-NEA, *loc. cit*. Back

34 WNA, *World Nuclear Power Reactors 2004-06 and Uranium Requirements* , *loc. cit* ; Dr Ron Cameron (ANSTO), *Transcript of Evidence*, 13 October 2005 , p. 2. Back

35 Areva, *op. cit.*, p. 5. Coolant is a liquid or gas circulating through the reactor core so as to transfer the heat from it. A moderator is material which slows down the neutrons released from fission so that they cause more fission. It is

usually water, but may be heavy water or graphite. See: UIC, *Nuclear Power Reactors*, Briefing Paper No. 64, viewed 7 June 2006 , <http://www.uic.com.au/nip64.htm>. Back

36 UIC, *Nuclear Power Reactors*, *loc. cit*. Back

37 UIC, *Research reactors*, Nuclear Issues Briefing Paper No. 66, UIC, Melbourne, 2004, viewed 10 may 2006, <http://www.uic.com.au/nip66.htm>; UIC, *Nuclear powered ships*, Briefing Paper No. 32, UIC, Melbourne, 2005, viewed 10 may 2006 <http://www.uic.com.au/nip32.htm>. Back

38 WNA, *The Global Nuclear Fuel Market—Supply and Demand 2005–2030*, WNA, London , 2005, pp. 28, 69, 78; UIC, *Submission no. 12*, p. 29. Back

39 IEA, *World Energy Outlook 2004, op. cit.*, pp. 196, 208. Back

40 *ibid.*, p. 197. Back

41 *ibid.*, pp. 196–203. Back

42 *ibid.*, pp. 200, 207. Back

43 *ibid.*, p. 201. Back

44 IEA, *World Energy Outlook 2005*, *op. cit.*, p. 85. Back

45 IEA, *World Energy Outlook 2006*, OECD/IEA, Paris, 2006, p. 43. Back

46 *ibid*., p. 376. Back

47 WNA, *The Global Nuclear Fuel Market—Supply and Demand 2005–2030*, *op. cit.*, pp. 38–40. Back

48 *ibid.*, p. 2. Back

49 WNA, *The New Economics of Nuclear Power*, WNA, London, 2005, p. 14. Back

50 *ibid*. Back

51 WNA, *The Global Nuclear Fuel Market—Supply and Demand 2005–2030*, *op. cit.*, p. 2. Back

52 *ibid*. Back

53 *ibid*. Back

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Last reviewed 14 March 2007 by Committee Secretariat

Australia’s uranium — Greenhouse friendly fuel for an energy hungry world

A case study into the strategic importance of Australia’s uranium resources for the Inquiry into developing Australia’s non-fossil fuel energy industry

Print *Chapter 3* (PDF 1660KB) < - Report Home < - Chapter 2 : Chapter 4 - >

Chapter 3 Australia’s uranium resources, production and exploration

> *… world stockpiles of uranium are diminishing. An increase in reliance on mine production for uranium supplies by nuclear power plant operators should have the effect of increasing the significance of Australia’s uranium reserves. Factors such as the size and quality of those reserves, and Australia’s record as a stable and low-cost supplier, should ensure that Australia is well placed to continue to supply traditional customers and to achieve significant market penetration in Asia, which is the most rapidly growing area for use of nuclear power.*[1]

> *Without doubt Australia’s known resources could be increased significantly … but there needs to be a significant change in how uranium is viewed and a clear level of support shown at both the Federal and State level. A change in political will and direction is required to give the clear message to companies that it is worthwhile exploring for uranium. Australia already plays an important role in supplying low cost uranium to support the generation of clean nuclear energy … and if properly funded and supported … the unfortunate trend of the past ten plus years can be reversed and Australia could take its rightful place as the world’s most important exporter.*[2]

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Key messages —

- **Australia possesses 38 per cent of the world’s total Identified Resources of uranium recoverable at low cost (less than US$40 per kilogram).**
- **According to company reports, Australia’s known uranium deposits currently contain a total of over 2 million tonnes of uranium oxide in in-ground resources. The in-situ value of this resource at spot market prices prevailing in June 2006 is over A$270 billion.**
- **Olympic Dam in South Australia contains 26 per cent of the world’s low cost uranium resources and is the world’s largest uranium deposit. Olympic Dam is estimated to contain more than 1.46 million tonnes of uranium oxide in overall resources.**
- **Some 75 per cent of Australia’s total Identified Resources of uranium are located in South Australia, but**

significant deposits are also located in the Northern Territory, Western Australia and Queensland.

- **Seven of the world's 20 largest uranium deposits are in Australia—Olympic Dam (SA), Jabiluka (NT), Ranger (NT), Yeelirrie (WA), Valhalla (Queensland), Kintyre (WA) and Beverley (SA).**
- **Australia has the greatest diversity of economically important uranium deposit types of any country in the world, with resources of economic significance in many uranium deposit types.**
- **Despite the extent of its resources, over 10 per cent of Australia's low cost uranium resources are inaccessible, due in part to state government policies prohibiting uranium mining.**
- **In 2005, Australia achieved record national production of 11 222 tonnes of uranium oxide from three operational mines—Ranger, Olympic Dam and Beverley. Beverley is the world's largest uranium mine employing the in-situ leach (ISL) mining method.**
- **The Board of Canadian mining company sxr Uranium One has approved development of its Honeymoon deposit in SA. Honeymoon will also be an ISL operation, producing some 400 tonnes of uranium oxide per year for seven years. Production will commence from Honeymoon during 2008.**
- **A proposal to expand Olympic Dam would see uranium production from the mine treble to 15 000 tonnes of uranium oxide per year, which would make Olympic Dam and its owners, BHP Billiton Ltd, by far the world's largest producer. The expanded mine would account for more than 20 per cent of world uranium mine production and Australia would become the world's largest supplier of uranium with a doubling of national production.**
- **Australia exported a record 12 360 tonnes of uranium oxide in 2005. This quantity of uranium was sufficient for the annual fuel requirements of more than 50 reactors (each of 1 000 megawatt electrical capacity), producing some 380 terawatt-hours of electricity in total—some one and a half times Australia's total electricity production. The value of uranium exports reached a record high of $573 million in 2005. The outlook for further increases in production and export earnings is positive.**
- **Over 80 per cent of Australia's uranium is currently supplied to customers in four countries—USA, Japan, France and the Republic of Korea.**
- **The increase in uranium price and the anticipated decline in secondary supplies have stimulated a resurgence in exploration activity and expenditure in Australia. In 2005, total exploration expenditure for uranium was $41.09 million, which was almost a three-fold increase on 2004 expenditure of $13.96 million.**
- **While there has been a trend of increasing exploration expenditure since early 2003, there has been relatively little exploration for uranium over the past two decades and Australia's known uranium resources generally reflect exploration efforts that took place 30 years ago. The size of Australia's known uranium resources significantly understates the potential resource base and there is great potential for new and significant discoveries.**
- **To assist in the discovery of new world-class uranium deposits, particularly those located at considerable depth, and to assist the junior companies which are now conducting a significant share of exploration activities, the Committee repeats key recommendations made in its last report that:**
- **a flow-through share scheme for companies conducting eligible minerals exploration activities in Australia be introduced; and**
- **Geoscience Australia be granted additional funding to develop and deploy techniques to provide precompetitive geoscience of prospective areas, in order to assist in the discovery of new world-class uranium and other mineral deposits located under cover and at depth.**

Top

Introduction

3.1 This chapter, which is divided into three sections, provides a detailed overview of Australia's uranium resources, uranium mine production and exploration for uranium.

3.2 The Committee first considers Australia's uranium resources in world context, the distribution of uranium resources across the country, and the major uranium deposit types and their economic significance in Australia.

3.3 In the second section, the Committee summarises Australia's uranium mine production and exports performance, and provides an overview of the three currently operational mines—Ranger, Olympic Dam and Beverley. This section also describes recent developments at these mines, including the pre-feasibility study currently being undertaken for a proposed expansion of Olympic Dam. The likely development of the Honeymoon deposit in South Australia and the issue of recovering uranium from brannerite are also considered.

3.4 Finally, the Committee examines Australia's uranium exploration performance, recent exploration activity and the potential for new discoveries. The Committee concludes with a discussion of the important role now played by junior exploration companies and the importance of precompetitive geoscientific data for the discovery of new world class uranium deposits located at depth.

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Resources

Resource classification schemes

3.5 Estimates of uranium resources at national and international levels are prepared in accordance with a resource classification scheme developed by the Uranium Group—a joint initiative of the OECD Nuclear Energy Agency (OECD-NEA) and the International Atomic Energy Agency (IAEA)—which collects and reports on data relating to uranium resources, production and demand. These estimates are published biennially in the OECD-NEA and IAEA publication *Uranium Resources, Production and Demand,* commonly known as the 'Red Book'. The classification scheme has been adopted internationally. Resource estimates for Australia are prepared by Geoscience Australia. Uranium resources at the level of individual deposits in Australia are reported by mining companies according to the categories of the *Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves*.[3] An explanation of these two resource classification schemes follows.

3.6 The OECD-NEA and IAEA classification scheme divides uranium resource estimates into categories that reflect the level of confidence in the quantities of recoverable uranium against the cost of production. Uranium resources are broadly classified as either conventional or unconventional. Conventional resources are those that have an established history of production where uranium is a primary product, co-product or an important by-product (e.g. from the mining of copper and gold). Very low-grade resources, or those from which uranium is only recoverable as a minor by-product, are considered unconventional resources (e.g. uranium in phosphate deposits, black shale and seawater).[4]

3.7 Conventional resources are further divided, according to the level of confidence in the occurrence of the resources, into four categories:

- Reasonably Assured Resources (RAR) refers to uranium that occurs in known mineral deposits of delineated size, grade and configuration such that the quantities which could be recovered can be specified.
- Inferred Resources refers to uranium, in addition to RAR, that is inferred to occur based on direct geological evidence, in extensions of well-explored deposits, or in deposits in which geological continuity has been established but where specific data are considered to be inadequate to classify the resources as RAR. Less reliance can be placed on the estimates in this category than in RAR.
- Prognosticated Resources refers to uranium, in addition to Inferred Resources, that is expected to occur in deposits for which the evidence is mainly indirect and which are believed to exist in well-defined geological trends or areas of mineralisation with known deposits.
- Speculative Resources refers to uranium, in addition to Prognosticated Resources, that is thought to exist, mostly on the basis of indirect evidence and geological extrapolations, in deposits discoverable with existing exploration techniques. As the name implies, the existence and size of such resources are speculative.

3.8 In this classification scheme, RAR and Inferred Resources combined are referred to as Identified Resources, while Prognosticated and Speculative Resources are referred to as Undiscovered Resources. Identified Resources are normally expressed in terms of tonnes of recoverable uranium (tU), rather than quantities contained in mineable ore (quantities in situ). That is, the estimates include allowances for expected mining and ore processing losses.

3.9 Identified Resources are further separated into categories based on the cost of production, which are expressed in US dollars per kilogram of uranium (comparable cost categories in US dollars per pound of uranium oxide, U_3O_8, are included in brackets) as follows:

- less than US$40/kg U (less than US$15/lb U_3O_8);
- US$40-80/kg U (US$15-30/lb U_3O_8); and
- US$80-130/kg U (US$30-50/lb U_3O_8).[5]

3.10 The *Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves* (the 'JORC Code') has been developed by the Joint Ore Reserves Committee of the Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and the Minerals Council of Australia. The Code sets out minimum standards, recommendations and guidelines for public reporting in Australasia of exploration results, mineral resources and ore reserves. The Code has been adopted by and included in the listing rules of the Australian Stock Exchange.[6]

3.11 The JORC Code defines a Mineral Resource as a concentration or occurrence of material of intrinsic economic interest in or on the Earth's crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, geological characteristics and continuity of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge. Mineral Resources are sub-divided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories.[7]

3.12 The Code defines an Ore Reserve as the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified. Ore Reserves are sub-divided in order of increasing confidence into Probable Ore Reserves and Proved Ore Reserves.[8]

3.13 Ore Reserves are further defined in the JORC Code as those portions of Mineral Resources which, after the application of all mining factors, result in an estimated tonnage and grade which, in the opinion of the person competent to make the estimates, can be the basis of a viable project, after taking account of all relevant modifying factors listed above.

3.14 Proved and Probable Ore Reserves plus Measured and Indicated Mineral Resources in the JORC Code are equivalent to RAR in the OECD-NEA and IAEA classification scheme. Inferred Resources in the JORC Code are equivalent to Inferred Resources in the OECD-NEA and IAEA scheme.[9]

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Australia's uranium resources in world context

3.15 As at January 2005, Australia's total Identified Resources recoverable at less than US$40/kg U (i.e. recoverable at 'low-cost') amounted to 1 044 000 tU (1 230 758 t U_3O_8). This represented 38 per cent of the world's total Identified Resources in this cost category. Combined across all production cost categories, Australia's Identified Resources amounted to 1 143 000 tU.[10] Australian and world totals of Identified Resources for each cost category are listed in table 3.1.

3.16 The data in table 3.1 shows that of Australia's total Identified Resources, over 90 per cent is recoverable at low cost.[11] Furthermore, more than 67 per cent of Australia's Identified Resources recoverable at low cost are classified as RAR.

Table 3.1 Australian and World Identified Resources as at January 2005

Categories of Identified Resources	Production cost ranges		
	Tonnes U recoverable at <US$40/kg U	Tonnes U recoverable at <US$80/kg U	Tonnes U recoverable at <US$130/kg U
Reasonably Assured Resources	701 000	714 000	747 000
Inferred Resources	343 000	360 000	396 000
Australia's total Identified Resources	1 044 000	1 074 000	1 143 000
World total Identified Resources	*2 746 380*	*2 804 381*	*4 742 853*
Australia's share of world total Identified Resources	38%	38%	24%

Source IAEA and OECD-NEA, *Uranium 2005: Resources, Production and Demand* , pp. 15–16, 102–103.

3.17 Geoscience Australia (GA) submitted that as at December 2005 Australia's RAR recoverable at low cost amounted to 716 000 tU (844 340 t U_3O_8). This represents 36 per cent of the world's uranium resources in this category.[12]

3.18 As shown in table 3.1, Australia possesses 343 000 tU in Inferred Resources recoverable at low cost, which is by far the world's largest resources in this category—43 per cent of the world total. The majority of these resources are located in the south-eastern part of the Olympic Dam deposit, where exploration drilling has defined large tonnages of additional resources.[13]

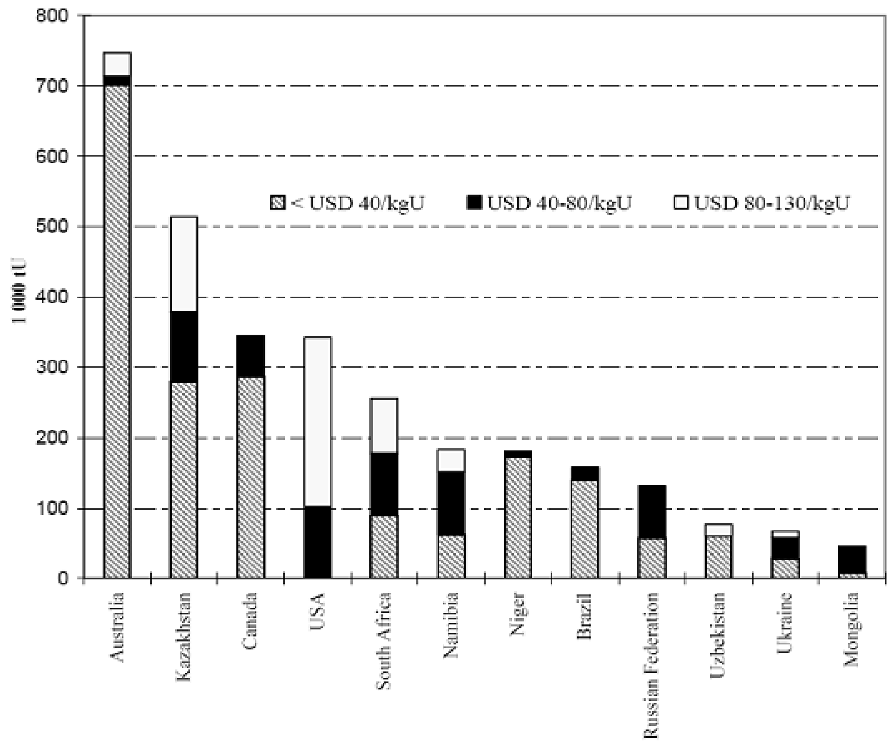
3.19 Other countries that have large quantities of RAR recoverable at low cost include Canada (15 per cent of the world total), Kazakhstan (14 per cent), Niger (9 per cent), Brazil (7 per cent), South Africa (5 per cent), Uzbekistan (4 per cent), Namibia (3 per cent) and the Russian Federation (3 per cent).[14] Table 3.2 and figure 3.1 show the distribution of RAR among countries with major resources.

Table 3.2 Reasonably Assured Resources (tU) as at January 2005

Country	Production cost ranges		
	<US$40/kg U	US$40–80/kg U	US$80–130/kg U
Australia	701 000	13 000	33 000
Brazil	139 900	17 800	0
Canada	287 200	58 000	0
Kazakhstan	278 840	99 450	135 607
Mongolia	7 950	38 250	0
Namibia	62 186	89 135	31 235
Niger	172 866	7 580	0
Russian Federation	57 530	74 220	0
South Africa	88 548	88 599	78 446
Ukraine	28 005	30 493	8 208
United States	NA	102 000	240 000
Uzbekistan	59 743	0	17 193
Others	*63 615*	*77 433*	*209 657*
World total	1 947 383	695 960	653 346

Source IAEA and OECD-NEA, *Uranium 2005: Resources, Production and Demand* , p. 15.

Figure 3.1 Distribution of Reasonably Assured Resources among countries with major resources



Source IAEA and OECD-NEA, *Uranium 2005: Resources, Production and Demand* , p. 18.

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Distribution of uranium resources in Australia

3.20 Approximately 98 per cent of Australia's Identified Resources recoverable at less than US$40/kg U are contained within the following six deposits:

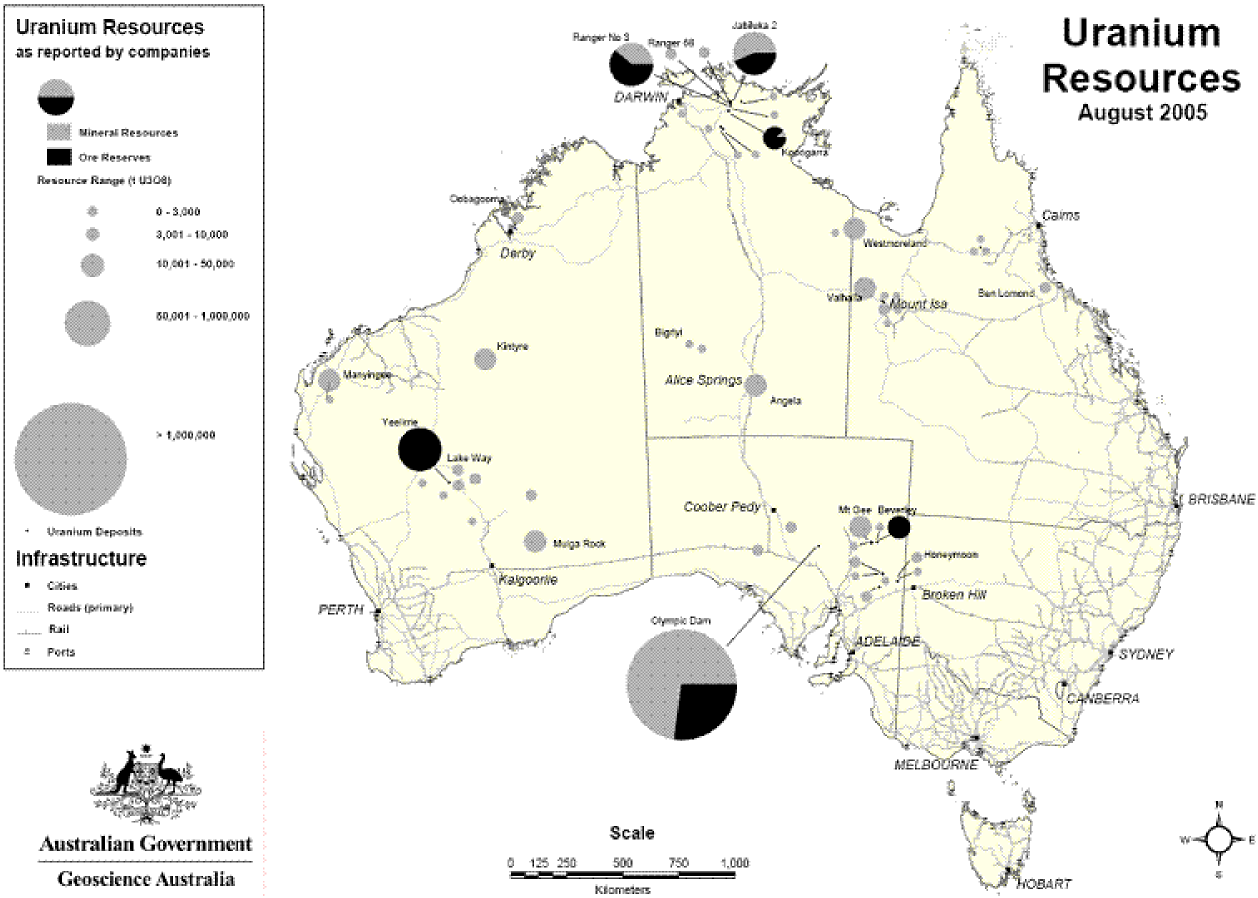
- Olympic Dam in South Australia (SA);
- Ranger, Jabiluka and Koongarra in the Alligator Rivers Region Uranium Field (ARUF) of the Northern Territory (NT); and
- Kintyre and Yeelirrie in Western Australia (WA).[15]

3.21 Australia has some 85 known uranium deposits, varying in size from small to very large, scattered across the continent. Approximately 75 per cent of Australia's total Identified Resources recoverable at low cost are located in South Australia (782 798 tU or 923 111 t U_3O_8), 19 per cent is located in the Northern Territory (193 818 tU or 228 559 t U_3O_8) and 6 per cent in Western Australia (67 067 tU or 79 088 t U_3O_8).[16]

3.22 Olympic Dam is the world's largest deposit of low cost uranium. Based on ore reserves and mineral resources reported by the mine's owners as at June 2005, GA estimated that Olympic Dam contains 503 300 tU in RAR recoverable at less than US$40/kg U. This represents 26 per cent of the world's total resources and over 70 per cent of Australia's resources in this category.[17] Olympic Dam is estimated to contain in excess of 1.46 million t U_3O_8 (1.27 million tU) in total resources.[18] Moreover, of the world's 20 largest uranium deposits, seven are in Australia—Olympic Dam, Jabiluka, Ranger, Yeelirrie, Valhalla (Queensland), Kintyre and Beverley (SA).[19]

3.23 The location of Australia's uranium deposits and the relative size of ore reserves and mineral resources for each deposit are depicted in figure 3.2. Australia's major undeveloped uranium deposits, prospective mines and their main owners are listed in table 3.3.[20]

Figure 3.2 Location of Australia's uranium deposits and the relative size of ore reserves and mineral resources for each deposit



Source Geoscience Australia , *Exhibit no. 61, Australia 's uranium resources and exploration.*

Table 3.3 Australia's major undeveloped uranium deposits and prospective mines as at April 2006

State / Territory	Deposit	Main owner	Grade (per cent U 3O 8)	Contained U 3O 8 (tonnes)	Category
Northern Territory	Jabiluka	Energy Resources of Australia Ltd (Rio Tinto 68%)	0.52	67 000	reserves
			0.39	21 000	measured and indicated resources
			0.48	75 000	inferred resources
	Koongarra	Areva	0.8	14 540	reserves
	Angela	Cameco	0.1	10 250	resources
Western Australia	Kintyre	Canning Resources Pty Ltd (Rio Tinto)	0.15 – 0.4	36 000	reserves and resources
	Yeelirrie	BHP Billiton Ltd	0.15	52 500	indicated resources
	Mulga Rock	Eaglefield Holdings Pty Ltd	0.14	13 300	resources
	Many ingee	Paladin Resources Ltd	0.09	12 000	resources
	Oobagooma		not known	5 000	resources
	Lake Maitland	Redport Ltd	0.052	7 900	resources
	Lake Way	Nova Energy Ltd	not known	4 000	resources
	Centipede		0.063	4 400	resources
	Thatchers Soak	Uranex NL	0.03	4 100	resources
South Australia	Honeymoon	sxr Uranium One Inc	0.24	2 900	resources
	Goulds Dam		0.045	2 500	indicated resources
	Curnamona	Curnamona Energy Ltd	not known	Not known	-
	Prominent Hill	Oxiana Ltd	0.012	9 900	inferred

					resources
	Mt Gee	Marathon Resources Ltd	0.073	33 200	inferred resources
	Crocker Well	PepinNini Minerals Ltd	0.51	6 338	resources
Queensland	Westmoreland (Qld/NT)	Laramide Resources Ltd	up to 0.2	22 500	inferred resources
	Valhalla	Summit Resources Ltd	0.144	16 500	indicated resources
				25 000	inferred resources
	Skal		0.119	5 000	resources
	Andersons Lode		0.143	6 500	inferred resources
	Ben Lomond	Mega Uranium Ltd	0.25	4 760	resources
	Maureen		0.123	2 940	resources

Source UIC, *Submission no. 12*, p. 24; UIC, *Australia's Uranium Deposits and Prospective Mines*.

3.24 In addition to the currently operational mines described below, GA submitted that several uranium deposits have in previous years been subject to either a comprehensive feasibility study or an Environmental Impact Statement (EIS), or both. These projects have not proceeded to mining for a variety of reasons including state government mining restrictions or previously low uranium prices. These deposits are: Jabiluka and Koongarra in the NT; Kintyre, Yeelirrie, Many ingee and Lake Way in WA; and Ben Lomond and Valhalla in Qld.[21]

3.25 Several of the junior mining and exploration companies that submitted to the inquiry made observations about the resources contained in their uranium deposits:

- Summit Resources submitted that the company's Mount Isa uranium project (the Valhalla, Skal and Andersons Lode deposits) in Queensland (Qld) contains a total uranium resource (RAR and Inferred) of over 34 500 t U_3O_8 (29 255 tU) recoverable at low cost.[22] GA have now incorporated these resources into the estimates for Australia's RAR recoverable at low cost, provided above.
- Eaglefield Holdings, owners of the Mulga Rock deposit (MRD) in WA, noted that the MRD was evaluated by the deposit's previous owner to contain an estimated 46 000 t U_3O_8 (33 918 tU). However, the age of the resource estimation renders it non-JORC compliant. In addition to its uranium content, Eaglefield Holdings submitted that the MRD may also contain the largest known exploitable resource of scandium in the world, as well as a very large resource of oily-lignite.[23]
- Nova Energy noted that, combined, its Lake Way and Centipede/Millipede deposits in WA contain an estimated 8 860 t U_3O_8 (7 513 tU).[24]
- Compass Resources announced in July 2006 that its Mt Fitch uranium prospect in the NT contains an estimated 4 050 t U_3O_8 (3 434 tU) in indicated and inferred resources.[25]

3.26 Just over 10 per cent of Australia's RAR recoverable at less than US$40/kg U has been classified by GA as inaccessible for mining. This is due in part to prohibitions on mining in WA. WA State Government policy prohibits uranium mining on leases granted after June 2002, hence deposits in that State are classified as 'inaccessible resources'. The MCA submitted that current WA Government policy prevents Kintyre and Yeelirrie from being developed. The Qld State Government has also discouraged potential new mine developments, despite the absence of legislation that specifically prohibits uranium mining.[26]

3.27 Inaccessible resources also includes those deposits in the ARUF where mining leases are too small to accommodate the proposed mine and treatment plant facilities, such as Koongarra. These leases may not be able to be increased in size as they are surrounded by the Kakadu National Park. However, the MCA noted that the leases for both Jabiluka and Koongarra predate and were excluded from the Kakadu National Park.[27]

3.28 According to company reports, Australia's uranium deposits contain a total of over two million t U_3O_8.[28] The in-situ value of this resource at uranium spot market prices prevailing in June 2006 is over A$270 billion.[29] The uranium ore reserves and mineral resources for each of Australia's uranium deposits, as reported by the mining companies, are listed in appendix E by state and territory.

3.29 Notwithstanding the size of Australia's known uranium resources, submitters argued that these underestimate the potential uranium resource base because, until recently, there has been very little exploration activity in Australia for more than 20 years.[30] This matter is considered in the final section of this chapter.

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Uranium deposit types and their economic significance in Australia

3.30 The OECD-NEA and IAEA have classified uranium deposits worldwide into fifteen deposit types on the basis of their geological setting.[31] GA explained that 98 per cent of Australia's uranium resources occur within four such deposit types:

- Hematite breccia complex deposits—deposits of this type occur in hematite-rich breccias and contain uranium in association with copper, gold, silver and rare earths.
- Some 70 per cent of Australia's total uranium resources occur in Proterozoic hematite-rich granitic breccias at Olympic Dam, which is also the only known breccia complex that has a significant resource of uranium in the world. Broadly similar, but apparently smaller, hematite-rich breccia mineralisation is being evaluated elsewhere in the same geological province (the Gawler Craton), at Prominent Hill in South Australia. These are examples of 'iron oxide copper gold deposits' with higher uranium contents than most deposits of this type.
- Unconformity-related deposits—deposits of this type are associated with and occur immediately below and above an unconformable contact that separates a crystalline basement intensively altered from overlying clastic sediments of either Proterozoic or Phanerozoic age.
- About 18 per cent of Australia's resources are associated with Proterozoic unconformities, mainly in the ARUF of the NT (Ranger, Jabiluka, Koongarra).
- Sandstone uranium deposits—deposits of this type occur in medium to coarse-grained sandstones in a continental fluvial or marginal marine sedimentary environment.
- Some six per cent of Australia's resources are sandstone uranium deposits and are located mainly in the Frome Embayment field, SA (Beverley, Honeymoon) and the Westmoreland area, which straddles the NT and Qld.
- Surficial (calcrete) deposits—deposits of this type are broadly defined as young (Tertiary to recent) near-surface uranium concentrations in sediments and soils.
- These deposits constitute about four per cent of Australia's uranium resources, mostly in the Yeelirrie deposit (WA).[32]

3.31 Cameco noted that other deposit types are found in Australia, such as metasomatite type deposits including Valhalla in Qld, where disseminated uranium is deposited in deformed rocks. Intrusive type deposits such as Maureen and Ben Lomond are found within the Georgetown Inlier in Northwest Qld and the Westmoreland area hosts a number of vein and other sandstone deposits.[33]

3.32 The Northern Territory Minerals Council (NTMC) noted that uranium occurrences in the NT can be grouped into unconformity-related, vein-like, Westmoreland and sandstone type deposits. Almost all mined deposits and most of the currently known resources are unconformity-related and occur within Palaeoproterozoic rocks of the Pine Creek Orogen, near the unconformity with overlying platform cover sandstone of the McArthur Basin or Birrindudu Basin. The NTMC noted that large unconformity deposits in the ARUF account for 96 per cent of past production and 95 per cent of known resources in the Territory. Smaller Westmoreland-type deposits (e.g. Eva) are present in the eastern McArthur Basin. Sandstone-hosted deposits are present in the Ngalia (e.g. Bigrlyi) and Amadeus (e.g. Angela) basins. Small vein-type deposits in the Pine Creek Orogen (e.g. Adelaide River) have been mined in the past.[34] The location of the known uranium deposits in the NT and their geological settings are depicted in appendix F.

3.33 Dr Donald Perkin submitted that 'world class' deposits are those that contain high-grade uranium ore, coupled with large tonnages and/or features which reduce the cost of mining such as convenient shape, well defined ore zones, easily treatable ore and good location. Because world class deposits are lowest cost, they are the most competitive and least vulnerable to downturns in the industry.[35]

3.34 Dr Perkin argued that ' Australia is unique in having the greatest diversity of economically important uranium deposit types of any country in the world', with resources of economic significance in many uranium deposit types.[36]

3.35 It was argued that the unconformity-related and sandstone deposit types:

> … represent potentially viable uranium mining operations and exploration target types into the future, and with their relatively high grades and large resources, these types will easily be able to withstand … erosion in real price and, in a more positive market, able to provide strong future cash flows and profits.[37]

3.36 Consequently, Dr Perkin argued that Australia along with Canada and Niger, which have a predominance of the world's relatively high-grade resources in these deposit types, are therefore 'uniquely suited to become chief suppliers of low-cost uranium to the world nuclear power industry well into the 21 st century.'[38]

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Thorium

3.37 In addition to uranium resources, Australia also possesses the world's largest quantity of economically recoverable thorium resources—300 000 t—more than Canada and the US combined, as shown in table 3.4. The 2005 Red Book states that current estimates put world thorium resources at 4.5 million tonnes (Mt), but this figure is considered conservative.[39]

Table 3.4 World's economically extractable thorium resources

Country	Reserves (tonnes)
Australia	300 000
India	290 000
Norway	170 000

USA	160 000
Canada	100 000
South Africa	35 000
Brazil	16 000
Other countries	95 000
World total	1 200 000

Source UIC, *Thorium* , Briefing Paper No. 67.

3.38 Like uranium, thorium can be used as a nuclear fuel. Interest in utilising thorium has arisen because it is three times more abundant in the Earth's crust than uranium, and almost all of the mined thorium is potentially usable in a reactor, compared with only 0.7 per cent of natural uranium. Thus, thorium may contain some 40 times the amount of energy per unit mass than uranium, without recourse to fast breeder reactors.[40] Thorium-based fission is described further in chapter 12.

3.39 India, which has about six times more thorium than uranium, is currently building two reactors which will use thorium-based fuel and has made the utilisation of thorium for large-scale energy production a major goal in its nuclear power program. While thorium has been the subject of research for several decades, the thorium fuel cycle is not yet commercialised.[41]

3.40 Arafura Resources submitted that the company's Nolan's Bore deposit, located 135 km north of Alice Springs, contains both thorium and uranium hosted in phosphate rock. Recent drilling indicates that the deposit contains some 24 000 t of thorium, as well as 1 800 tU and 227 000 t of rare earths.[42]

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Production and exports

Australia's uranium mine production and exports

3.41 Australia's uranium production in 2005 came from three mines: Ranger (5 910 t U_3O_8), Olympic Dam (4 335 t U_3O_8) and Beverley (977 t U_3O_8). Combined, the mines achieved record national production of 11 222 t U_3O_8, six per cent higher than in 2004. As noted in the previous chapter, Australia is the world's second largest producer of uranium, accounting for 23 per cent of world uranium mine output in 2005, after Canada (28 per cent).[43]

3.42 All of Australia's uranium mine production is exported for use in electrical power generation. Australian export tonnages have increased steadily from less than 500 t U_3O_8 in 1976, to reach a record level of 12 360 t U_3O_8 in 2005. Exports for 2005 were valued at A$573 million—a record for annual export earnings. In the five years to 2006, Australia exported 48 496 t U_3O_8 with a value of $2.2 billion. The average export value in 2005 was $46 360 per tonne of U_3O_8.[44] Table 3.5 shows Australia's uranium mine production and exports for 2000 to 2005.

3.43 The Australian Bureau of Agricultural and Resource Economics (ABARE) has forecast that Australian uranium mine production will grow by over eight per cent in financial year 2005–06 to nearly 11 900 t U_3O_8, largely due to higher output from Olympic Dam and Ranger. The value of uranium exports is forecast to reach A$712 million in 2005–06, an increase of 50 per cent on the 2004–05 export value of $475 million.[45]

3.44 Uranium produced in Australia is shipped to uranium conversion plants in France, USA, Canada and the UK. Following the other steps of the 'front end' of the fuel cycle, outlined in chapter two, Australian uranium is used to fabricate fuel elements for use in nuclear power stations.[46]

Table 3.5 Australian uranium mine production and exports (tonnes U_3O_8), 2000–2005

	2000	2001	2002	2003	2004	2005
Ranger	4 437	4 203	4 407	5 065	5138	5 910
Percentage of world production	10%	10%	11%	12%	11%	12%
Olympic Dam	4 500	4 335	2 867	3 176	4 370	4 335
Percentage of world production	11%	10%	7%	7%	9%	9%
Beverley	—	546	746	689	1 084	977
Percentage of world production		1%	2%	2%	2%	2%
Australian total	8 937	9 104	8 083	8 931	10 592	11 222
Percentage of world production	21%	21%	20%	21%	22%	23%^
World mine production	42 466	43 656	42 502	42 184	47 955^	49 375^
Australian exports	8 757	9 239	7 637	9 612	9 648	12 360
Value of Australian	426	463	363	398	411	573

exports* (A$ million)						
Average export value in A$/lb U_3O_8	22.07	22.72	21.58	18.78	19.32	21.03
Average export value in US$/lb $_3O_8$	12.85	11.78	11.73	12.24	14.22	16.03

Source UIC, *Submission no. 12* , p. 27; GA, *Submission no. 42* , p. 7; UIC, *Australia's Uranium and Who Buys It* , Nuclear Issues Briefing Paper No. 1.
* Export values are free-on-board estimates.
^ Figures obtained from RWE NUKEM , *NUKEM Market Report*, May 2006, p. 14.

3.45 Australian mining companies supply uranium under long-term contract to electricity utilities in the following countries: USA, Japan, European Union (UK, France, Germany, Spain, Sweden, Belgium, Finland), South Korea, Canada and to Taiwan under safeguards agreements with the USA.[47] In 2004, Australian uranium was supplied to customers in the countries listed in table 3.6.

3.46 In April 2006, Australia and China entered into a bilateral safeguards agreement on the transfer of nuclear material, whereby sales of uranium to China will now be permitted.[48]

Table 3.6 Supplies of Australian uranium shown by end-user, 2004

Country	Tonnes U 3O 8	% of total
United States	3 513.89	38.4
Japan	2 292.49	25.0
France	939.06	10.3
Republic of Korea	930.00	10.1
Sweden	400.95	4.4
United Kingdom	382.84	4.2
Germany	249.48	2.7
Spain	200.00	2.2
Canada	136.08	1.5
Finland	112.03	1.2
TOTAL	**9 156.82***	**100.0**

Source Australian Safeguards and Non-Proliferation Office, *Annual Report 2004–2005* , p. 45.
* Total quantity supplied does not equal total exports (9 648 t U_3O_8) during 2004 due to timing differences in the reporting of exports and receipts.

3.47 Uranium produced from Australia's mines is largely sold under long-term contracts and thus the spot market price for uranium is not indicative of the price paid for current production. The spot market price is currently well above the long-term contract price. For example, in 2005 the average realised sale price of U_3O_8 sold by Energy Resources of Australia from its Ranger mine was US$16/lb, whereas the spot market price on 31 December 2005 was more than double this at US$36/lb U_3O_8.[49] In June 2006 the spot price reached US$45/lb U_3O_8.[50] Similarly, BHP Billiton reported that the contract price for uranium produced at Olympic Dam is currently approximately US$15/lb.[51]

3.48 In financial year 2004–05, Australia exported 11 215 t U_3O_8, in 64 shipments from the three operational mines. This quantity of uranium was sufficient for the annual fuel requirements of approximately 50 reactors (each of 1 000 MWe capacity), producing some 380 TWh of electricity in total—some one and a half times Australia's total electricity production. Effectively, Australian uranium supplied about 2 per cent of total world electricity production in 2004–05.[52]

3.49 As noted above, Australia currently has three operational uranium mines—Ranger in the NT, and Olympic Dam and Beverley in SA. The locations of these mines are shown in figure 3.2.

3.50 In 2005, the Ranger and Olympic Dam mines were respectively the world's second largest (12 per cent of world uranium mine production) and third largest (9 per cent of world mine production) uranium producers (see table 2.4 of chapter two). Beverley was the tenth largest producer in 2005.[53] In addition to the operational mines, a fourth—Honeymoon in SA —has government approvals in place to commence construction and in August 2006 the deposit's owners approved development of the project.[54] Following a brief overview of the history of uranium mining in Australia, the Committee describes the three currently operational mines.

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Australia's uranium mining history

3.51 Uranium was first identified in Australia in 1894 at Carcoar (NSW). The earliest uranium deposits mined in Australia were at Radium Hill and Mount Painter (SA). These deposits were worked from 1910 to 1931 for radium, a radioactive daughter product of uranium, which was used mainly for medical purposes.

3.52 Exploration for uranium in Australia began in 1944 at the request of the British and US Governments. The Commonwealth Government offered financial rewards for the discovery of uranium orebodies and in 1949 the Rum Jungle deposit (NT) was discovered. Subsequently, the Mary Kathleen deposit (Qld) and a number of smaller deposits in the South Alligator Valley (NT) were discovered.[55]

3.53 There have been two phases of uranium mining in Australia:

- from 1954 until 1971; and
- from 1976 to the present.[56]

3.54 Between 1954 and 1971 the following deposits were mined: Rum Jungle (1954 to 1971), Radium Hill (1954 to 1962),MaryKathleen (1958 to 1963) and South Alligator Valley (1959 to 1964). During this phase, Australia produced some 9 118 t U_3O_8 (7 732 tU) and sales were to the USA and UK for use in weapons programs. The first phase of uranium production in Australia ceased after the closure of the Rum Jungle plant in 1971.

3.55 Uranium exploration declined during the late 1950s but increased again in the late 1960s, stimulated by the easing of a Commonwealth Government export embargo and predictions of increased world demand for uranium in the early 1970s for generating nuclear power.

3.56 Important deposits were discovered between 1969 and 1973 at Nabarlek, Ranger, Koongarra and Jabiluka in the Alligator Rivers area, at Beverley and Honeymoon in the Lake Frome area (SA), and at Yeelirrieand Lake Way (WA). The Olympic Dam and Kintyre deposits were discovered in 1975 and 1985 respectively.

3.57 Mary Kathleen began recommissioning its mine and mill in 1974. Consideration by the Commonwealth Government of additional sales contracts was deferred pending the findings of the Ranger Uranium Environmental Inquiry which commenced in 1975. In 1977 the Commonwealth announced that new uranium mining could proceed, commencing with the Ranger project in the Northern Territory. The Ranger mine opened in 1981.

3.58 Australia's second phase of uranium mining commenced in 1976, with the resumption of mining at Mary Kathleen, and continues to the present. In addition to Mary Kathleen, mining has been from the Nabarlek, Ranger, Olympic Dam and Beverley operations.

3.59 Mary Kathleen ceased production in 1982 and 4 802 t U_3O_8 (4 072 tU) was produced from the mine during its second period of operation. The Nabarlek deposit was mined and stockpiled in 1979. The stockpiled ore was then processed from 1980 to mid-1988 for a total output of 10 858 U_3O_8 (9 208 tU), which was sold to Japan, Finland and France.

3.60 Since the start of Australia's second phase of uranium mining in 1976, cumulative uranium production to the end of 2005 has been 146 315 t U_3O_8 (124 068 t U). This includes production from Mary Kathleen, Nabarlek, Ranger (1981 to the present), Olympic Dam (1988 to the present), and from Beverley (2001 to the present).

3.61 Having won Government in 1983, the Australian Labor Party's 1984 National Conference amended the Party's Platform to what has become known as the 'three mines policy', nominating Ranger, Nabarlek and Olympic Dam as the only projects from which exports would be permitted. Provisional approvals for marketing from other prospective uranium mines were cancelled. This policy prevailed until the election of the Coalition Government in 1996.

3.62 The following section of this chapter describes Australia's three currently operational uranium mines and associated recent developments.

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Ranger

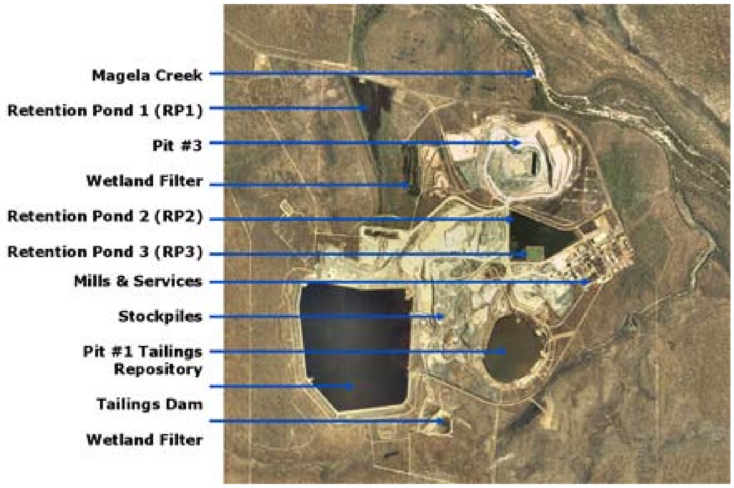
3.63 The Ranger uranium deposit, which is located 230 km east of Darwin in the Alligator Rivers region (see figure 3.2 and appendix F), was discovered in 1969 by a joint venture of Peko Wallsend and The Electrolytic Zinc Company of Australia. Development of the Ranger mine was the subject of the Ranger Uranium Environmental Inquiry, a major Commonwealth Government inquiry under Justice RW Fox between 1975 and 1977. The findings of the inquiry allowed the development of both the Ranger and Nabarlek mines. In 1978 the Commonwealth Government and the Northern Land Council, acting on behalf of the Traditional Aboriginal land Owners, reached agreement to proceed with mining, which commenced in 1979.[57]

3.64 The Ranger Project Area and the adjoining Jabiluka Mineral Lease are surrounded by, but not part of, the Kakadu National Park. Both areas are located on Aboriginal land, under title granted to the Traditional Owners, the Mirrar Gundjeihmi people, under the *AboriginalLand Rights Act (NT) 1976*.[58] Ranger is served by the township of Jabiru, which was constructed largely for the purpose.

3.65 Ranger is a large unconformity-related deposit and the ore is mined by open cut methods. As depicted in figure 3.3, within the Ranger Project Area there are two orebodies—Ranger No. 1 (now mined out) and Ranger No. 3 which is currently being mined. Open cut mining at the Ranger No. 1 orebody began in August 1981 and was completed by December 1994. Production from the processing plant continued from stockpiled ore until open cut mining commenced at Ranger No. 3 orebody in October 1996.

3.66 The Ranger mill has a nominal production capacity of 5 000 t U_3O_8 per year (4 240 tU), however production has exceeded this in recent years. Approximately 2.1 Mt of ore are milled annually (a record 2.3 Mt in 2005). Uranium recovery from the processed ore is about 91.5 per cent and ranges up to 93 per cent.[59] The mill uses a sulphuric acid leach process to dissolve uranium from the ore. Uranium is recovered from the leachate by solvent extraction and is precipitated as ammonium diuranate (yellowcake). This is then calcined (heated to more than 200 °C to remove volatile components) to produce concentrates of uranium oxide (grey-green coloured powder) assaying 99.2 per cent U_3O_8.[60]

Figure 3.3 Ranger mine site



Source Energy Resources of Australia .

3.67 Since August 1997, the No. 1 orebody open cut (Pit 1) has been used as a repository for mill tailings. The company proposes to finally dispose of all mill tailings into the No. 1 and No. 3 orebody open cuts, on completion of mining.[61]

3.68 Production from Ranger was a record 5 910 t U_3O_8 (5 012 tU) in 2005, 15 per cent above production levels for 2004.[62] In 2005, production from Ranger amounted to 12 per cent of the world total and was the world's second largest uranium mine (in terms of annual production), behind the very high grade McArthur River mine in Saskatchewan (Canada) which produced 8 491 t U_3O_8.[63] Uranium mined from Ranger is sold to utilities in Japan, South Korea, Europe (France, Spain, Sweden and the UK) and North America.[64] In 2005, the Ranger mine employed more than 350 people, including 46 Indigenous people.[65]

3.69 Ranger is now owned by Energy Resources of Australia (ERA), a subsidiary of Rio Tinto (which owns 68 per cent of ERA). In 2005, Rio Tinto was the world's second largest producer of uranium after Cameco (Canada), with Areva (France) the third largest producer.[66]

3.70 At the end of 2005, Ranger contained total Proved and Probable Reserves of 44 458 t U_3O_8 and an additional 42 587 t U_3O_8 in mineral resources (total of Measured, Indicated and Inferred Resources), as listed in table 3.7.

3.71 In October 2005 ERA announced that, due to the recent increases in uranium price, it is now economic for the company to lower the cut-off grade down to which it will process uranium ore (from 0.12 per cent to 0.08 per cent U_3O_8). The consequences of the reduction in cut-off grade are that milling operations will now continue at Ranger until 2014 and reserves have been increased. ERA intends to mine at Ranger until at least 2008 and the company has recently been exploring for extensions of the No. 3 orebody.[67]

Table 3.7 Ranger uranium ore reserves and mineral resources as at 31 December 2005

Reserves/Resource classification	**Ore** (Mt)	**Grade** (% U 3O 8)	**Contained U_3O_8** (tonnes)
Ore Reserves			
Current stockpile	9.98	0.15	14 716
Proved	4.48	0.25	11 314
Probable	8.42	0.22	18 428
TOTAL RESERVES	22.78	0.20	44 458
Mineral Resources *(In addition to reserves)*			
Measured	1.42	0.15	2 115
Indicated	12.55	0.14	18 018
Inferred	16.11	0.14	22 454
TOTAL RESOURCES	30.08	0.14	42 587

Source Energy Resources of Australia , *2005 Annual Report,* p. 8.

3.72 In other developments at Ranger, in December 2005 ERA completed construction of a $28 million water treatment plant, which the Committee inspected during its visit to the ranger mine site in October 2005. The plant will ensure that process and other water reaches drinking water standard before it is released from the site to the surrounding environment. In addition to assisting mining operations, it is intended that the plant will eventually become part of rehabilitation plans after the mine's closure.[68]

3.73 Figure 3.4 depicts several Committee members during an inspection of the Ranger mine site, standing on uranium ore stockpiles overlooking the processing plant. Figure 3.5 shows open cut mining of the Ranger No. 3 orebody.

Jabiluka

3.74 ERA holds title to the Jabiluka deposit, situated 22 km north of Ranger. The orebody was discovered in 1971, one year after Ranger, and the NT Government granted a mineral lease in 1982 following the signing of an agreement between the senior Mirarr Traditional Owner and the mining company (Pancontinental Mining). Jabiluka is a world class uranium deposit with total Proved and Probable Reserves of 67 000 t U_3O_8 and an additional 92 000 t U_3O_8 in mineral resources, as listed in table 3.8.[69]

Table 3.8 Jabiluka uranium ore reserves and mineral resources as at 31 December 2005

Reserves / Resource classification	**Ore** (Mt)	**Grade** (% U 3O 8)	**Contained U_3O_8** (tonnes)
Ore Reserves			
Proved	6.40	0.59	38 000
Probable	6.42	0.45	29 000
TOTAL RESERVES	12.82	0.52	67 000
Mineral Resources *(In addition to reserves)*			
Measured	1.80	0.41	7 000
Indicated	3.75	0.39	14 000
Inferred	15.70	0.48	75 000
TOTAL RESOURCES	21.07	0.46	96 000

Source Energy Resources of Australia , *2005 Annual Report,* p. 8.

3.75 Mining at Jabiluka was approved in 1999 subject to over 90 environmental conditions. As with Ranger, Jabiluka is surrounded by, but is not part of, Kakadu National Park. In consideration of World Heritage concerns about the impact of Jabiluka’ s development on the park, ERA previously agreed that Jabiluka and the Ranger operation would not be in full operation simultaneously.[70]

Figure 3.4 Committee members standing on ore stockpiles at the Ranger uranium mine in the Northern Territory

Source Energy Resources of Australia .

Figure 3.5 Open pit mining of uranium and processing plant at the Ranger uranium mine

Source Energy Resources of Australia .

3.76 Development of the Jabiluka deposit has been opposed by the Traditional Owners and allied environmental groups. The Traditional Owners have refused to grant approval for development of the mine, with the Mirarr people arguing that they were under duress when they signed the 1982 agreement.[71] The Mirarr and their supporters appeared before the United Nation's (UN) World Heritage Committee to argue that the mine would damage heritage values in the Kakadu region. However, the UN ultimately rejected this contention.[72]

3.77 Following a dialogue with the Mirarr which commenced in 2002, ERA has announced that there will be no further development at Jabiluka without the formal support of the Traditional Owners, and subject to feasibility studies and market conditions.[73]

3.78 In February 2005, the Gundjeihmi Aboriginal Corporation (representing the Traditional Owners), ERA and the Northern Land Council signed an agreement on the long-term management of the Jabiluka lease. This agreement obliges ERA (and its successors) to secure Mirrar consent prior to any future mining development of uranium deposits at Jabiluka. The decline which had previously been sunk at the Jabiluka site has been backfilled and the project site is currently under long-term care and maintenance.[74]

3.79 Mr Harry Kenyon-Slaney, Chief Executive of ERA, explained that ERA is determined to end years of adversarial and acrimonious debate over the future of Jabiluka:

> It is my view, and I think it is also the view of the majority shareholder of ERA [Rio Tinto], that it is very important that you do not bulldoze into people's backyards and develop mining operations without their consent. Clearly, there was not implicit consent, given the adversarial nature of the debate over Jabiluka. Sometimes you have to take a step back before you can move forward. We are now in the process of discussing with the traditional owners what might happen. When the parties are ready, hopefully we will be able to move forward, but that long period of acrimony is still very recent and I think the parties need time to think about the future.[75]

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Olympic Dam

3.80 The Olympic Dam deposit, which is located 560 km north of Adelaide, was discovered in 1975 by Western Mining Corporation (WMC) which was exploring in the area for copper. After considering geophysical data, a drill hole was sunk near a small stock water dam known as Olympic Dam, named in 1956 after the Olympic Games which took place in Melbourne that year. The speculative surface drilling struck copper and later drilling confirmed a resource of more than 2 000 million tonnes of ore containing both copper and uranium. From 1979 the deposit was developed as a joint venture between WMC and British Petroleum (BP) and production commenced in 1988. WMC, which took over BP Minerals' share in 1993, was acquired by BHP Billiton in July 2005.[76]

3.81 Olympic Dam is the largest known uranium orebody in the world, with an estimated overall resource of more than 1.46 Mt

U_3O_8 contained in some 3.9 billion tonnes of ore. The grade of the uranium resource is relatively low at between 0.03 and 0.06 per cent U_3O_8. The orebody starts at a depth of 350 metres and continues down to (at least) 1 000 metres. The mineralisation occurs in a hematite-rich granite breccia complex and lies beneath flat-lying sedimentary rocks of the Stuart Shelf geological province of SA.[77] Olympic Dam's uranium ore reserves and mineral resources as at June 2005 are listed in table 3.9.

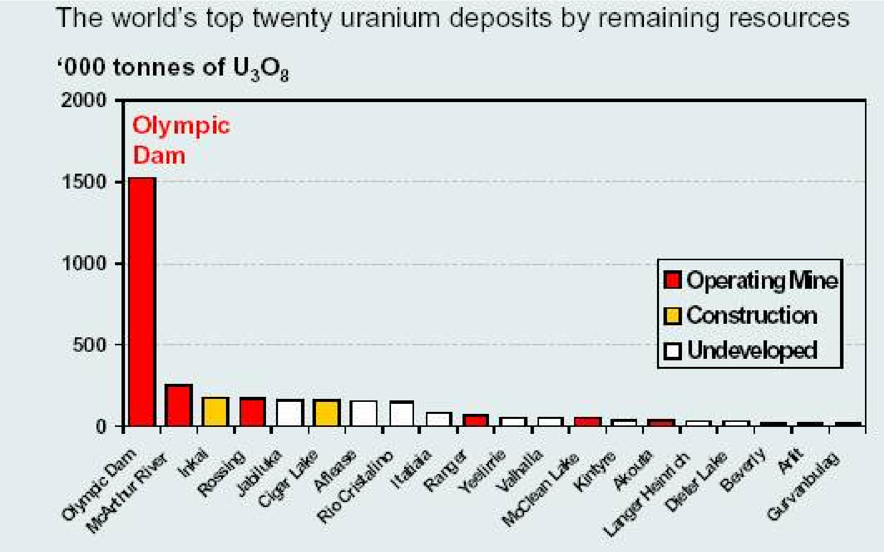
Table 3.9 Olympic Dam uranium ore reserves and mineral resources as at June 2005

Reserves/Resource classification	Ore (Mt)	Grade (% U_3O_8)	Contained U_3O_8 (tonnes)
Ore Reserves			
Proved	119	0.06	71 000
Probable	642	0.05	321 000
Mineral Resources*			
Measured	650	0.05	325 000
Indicated	1 440	0.04	576 000
Inferred	1 880	0.03	564 000
TOTAL RESOURCES	3 970	0.04	1 465 000

Source Geoscience Australia , *Submission no. 42* , p. 18; BHP Billiton PLC, *Annual Report 2005* , pp. 196–97.
* Measured and Indicated Resources are inclusive of those resources classified as Ore Reserves.

3.82 Despite conducting a large drilling program (a total of 2 270 km of drill core will have been completed by the end of 2007) as part of the pre-feasibility study for its proposed expansion of Olympic Dam (discussed below), BHP Billiton stated that the company has *not* yet defined the limits of the orebody in all dimensions. In particular, the boundaries of mineralisation at Olympic Dam are still open to the south and at depth.[78] Figure 3.6 illustrates Olympic Dam's immense size and global significance, ranking it alongside the world's top 20 uranium deposits by quantity of remaining resources.

Figure 3.6 The world's twenty largest uranium deposits by quantity of remaining resources



Source WMC Resources, *Developing the World's Biggest Uranium Resource* , Presentation by Mr Michael Nossal , April 2005, p. 5.

3.83 Olympic Dam is primarily a copper mine and the relatively low average grade of uranium (0.04 per cent U_3O_8) means that Olympic Dam would not support a uranium mine in its own right. The orebody is mined principally for its copper, gold and silver, with uranium as a valuable by-product. Olympic Dam ranks as the world's fourth largest known deposit of copper and fourth largest known deposit of gold.[79] In the mix of products, uranium represents 20–25 per cent of revenue from Olympic Dam, which totalled $1.1 billion in 2004.[80]

3.84 Olympic Dam is a large-scale underground mining operation using sub-level open stoping methods. Between 1989 and 1995, the annual capacity of the processing plant was increased in two stages to 85 000 t copper and 1 700 t U_3O_8 (1 440 tU) plus associated gold and silver from the processing of 3.0 Mt ore per year.[81]

3.85 A major expansion of the project was completed in March 1999 at a cost of $1.94 billion. Annual production capacity was increased to 200 000 t copper, 4 600 t U_3O_8 (3 900 tU), 2 050 kg gold and 23 000 kg silver. To sustain this rate of production, approximately 8.7–9.2 Mt ore are mined and processed annually. Water required for mining and processing operations and for the township of Roxby Downs is pumped from borefields within the Great Artesian Basin (GAB). The main borefield is located more than 175 km north-east of the mine.[82]

3.86 Government approval for the major expansion was granted after a comprehensive EIS was assessed jointly by the Commonwealth and SA Governments. In addition to the existing environmental regulations and controls on the project, new requirements were imposed relating to the management of the GAB water resources, future assessments of the tailings management systems, and impacts of future changes to technology and mining practices.[83]

3.87 GA noted that the metallurgical processes to recover copper, uranium, gold and silver at Olympic Dam are complex, however the processes relating to uranium recovery can be summarised as follows. After crushing and grinding, the ore is mixed with water and the slurry is pumped to the flotation plant. Copper concentrates are produced using standard flotation processes. The non-sulphide particles, which do not float (referred to as flotation tailings), contain most of the uranium minerals. Acid mixed with an oxidant is then added to leach uranium from the flotation tailings, and the slurry is heated to 60 °C to improve the leach process. Uranium is recovered from the leach liquor by solvent extraction. Pulsed column technology is used to improve the recovery rate and to reduce the consumption of organic reagents. As at Ranger, the solutions containing dissolved uranium are treated with ammonia and calcined to produce uranium oxide powder.[84]

3.88 In 2005 Olympic Dam produced 4 335 t U_3O_8 (3 676 t U), which was nine per cent of the world's total mine production and the third largest uranium producer. This represented a marginal decrease on 2004 production of 4 370 t U_3O_8 (3 735 tU). However, production from Olympic Dam has continued to expand since mining commenced in August 1988—production in 1988 was 1 180 t U_3O_8, in 1991 it was 1 400 t U_3O_8, in 1993 it was 1 900 t U_3O_8, and in 1998 it was 4 500 t U_3O_8.[85] Uranium sales are to the US, Canada, Sweden, UK, Belgium, France, Finland, South Korea and Japan.[86]

3.89 The Olympic Dam operation employs 1 670 people of which some 283 people work in the uranium production sector.[87] The scale of Olympic Dam (approximately 6–7 km in length) and the mine's processing plant, smelter and refinery are depicted in figures 3.7 and 3.8.

Proposed expansion of Olympic Dam

3.90 Prior to the acquisition by BHP Billiton, in 2004 WMC commenced a study to investigate the feasibility of a major expansion of the Olympic Dam operations. One of the proposals was an open pit mining expansion that would increase annual uranium production, from some 4 000 t U_3O_8 currently, to approximately 15 000 t U_3O_8, as well as expand copper production to 500 000 t per year and gold to 500 000 ounces per year. This would require mining 40 Mt of ore per year—a four-fold increase in the mining rate.[88] Table 3.10 compares current activity at Olympic Dam with the proposed development.

Table 3.10 Proposed Olympic Dam expansion

	Current	Proposed (2013+)
Mine production (per year)	Ore mined = 10 Mt Uranium = 4 000 t Copper = 220 000 t Gold = 80 000 ounces Silver = 800 000 ounces	Ore mined = ~40 Mt Uranium = ~15 000 t Copper = ~500 000 t Gold = ~500 000 ounces Silver = ~2 900 000 ounces
Roxby Downs population	4 100 (average age 27 yrs, 32 per cent under 15 yrs)	Total = 8 000–10 000
Energy (per year)	120 MW, from State grid	Total of ~420 MW, from State grid, on-site gas fired generation, or a combination
Water (per year)	12 GL (32 ML per day), from Great Artesian Basin (GAB)	Total of ~48 GL, from GAB/regional aquifers or coastal desalination (Whyalla area)
Transport In/Out (per year)	1 Mt, by road 12 000 trucks (30 per day)	Total of ~2.2 Mt, by road/rail intermodal or direct rail 26 500 trucks (70 per day)
Exports	Via Port Adelaide	Via Port Adelaide and/or Darwin

Source BHP Billiton, *Exhibit no. 78, Presentation by Dr Roger Higgins* , p. 13.

Figure 3.7 Processing facilities at Olympic Dam in South Australia

Source BHP Billiton.

Figure 3.8 Aerial view of Olympic Dam

Source BHP Billiton.

3.91 The study for the proposed expansion has included:

- a major drilling program (90 drill holes) to better define the resources in the southern part of the deposit;
- assessing the alternative mining, treatment and recovery methods for the southern part of the deposit;
- identifying and evaluating water and energy supply options; and
- logistics planning that may include linking Olympic Dam to the national rail network.[89]

3.92 Recent drilling has identified significant additional resources in the south-eastern portion of the deposit. The resources as at March 2005 were almost a 35 per cent increase over the resources at December 2003.[90] WMC considered that these resources were 'of sufficient size to support an expanded world-class operation for many decades.'[91]

3.93 Evaluation of the various mining methods and the scale of operations were completed in March 2005. Two mining options were evaluated: underground (sub-level caving or block caving) and open pit. From the results of the study, WMC selected open pit as the preferred method because it provided 'clear economic benefits over the alternatives based upon commercially proven technology.'[92]

3.94 The mine's current owners, BHP Billiton, are now undertaking an extensive pre-feasibility study (PFS) for the proposed expansion, with the study expected to be completed by October 2007. Under the company's capital investment procedures, the PFS is the predominant decision making activity, with only a brief feasibility study, of perhaps one year's duration, to follow. BHP Billiton will expend approximately $300 million on the PFS and a further $100 million on the feasibility study.[93] The objectives of the study are to:

- identify the mine's total resource base;
- select a single preferred, sustainable life of mine plan;
- identify financing needs;
- identify implementation requirements; and
- assess strategic implications of the preferred development option.[94]

3.95 It is expected that by late 2007, or early 2008, BHP Billiton will have decided on the size and shape of the expansion project. An Environmental Impact Study will be completed by the end of 2007. The feasibility study phase is expected to be completed by early 2009, with construction (the execution phase) commencing in that year and continuing for four years until 2013. The expanded facilities are expected to become operational in 2013.[95]

3.96 As the mineralisation at Olympic Dam commences at about 300 metres below surface, the execution phase will require the removal of a substantial overburden, amounting to one billion tonnes of rock that will need to be pre-stripped. During this phase, it is likely that production will continue from underground, but begin to diminish as the open pit starts up. It is expected that the underground and open pit operations will run in parallel for up to eight years.[96] The dimensions of the completed pit will be approximately three kilometres across and one kilometre deep.[97]

3.97 The proposed expansion would more than treble uranium production from the mine and, in doing so, double Australia's current national production.[98] Olympic Dam would become the world's largest uranium producer, accounting for over 20 per cent of total world production annually. Furthermore, the quantity of remaining uranium resources means that Olympic Dam could be mined at the expanded rate for over 70 years. WMC estimated that once the expansion is complete, uranium production will contribute 35–40 per cent of revenues from the mine.[99]

3.98 The majority of the mine's workforce of some 1 750 employees (with a similar number of permanent contractors) live at Roxby Downs, located 15 kilometres to the south of the mine. The town, which was developed by the mine, currently has a population of 4 000. The expanded mine would double the workforce, requiring an expansion of the town and its facilities.

3.99 As listed in table 3.9, BHP Billiton is studying options to provide water (including possible construction of a desalination plant located near Whyalla and piping the water inland, a distance of 300 km), power (including gas piped from Moomba) and transport (including the construction of a rail link between Pimba and Olympic Dam of 90 km) for the expanded mine.[100]

3.100 The proposed expansion would involve an investment of up to US$5 billion. The four-year execution phase would employ an average of some 5 000 construction workers, with a peak of up to twice this number.[101] Chapter nine discusses Olympic Dam's economic significance and the benefits that may flow from the proposed expansion of the mine. Some submitters were critical of the proposed expansion, primarily on the grounds of the possible environmental impacts, and these concerns are summarised in chapter ten.

3.101 In relation to its other uranium asset in Australia, the Yeelirrie deposit in WA (Australia's third largest uranium deposit), BHP Billiton stated that 'at the moment, opening Yeelirrie is not an option.'[102]

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Beverley

3.102 The Beverley uranium deposit, which is located 520 km north of Adelaide and adjacent to the northern Flinders Ranges on the plains north-west of Lake Frome, is a relatively young sandstone deposit with uranium mineralisation leached from the Mount Painter region. The deposit was discovered in 1969 and purchased by its current owners, Heathgate Resources (a wholly-owned subsidiary of General Atomics of the US), in 1990. The deposit consists of three mineralised zones (north, central and south) in a buried palaeochannel (the Beverley aquifer) at a depth of between 100 and 130 metres below surface, and 10 to 20 metres thick. The aquifer is isolated from other groundwater, most notably the GAB, which is about 150 metres below it, and small aquifers above it which are used for stock watering.[103]

3.103 The Beverley project is Australia's first commercial in situ leach (ISL) uranium mining operation. At Beverley, uranium occurs in porous sandstones saturated with groundwater. GA and the UIC explained the ISL technology as follows. Uranium is leached in situ using sulphuric acid and an oxidant (hydrogen peroxide) which is introduced into the sandstones via injection wells. The leach solutions containing dissolved uranium are then pumped to the surface via production (extraction) wells and into the processing plant. Thus, the Beverley mine consists of wellfields which are progressively established over the orebody as uranium is depleted from sections of the orebody immediately underneath. Wellfield design is on a grid with alternating extraction and injection wells, each identical to typical water bores. The spacing between injection wells is about 30 metres with each pattern of four having a central extraction well. Monitor wells are situated to detect any leakage of mining fluids into other aquifers.[104] Figure 3.9 shows Committee members inspecting one of the extraction wells at the Beverley uranium mine.

3.104 Uranium is recovered in the processing plant using ion-exchange technology. The final product is hydrated uranium oxide ($UO_4.2H_2O$) which is a yellow powder, also referred to as 'yellowcake'. This is heated in a low temperature zero-emissions dryer to remove moisture and residual chemical reagents.[105] Figure 3.10 shows Committee members with drums of yellowcake at Beverley being prepared for shipping.

3.105 Production from the northern zone at Beverley commenced in 2000. In 2005 the mine produced 977 t U_3O_8, which was marginally less than 2004 production of 1 084 t U_3O_8.[106] Heathgate Resources aims to increase the mine's capacity to 1 500 t U_3O_8 per year and plans to achieve this level of production in 2009.[107]

3.106 Beverley is the world's largest single ISL uranium mine. In 2004, production from Beverley was greater than total US production, which was from a number of ISL operations in Wyoming, Nebraska and Texas. In 2005 Beverley accounted for two per cent of world mine output. Beverley has sales contracts with utilities in the US, Japan, South Korea and Europe and the mine employs some 180 people.[108]

3.107 Mr Mark Chalmers, the former Senior Vice President and General Manager of Heathgate Resources, argued that:

> … whilst small in comparison to Olympic Dam and Ranger, [Beverley] is important in terms of setting a standard for the small and medium sized producers of the future. Our mine is the most technologically advanced ISL uranium mine in the world. It is equipped with the latest instrumentation and controls. Our method of extraction minimises environmental impact and health and safety impacts to our employees and to the public.[109]

Figure 3.9 Committee members inspecting an extraction well at the Beverley in-situ leach uranium mine in South Australia

Figure 3.10 Committee members with drums of yellowcake (hydrated uranium peroxide) in a container being prepared for shipping at the Beverley uranium mine

3.108 As at April 2005, the Beverley deposit contained 5 897 t U_3O_8 in Proved and Probable Reserves. The deposit contains an overall resource of 21 600 t U_3O_8 at a grade of 0.18 per cent.[110]

3.109 During 2003, ISL mining at Beverley progressed from the deposit's north orebody into the much larger central orebody. Installation of the main pipelines (trunklines) connecting the plant to the central orebody was completed and, by early 2004, production reached an annualised rate of 1 000 t U_3O_8, the licensed capacity of the plant at that time.

3.110 Commonwealth and SA Government agencies have recently considered a proposal from Heathgate Resources to optimise the Beverley operations to produce up to 1 500 t U_3O_8 per year. Geoscience Australia and the Bureau of Rural Sciences (BRS), which provided technical advice on this proposal to the Australian Government Departments of Industry (DITR) and the Environment and Heritage (DEH), advised that the company should be required to undertake groundwater studies to determine the hydrological impacts on the Beverley aquifer which could result from increased rates of disposal of liquid wastes from the ISL operations.

3.111 GA informed the Committee that in 2004, after considering this technical advice together with further reports from the company, the Minister for Industry, Tourism and Resources approved the extension and granted Heathgate Resources a new uranium export permit. As part of the export permit, the Minister imposed a number of conditions including, inter alia, that the Beverley operations are to be carried out on the basis of a neutral water balance;that is, the total volume of fluid injected into the aquifer from all sources must equal the total volume pumped out.[111]

3.112 In 2004 Heathgate Resources announced the discovery of a new zone of uranium mineralisation approximately three km south of the Beverley deposit. This ore zone, referred to as the Deep South zone, was discovered using a range of geophysical surveys followed up by an extensive drilling program comprising more than 120 holes totalling 23 745 metres. The Deep South ore zone is within sands similar to the main Beverley deposit. Resource estimates for this zone have not been reported to date.

3.113 The company has also recently reported other discoveries in and around the Beverley mine area in addition to the Deep South zone. These more recent discoveries are new and require additional follow-up, however, the success of on-going exploration is expected to increase the life of the project.[112]

3.114 ISL mining has numerous advantages over traditional excavation techniques, including: minimal disturbance to the land surface; no excavation of large volumes of overburden or mine wastes; a simple processing plant with no crushing or grinding required; no large volumes of tailings or tailings dams; no exposure of the orebody to the atmosphere; reduced radiation exposure to workers and the public; and relatively simple rehabilitation requirements.[113] However, for the ISL mining method to be applicable requires unique geological and hydrological conditions. In general, the deposits need to be located in sedimentary permeable zones. Heathgate Resources estimated that ISL would be applicable to some 15 to 20 per cent of uranium deposits worldwide. In addition to Beverley, other in situ leachable uranium deposits in Australia include Honeymoon and Goulds Dam in SA, and Oobagooma and Manyingee in WA.[114]

3.115 The Committee received some evidence that was critical of the environmental impacts of ISL mining and these are considered in chapter ten.

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Other industry developments

3.116 In addition to the industry developments described above, evidence to the inquiry mentioned the likely development of the Honeymoon deposit in SA and the problematic issue of recovering uranium from brannerite ores, such as those at Olympic Dam and the Valhalla deposit in Qld.

Honeymoon Project

3.117 The Honeymoon deposit, located 75 km north west of Broken Hill in South Australia (see figure 3.2), was discovered in 1972 and is contained within unconsolidated sands at a depth of 100 metres in the Yarramba palaeochannel. The deposit extends over 150 hectares. Honeymoon, along with the adjacent East Kalkaroo deposit and the Goulds Dam–Billaroo West deposits (located 80 km north west of Honeymoon–East Kalkaroo), were acquired by Canadian company Southern Cross Resources in 1997. In 2005, Southern Cross Resources merged with South African companies Aflease Gold and Uranium Resources to form sxr Uranium One, which has a primary listing on the Toronto stock exchange. Uranium One also owns uranium and gold projects in South Africa.[115]

3.118 Honeymoon and East Kalkaroo contain 4 200 t U_3O_8. [116] Table 3.11 summarises the resource estimates for both the Honeymoon and Goulds Dam deposits.

3.119 Southern Cross Resources submitted an initial EIS to develop the Honeymoon deposit in June 2000. Following the approval of the EIS, the company was granted an export license by the Commonwealth Government in November 2001.[117] Following the conclusion and signing of a Native Title Agreement with the Adnyamathanha people (a similar agreement with the Kuyani people was concluded in 1998), the State Government granted Southern Cross Resources a mining lease to develop Honeymoon as an ISL project in February 2002.[118] The current State Government reportedly considers that the project is an existing mine, because the mining lease was granted by the previous State Government, and will therefore allow the mine to proceed.[119]

Table 3.11 Mineral resources for Honeymoon, East Kalkaroo, Goulds Dam and Billeroo

Deposit	Resource category	Million tonnes	Average grade (% U_3O_8)	Contained U_3O_8 (tonnes)
Honeymoon*	Indicated	1.2	0.24	2 900
East Kalkaroo	Indicated	1.2	0.074	910
Goulds Dam	Indicated	5.6	0.045	2 500
Billeroo	Inferred	12.0	0.03	3 600
Total Resources				**10 310**

Source Southern Cross Resources , *2004 Annual Report,* p. 6
* Resource figures for Honeymoon from sxr Uranium One, *sxr Uranium One Announces Honeymoon Feasibility Study and Approves Honeymoon Project* , News Release, 29 August 2006.

3.120 In 2004 Southern Cross Resources commissioned a cost and engineering study for a plant at Honeymoon with a design capacity of 400 t U_3O_8 per year and a mine life of six to eight years. However, the company decided to defer production pending higher uranium prices.[120]

3.121 In May 2006 Uranium One submitted an application for a license to commercially mine uranium at the Honeymoon site to the SA Environment Protection Authority (EPA). The license application relates to mine design, radiation and waste management, and rehabilitation.[121] In June 2006 the company completed feasibility studies and additional drilling to better define the Honeymoon and East Kalkaroo deposits. Subject to State Government approval of the subsidiary plans, the Board of Uranium One was expected to decide on whether to proceed with production in mid 2006. Plant construction is expected to take less than 18 months with production commencing in the first quarter of 2008.[122]

3.122 In August 2006 the Board of Uranium One announced that it had approved the development of the deposit.[123] The Honeymoon project, which will be an acid ISL operation similar to the Beverley uranium mine, is expected to produce a total of 2 400 t U_3O_8 over a period of seven years. The project will employ approximately 50 people.[124]

Recovery of uranium from brannerite ores

3.123 At Olympic Dam, Ranger and many other uranium mines worldwide, sulphuric acid is used to dissolve uranium minerals from uraninite ores using conventional acid leach plants. However, brannerite, which is another important uranium mineral, is not dissolved in these sulphuric acid plants. The consequence is that less uranium is recovered after processing these ores and the brannerite is sent to tailings dams for disposal. This was confirmed by the Australian Atomic Energy Commission during the 1960s, after research on bulk metallurgical samples from brannerite-rich mineralisation at the Valhalla deposit in Qld.[125]

3.124 GA argued that this is a key issue for the Australian uranium industry because cost effective processes to recover uranium from brannerite would result in a significant increase in Australia's recoverable low cost resources of uranium. As noted above, under the IAEA and OECD-NEA resource classification scheme, Identified Resources are quantified as *recoverable* uranium—that is, after mining and processing losses have been deducted. This issue is of particular importance for Australia because much of the uranium at Olympic Dam (approximately 30 per cent) is contained in brannerite and only about 70 per cent of the uranium is recovered.[126] Hence, if uranium recoveries from Olympic Dam could be increased it would mean much greater production of uranium from the same quantity of ore, and therefore have a dramatic effect on the quantity of Australia's overall recoverable uranium resources.

3.125 GA noted that the mine's former owners, WMC Resources, commenced a major research program to improve uranium recoveries, including testing various new recovery techniques such as elevating the temperature of the leach tailings.[127] During 2004 the company implemented a first phase of these metallurgical improvements and reported recoveries as high as 77 per cent. GA argued that:

> The implications of these results are far reaching because, if they can improve recoveries up to 85% (as proposed), this will have a marked improvement in production and revenues. In the lower grade ores at Olympic Dam, the ratio of brannerite:uraninite increases with decreasing ore grade. It is very important for future expansions of the operations into the southern section of the orebody (lower grade) that this brannerite problem be solved.[128]

3.126 Summit Resources stated that its metallurgical test work indicates a potential overall recovery of around 75 per cent of the uranium at the Valhalla deposit in Mount Isa.[129]

3.127 Before turning to a discussion of exploration and the potential for further discoveries of uranium in Australia, the Committee notes again a conclusion of the previous chapter—that there is great potential for Australia to expand production and become the world's premier supplier of uranium.

3.128 The UIC submitted that ' Australia is a preferred supplier to the world' and GA argued that 'Australian uranium mining companies have gained a reputation as reliable suppliers to customer countries and utilities.'[130] Similarly, ASNO argued that:

> As a stable, secure low-cost uranium producer Australia is likely to occupy a key position in world uranium supply. Not only does Australia hold the largest uranium reasonably assured recoverable resources, it also holds a significant share of the market in areas where nuclear power is expanding; principally, North Asia.[131]

3.129 Likewise, the Australian Nuclear Association (ANA) submitted that:

> Australia is a preferred uranium supplier in many markets, not only due its low cost high-quality product, but also because it is seen to have high economic and political stability.[132]

3.130 Moreover, Nova Energy argued that, unlike some other supplier countries, the Australian minerals industry can properly claim to be a 'mature, high technology and heavily regulated industry', where stringent safety and environmental regulations are imposed.[133]

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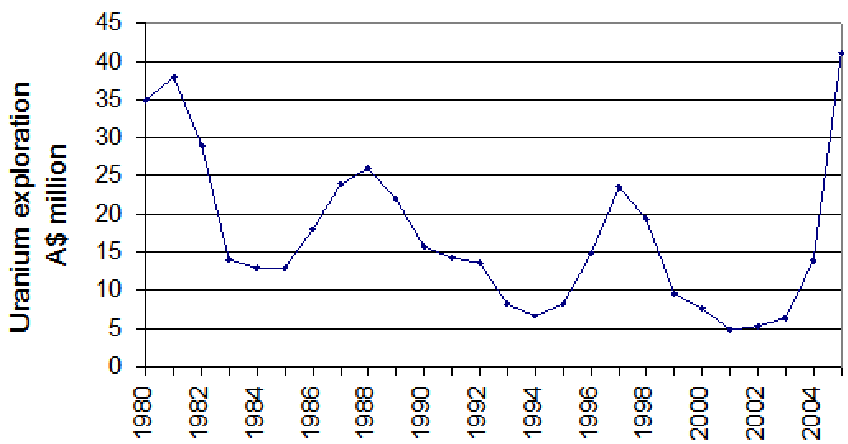
Exploration

3.131 The Australian Bureau of Statistics (ABS), which produces official exploration data for Australia, records that uranium exploration expenditure amounted to $20.7 million during financial year 2004–05. This figure was almost double the 2003–04 total of $10.5 million, which in turn was an increase on the 2002–03 figure of $6.9 million. In the first half of 2005–06, exploration expenditure totalled $27.7 million, already exceeding expenditure of the entire previous year.[134]

3.132 GA also undertakes an annual survey of uranium exploration in Australia, reporting expenditures on a calendar year basis. As with the ABS findings, GA has reported a significant increase in uranium exploration since early 2003. In 2005, total expenditure on uranium exploration was $41.09 million, which was the highest since 1988 (in constant 2005A$) and almost a three-fold increase on 2004 expenditure of $13.96 million. Exploration expenditure in 2003 was $6.38 million.[135] Figure 3.11 shows uranium exploration expenditure in Australia since 1980.

Figure 3.11 Uranium exploration expenditure in Australia 1980–2005



Source Geoscience Australia
Annual expenditures are nominal, dollar of the day, figures and have not been adjusted for inflation.

3.133 GA argued that exploration expenditure has risen for three principal reasons: the rise is uranium spot market price, which has increased four-fold from US$10/lb U_3O_8 in early 2003 to more than $45/lb U_3O_8 in June 2006; the rise in crude oil prices; and the perception in the market that secondary supplies of uranium are being exhausted. These factors were discussed in chapter two.[136]

3.134 GA observed that, historically, uranium exploration in Australia has been highly successful. The majority of Australia’s uranium deposits were discovered between 1969 and 1975—approximately 50 deposits were discovered during this short period, including several world-class deposits such as Ranger, Jabiluka, Nabarlek and Koongarra in the Alligator Rivers region (NT); Olympic Dam and Beverley (SA); and Yeelirrie in Western Australia (WA). From 1975 to 2003, only another four deposits were discovered and of these only one deposit (Kintyre in the Paterson Province of WA) has RAR recoverable at less than US$40/kg U.[137]

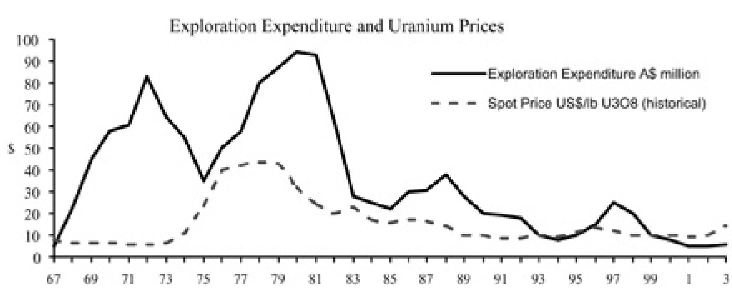
3.135 Despite steady growth in mining and exports, expenditures on uranium exploration in Australia fell progressively for 20 years, from a peak level of $35 million ($105 million in constant 2003A$) in 1980 to a historic low of $4.8 million in 2001 ($5.34 million in constant 2005A$).[138] The increase in expenditure that culminated in the 1980 peak was in large part due to the oil shocks of 1973 and 1979, which GA noted strongly resembles the current situation of high crude oil prices.[139]

3.136 During the late 1970s and early 1980s, up to 60 companies were actively exploring for uranium in Australia. Exploration was carried out in ‘greenfields’ areas, as well as the known uranium provinces. Subsequently, expenditures declined to 2001, when only five companies were actively exploring for uranium in areas adjacent to known deposits, mainly in western Arnhem Land (NT), the Frome Embayment and the Gawler Craton-Stuart Shelf (SA). This long decline was interrupted by two brief periods of increasing expenditures following the discovery of the Kintyre deposit in 1985, and the abolition of the ‘Three mines’ policy by the Commonwealth Government in 1996.[140] The decline in exploration expenditure resulted from several factors:

falling uranium prices over two decades—prices fell from an average of US$42.57/lb U_3O_8 in 1979 to an average of $8.30/lb U_3O_8 in 2002;

- restrictions in some jurisdictions on uranium exploration and production;
- increasing availability of supplies from secondary sources (mainly highly enriched uranium stocks); and
- decreasing costs of production resulting from large-scale, low-cost mining in Canada and Australia.[141]
- Figure 3.12 plots uranium exploration expenditure in Australia and the spot price for uranium from 1967 to 2003.

Figure 3.12 Exploration expenditure and uranium prices (1967–2003)



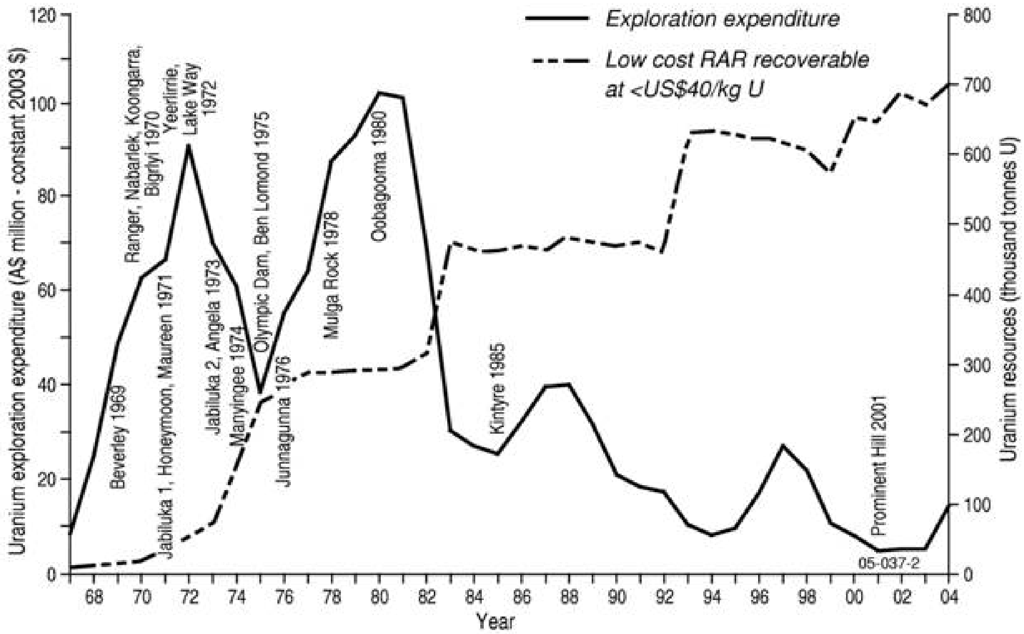
Source UIC, *Submission no. 12* , p. 13.

3.137 Cameco noted that the decline in exploration expenditure resulted in activity being focussed in relatively few areas, including the Frome Embayment in SA, the ARUF in the NT and, in the early 1980s, the Rudall Province of WA. However, apart from limited activity in these areas, ‘exploration has effectively stopped in the rest of Australia for the past twenty years.’[142]

3.138 Despite the paucity of discoveries since 1985, Australia’s low-cost resources have continued to increase as a result of the delineation of additional resources at known deposits, mostly at Olympic Dam.[143] Figure 3.13 illustrates exploration expenditure, discovery of deposits and the increase in low-cost resources over the period 1967 to 2004. While there has been a trend of increasing exploration expenditure since early 2003, there has been relatively little exploration for uranium over the past two decades and Australia’s known uranium resources generally reflect exploration efforts that took place 30 years ago. As the UIC argued:

> It can thus be seen that Australia’s known uranium resources largely reflect exploration efforts more than 25 years ago. Very little exploration for uranium has been carried out since. There is now significant potential for increasing exploration in the light of higher uranium prices, but state government policies need to be positive.[144]

Figure 3.13 Trends in uranium exploration expenditures, discovery of deposits and the increase in Australia’s low cost resources



Source Geoscience Australia , *Exhibit no. 60, Australia 's uranium resources, production and exploration,* p. 9.

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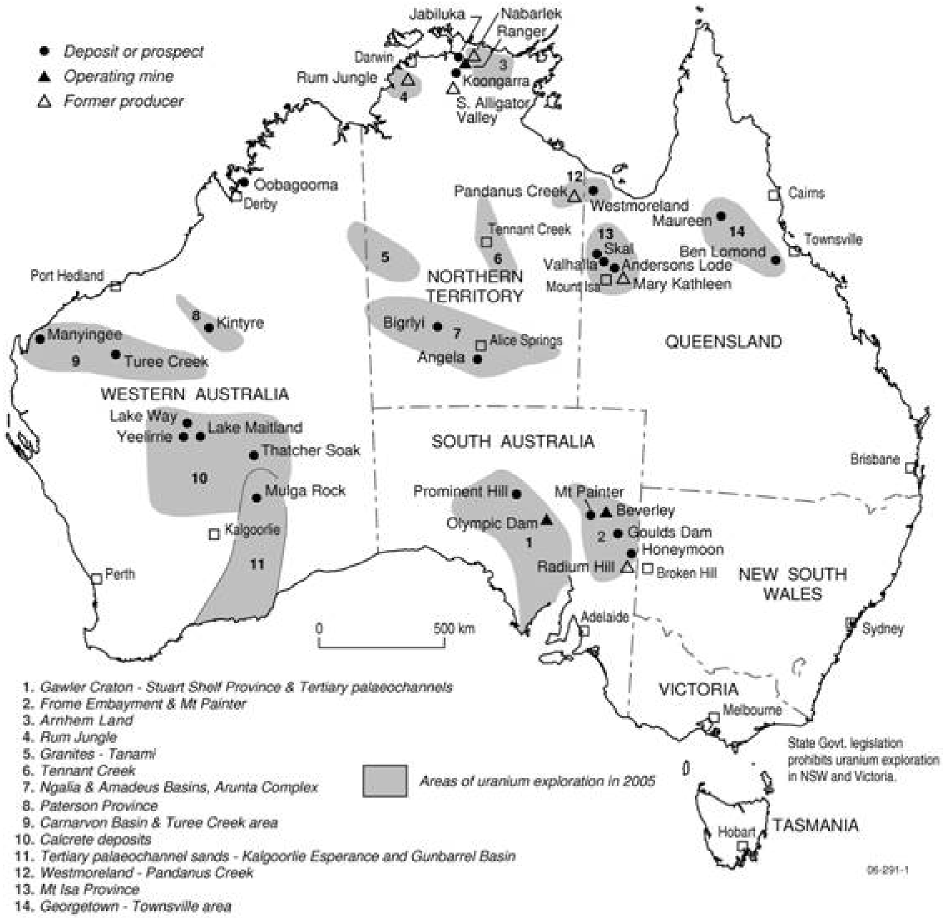
Recent exploration activity

3.139 The marked uranium price rise since 2003 (see figure 2.6 in chapter two) has stimulated a significant resurgence in exploration activity. In 2004 there were 14 active uranium exploration projects in Australia, while in 2005 the number of active projects had increased to 70. The number of companies actively exploring for uranium increased from five at the start of 2004 to more than 34 by late 2005.[145]

3.140 The proportions of total exploration expenditure spent in each jurisdiction in 2005 were: SA 42 per cent, NT 37 per cent, Qld 15 per cent and WA 6 per cent. The majority of expenditure was in SA and NT which together accounted for almost 80 per cent of the total. The main areas (in terms of expenditure) of exploration, which are illustrated in figure 3.14, were:

- South Australia —Gawler Craton-Stuart Shelf region; Tertiary palaeochannel sediments of the Frome Embayment; and palaeochannels overlying the Gawler Craton ;
- Northern Territory —Alligator Rivers region and Western Arnhem Land , and Ngalia Basin (including Napperby project in Tertiary sediments overlying the Ngalia Basin); and
- Queensland — Mount Isa province.[146]

Figure 3.14 Areas of uranium exploration in 2005

- 

Source Geoscience Australia .

3.141 Important uranium exploration results in 2005 included:

- discovery of major extensions of the Olympic Dam deposit to the south-east, and the proposal to test the deeper zones of mineralisation down to depths of 2.5 km below surface (currently resources have been evaluated to a depth of 1 km below surface);
- discovery of a new deposit, Beverley 4 Mile, which is 5–10 km west of the Beverley mine, and continued discovery of further mineralisation to the south of the Beverley mine; and
- discovery of extensions to the Valhalla , Skal and Andersons deposits and significant intersections in the Bikini and Mirrioola deposits.[147]

3.142 In other developments, GA noted that in 2005 Bullion Minerals explored for sandstone-hosted uranium deposits in Tertiary sands overlying granitic basement rocks in the Kalgoorlie–Esperance region of WA. This is the first time that uranium exploration has been undertaken in this area. Exploration also re-commenced in many geological provinces in which the last exploration for uranium occurred more than 20 years previously.[148]

3.143 In 2004–05 Southern Cross Resources and Heathgate Resources conducted drilling in areas of the Frome Embayment area of SA, which had first been identified by airborne electromagnetic surveys that defined the extent of buried palaeochannels. These activities were directed at exploring for sandstone-type deposits. As noted above, Heathgate Resources announced the discovery of a new zone of uranium mineralisation 3 km south of Beverley (the Deep South zone).[149]

3.144 In 2004 Southern Cross Resources discovered a new zone of low-medium grade uranium mineralisation in the area of the Yarramba palaeochannel, approximately 1.5 km north-west of the Honeymoon deposit, known as the Brooks Dam prospect. The grade and thickness of mineralisation were measured using a 'Prompt Fission Neutron' probe technology, which gives more reliable uranium grades than probes normally used in sandstone-hosted uranium deposits. Southern Cross Resources also completed airborne electromagnetic surveys and ground gravity surveys over the Billeroo region and defined the extent of the Billeroo palaeochannel. A program of drilling was also conduced to evaluate the resources at the Goulds Dam prospect. In August 2005, Marathon Resources announced an inferred resource of 33 200 t U_3O_8 at its Mount Gee prospect in the Curnamona Province of SA.[150]

3.145 The Beverley 4 Mile prospect, owned by Alliance Resources/Quasar Resources, is important because, if current interpretations prove to be correct, it represents the first known discovery of significant uranium mineralisation within Mesozoic sediments in SA. GA explained that this highlights the potential for further discoveries in the Mesozoic sediments [151] which underlie extensive regions of the Frome Embayment.

3.146 In the Gawler Craton of SA, Minotaur Resources continued exploration drilling of copper-gold-uranium mineralisation at the Prominent Hill deposit. The geological setting and style of mineralisation are similar to Olympic Dam, which is also located in the Gawler Craton 150 km to the southeast. However, uranium grades at Prominent Hill are lower than at Olympic Dam and GA noted that the company has no plans to recover uranium.[152]

3.147 The SA Government Department of Primary Industries and Resources has reported that there are currently more than 20 companies involved in uranium exploration in SA.[153] Media reports have stated that as at January 2006 some 25 Australian and international companies have been granted a total of 86 uranium exploration licenses in SA, an increase of 100 per cent in three years.[154]

3.148 The NTMC also explained that there has recently been considerable interest in uranium exploration in the Territory, with exploration licences granted to 17 companies in the five months to October 2005 alone. There are now some 25 companies currently active in the Territory, with most of these being Australian companies, three Canadian, one UK-linked and one French company, either exploring or planning to explore for uranium.[155] The recent interest in exploration was attributed to the uranium price rise and to the Commonwealth Government's decision to assume responsibility for uranium mine approvals, which gave certainty to the junior companies in the industry. The NTMC estimated that exploration expenditures varied from a couple of hundred thousand dollars by juniors, up to $5–6 million per year by Cameco, which is the largest explorer in the Territory.[156]

3.149 In terms of exploration activity and expenditure by individual companies, the Committee received the following evidence:

- Cameco noted that it has been exploring for uranium in Australia for ten years prior to the present price upturn, spending some $50 million in the ARUF of the NT and $4–5 million in the Rudall area of WA to August 2005.[157]
- Heathgate Resources, operators of the Beverley mine, noted that despite the company's small size it is one of the largest explorers for uranium in Australia, with exploration expenditure approximately equal to that of Cameco. Heathgate indicated that it may spend close to $6 million in uranium exploration in 2006.[158]
- Since commencing exploration in Australia, Areva has spent some $150 million with the company focussing on SA but with some exploration also in the NT. Areva argued that there has been negligible uranium exploration over the past twenty years and 'there appears to be a much greater potential for discovery of further uranium resources in Australia.'[159]

3.150 ERA reported that in 2005 the company conducted exploration drilling on the eastern vicinity of the Ranger Pit 3 for the purpose of determining the ultimate size of the orebody. Some 9 232 metres were drilled at a cost of $2.26 million. ERA also conducted airborne geophysical surveys which highlighted further opportunities and exploration drilling may be conducted in 2006.[160]

3.151 RWE NUKEM reported that BHP Billiton plans to spend US$130 million on surface and underground drilling over the next two years to better define the Olympic Dam orebody, as part of its pre-feasibility study for the possible mine expansion. A further US$25 million is budgeted for a new underground tunnel into the southern orebody for detailed resource drilling/technical evaluation.[161]

3.152 In terms of uranium exploration and mine development abroad, Australian mid-tier mining company, Paladin Resources, which owns uranium deposits in WA (Many ingee and Oobagooma), is currently developing a new uranium mine and mill at its Langer Heinrich project in Namibia. Paladin decided to develop the deposit in May 2005. The company is also completing a feasibility study on its Kayelekera Project in Malawi, with the intention of bringing that project into production in 2008 or 2009.[162]

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Potential for new discoveries

3.153 The UIC, GA and other submitters argued that:

> The potential for new discoveries is great. Not only have many prospective areas not been explored at all thoroughly, but also geological knowledge evolves and exploration technology improves, so that there is increased sophistication and effectiveness of the exploration effort going into the future. A significant example of this is that in the mid 1970s when the main uranium discoveries were made in Canada 's Athabasca Basin , airborne electromagnetic surveys there were effective only to 100 metres depth below the surface, today they yield useful data down to one kilometre. This is particularly relevant to uranium exploration in NT, much of which targets similar geological formations.[163]

3.154 The NTMC concurred with this observation, noting that in the Territory:

> [t]he potential for undiscovered [resources] is high. Only 20 per cent to 25 per cent of the prospective rock units has been effectively explored because superficial cover has masked any potential airborne anomalies.[164]

3.155 In addition to the known undeveloped uranium deposits in the NT (including Jabiluka and Koongarra in West Arnhem Land, and Angela near Alice Springs), there is said to be good uranium mineralisation in the following areas:

> … the Batchelor-Rum Jungle-Coomalie area … 100 kilometres south of Darwin; West Arnhem Land; the Napperby-Tanami-Arunta region, which is about 150 kilometres north-west of Alice Springs; and the Ngalia Basin, 250 kilometres north-west of Alice Springs.[165]

3.156 The NTMC observed that the Alligator Rivers Region is recognised a world class mineral province and unconformity-related uranium deposits are the main exploration target in the NT, because of the potential for large tonnage, low to medium grade resources. However, it was argued that a significant proportion of the most prospective area is included within the boundaries of the Kakadu National Park. Other areas considered prospective for unconformity-related deposits exist in the Ashburton and Davenport Provinces, Tanami Region and on the margins of the Murphy Inlier.[166] These geological provinces are shown in appendix F.

3.157 Cameco argued that: 'Significant potential remains throughout Australia in a variety of geological provinces and settings', and that the exploration activity 'to date has only relatively scratched the surface.'[167] Cameco mentioned prospective regions that may contain deposits of the following types:

- unconformity-related deposits may be found in the Pine Creek Inlier, particularly the ARUF in West Arnhem Land, in the NT. Other prospective areas for unconformity type mineralisation include the Ashburton and Bresnahan Basins in WA, the Birrindudu Basin in the NT and the Eyre Peninsula of SA.
- Sandstone hosted deposits, which are amenable to ISL mining, may be found in younger basins including the Gunbarrel, Carnarvon and Canning Basins of WA, and the Amadeus and Ngalia Basins of the NT.
- Near surface uranium deposits in very young sediments, which are often hosted in calcrete, may be found in the northern portion of the Yilgarn Craton of WA.[168]

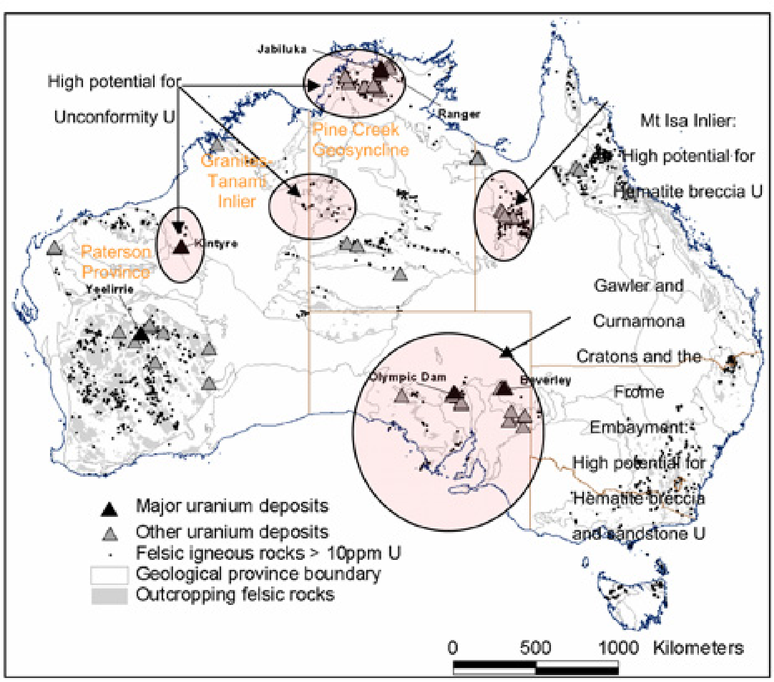
3.158 Southern Gold, which holds exploration tenements in the Gawler Craton of SA, argued that the Gawler contains highly prospective and under-explored geological terrain (relative to the Curnamona/Frome Craton which hosts the Beverley and Honeymoon deposits). It was argued that the Gawler Craton, which hosts the Olympic Dam and Prominent Hill deposits, offers excellent opportunities to discover new shallow resources such as calcrete-hosted deposits amenable to ISL technology.[169]

3.159 GA argued that there is significant potential for additional uranium deposits to be found in Australia, including:

- unconformity-related deposits, including high-grade deposits at and immediately above the unconformity, particularly in Arnhem Land in the NT but also in the Granites–Tanami region (NT–WA), the Paterson Province (WA) and the Gawler Craton (SA);
- hematite breccia deposits, particularly in the Gawler Craton and Curnamona Province of SA, and the Georgetown and Mount Isa Inliers of Qld;
- sandstone-hosted deposits in sedimentary strata in various regions adjacent to uranium-enriched basement; and
- carbonatite-related rare earth–uranium deposits in Archaean cratons and Proterozoic orogens.[170]

3.160 GA have identified regions of Australia having a high potential for further discoveries of uranium deposits. These regions are depicted in figure 3.15. GA observed that exploration is currently under way in all these areas, although there has not been much exploration in the Paterson Province in WA to date.[171]

Figure 3.15 Regions of Australia with high potential for uranium



Source Geoscience Australia *, Exhibit no. 60, Australia 's uranium resources, production and exploration,* p. 10.

3.161 Cameco and Areva urged that Australia's policy in relation to uranium exploration and mining be clarified. Dr Ron Matthews of Cameco stated that:

> From our perspective, we are here for the long term, but we would like to see clarity on uranium and for Australia's future to be clearly identified. We feel that Australia has significant potential, and that should be harnessed. With the present interest in nuclear energy worldwide, Australia's uranium is a resource that should clearly be developed. We would like to see that moved forward.[172]

3.162 It was submitted that state government opposition to the development of uranium deposits is impeding uranium exploration in those states. Areva observed that:

> Cogema [Areva] believes there is significant potential for uranium discoveries in other states of Australia, but at the moment it prefers to explore in those states that are not opposed to the concept of uranium exploration or mining.[173]

3.163 Likewise, Cameco submitted that 'Cameco Australia's exploration efforts are effectively on hold in WA because of the State government's policy with respect to uranium mining.'[174] It was noted that while a large number of junior companies have recently applied for licenses over prospective ground in WA, 'realistically the level of exploration expenditure will be limited until this policy is changed.'[175]

3.164 Cameco argued that 'without doubt Australia's known resources could be increased', but:

> … there needs to be a significant change in how uranium is viewed and a clear level of support shown at both the Federal and State level. A change in political will and direction is required to give the clear message to companies that it is worthwhile exploring for uranium.[176]

3.165 To this end, the Association of Mining and Exploration Companies (AMEC) recommended that Australia adopt an active exploration program to identify further uranium mineralisation.[177]

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The role of junior exploration companies

3.166 During 2004 and 2005, a number of small uranium-focussed exploration companies listed on the Australian Stock Exchange.[178] In 2005, 25 junior exploration companies were exploring for uranium nationwide.[179] While a substantial part of the increase in total exploration expenditure in 2005 was due to exploration in the south-east of Olympic Dam, junior companies now account for a significant proportion of total exploration expenditure.[180]

3.167 Several junior companies that submitted to the inquiry mentioned their exploration expenditures:

- Summit Resources, which owns the Valhalla, Skal and Andersons Lode deposits in Qld, reported that it spends between $2.5 and $3 million a year on exploration.[181]
- Compass Resources, which holds tenements at Batchelor (the Rum Jungle uranium field) in the NT, stated that it spent between $20 and $30 million over the past five years exploring for minerals, including uranium.[182]
- Southern Gold, which holds tenements in the Gawler Craton of SA (including the Southern Gawler Arc and Yarlbrinda projects), stated that it aimed to spend $500 000 in 2005 and $1 million per year over the next five years.[183]

3.168 Geoscience Australia observed that a comparison between the exploration expenditures of major mining companies in the early 1990s with those of today reveals that 'what they are spending now is an order of magnitude decrease in general.'[184] Instead, the major companies now:

> … prefer to have good small companies working for them. They can have a loose or somewhat tighter relationship with small companies—maybe seed funding—and then cherry pick the results. That seems to be a model that has emerged.[185]

3.169 Deep Yellow supported this view and argued that:

> The trend over the last 10 years has been for the bigger companies to let the smaller companies do that exploration work, let them take the risk at that early stage and then come in when they have found something. It is a similar case with uranium. It is a risky venture to spend a lot of money on exploration.[186]

3.170 Southern Gold emphasised the key role played by juniors following the rationalisation of the mining industry and the retreat of large companies from exploration activity. It was argued that because juniors are now 'carrying a greater burden for defining and developing Australia's uranium resources but with limited funding', these smaller companies merit support from government:

> The junior exploration sector warrants expanded financial and regulatory support from State and Federal governments in facilitating exploration for the country's future development, competitiveness and prosperity.[187]

3.171 Among other recommendations, Southern Gold called for the provision of high quality geoscientific data and encouragement for industry through programs such as the PACE initiative ('Plan for Accelerating Exploration') in SA, where 'the (State) government subsidises drilling programs dollar for dollar.'[188] The company also recommended subsidies for infrastructure development in regional areas.[189]

3.172 The MCA agreed that there has been structural adjustment in the minerals industry. A consequence of the rationalisation and consolidation of the industry is that now 'much of the exploration effort is essentially outsourced to junior companies.'[190] For the MCA, the significant role of juniors in conducting much of the uranium exploration points to the importance of:

> … one of the … fundamental platforms of the exploration action agenda, which is flow-through shares and improved financing or being able to wash out the tax liabilities to investors. The juniors do not have income to offset these tax liabilities, so there is a market failure in terms of tax asymmetry.[191]

3.173 The Committee notes that its previous report, *Exploring: Australia's Future*, recommended that the Australian Government examine the introduction of a flow-through share scheme for companies conducting eligible minerals and petroleum exploration activities in Australia.[192] The Committee also notes that the 2005 progress report on the implementation of recommendations from the Minerals Exploration Action Agenda (MEAA) strongly advocated the introduction of a flow-through share system to 'reinvigorate the search for the next generation of Australia's mineral deposits.'[193]

3.174 The NTMC expressed strong support for a close examination of a flow-through share scheme, 'to try and drive exploration expenditure in Australia, which has lost ground significantly compared to the rest of the world.'[194] Dr Ron Matthews of the NTMC argued that:

> I would see great benefits in that to drive greenfields exploration in particular, and also to benefit junior companies specifically, which really form the engine behind the resource industry. I think there is a move to look at that; I think we would all endorse this being looked at very seriously.[195]

3.175 In its previous report, which addressed impediments to exploration, the Committee accepted that future world-class uranium deposits are likely to be located at greater depths than those hitherto discovered. It was concluded that this will require large injections of exploration investment capital to overcome the technical challenges of locating bedrock deposits. These observations reinforce the need to ensure that juniors, which are generally efficient explorers, are appropriately assisted to discover Australia's future world-class uranium and other mineral deposits. The Committee is convinced of the merits of flow-through share schemes and repeats the recommendation contained in its previous report. The Committee makes additional observations about the challenges faced by junior companies in chapter 11.

Recommendation 1

> **The Committee recommends that the Australian Government introduce a flow-through share scheme for companies conducting eligible minerals and petroleum exploration activities in Australia .**

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New exploration technologies and geoscientific data

3.176 The Committee's previous report observed that future exploration programs aimed at major discoveries beneath thick cover are likely to require high-cost sophisticated exploration technology.[196]

3.177 Evidence presented to the Committee's current inquiry again pointed to the need for new technologies to identify deposits located at depth. For example, GA emphasised the need for a new generation of tools and technologies to assist in the discovery of uranium deposits located down to 500 metres below surface:

> … the focus has to be on the covered areas like the Gawler Craton where you have deep weathering and sedimentary cover. The information available for those covered areas is limited … We need a new generation of information … we have to look through the cover and get down to the rocks of 100 to 400 or 500 metres below the surface. We need to bring in a new set of technologies to do that. It is important to be able to identify palaeochannels in the Frome Embayment and to be able to identify the favourable alteration minerals in the Olympic Dam domain for that style of mineralisation. That requires a new generation. That is what we hope will eventually come to GA as a result of the various inquiries we have had in the last couple of years.[197]

3.178 Cameco argued that: 'The potential for new discoveries, in both previously defined terrains and new areas, using advanced techniques and deep exploration tools is very high.'[198] Similarly, the MCA argued that:

> Australia's current Economic Demonstrated Resources, though large, underestimates the potential resource. Indeed, given that exploration technology has improved significantly in recent years, there is a reasonable expectation that significantly more uranium would be discovered if the latest technologies and models of how ore bodies form were applied in Australia.[199]

3.179 CSIRO explained that future discoveries of uranium will require more sophisticated geochemical and geophysical technologies in order to see through the regolith to discover the deeper deposits.[200]

3.180 In terms of particular techniques to provide the needed precompetitive geoscience, GA mentioned that regional airborne electromagnetics could be more widely deployed to identify minerals and the graphite related to uranium hundreds of metres below surface.[201]

3.181 GA also informed the Committee that the Athabasca Basin in Canada, which contains several extremely high-grade deposits (such as Macarthur River and Cigar Lake), has been exhaustively surveyed in a collaborative study involving the Geological Survey of Canada and mining companies using these techniques:

> They have pulled it apart and done everything they possibly could to it—the sorts of things that we do here in Australia, depending on our level of resources. They have done seismic studies, airborne geophysical studies and a whole lot of pulling together of existing information. That has shown a number of areas of potential in that highly prospective Athabasca Basin.[202]

3.182 The MCA supported GA's call for the deployment of more sophisticated techniques to improve the under cover exploration activity. The MCA noted that a recommendation for additional funding for precompetitive geoscientific data was one of the four elements of the MEAA.[203] It was also noted that the use of exploration techniques that are classed as 'low impact' permit expedited approvals procedures under the Native Title Act. The MCA urged the Committee to 'back the increased resourcing for precompetitive geoscientific data for Geoscience Australia.'[204] The MCA stated that it:

> … strongly supports the Minerals Exploration Action Agenda proposal of a new, national innovative geoscience program to underpin the discovery of the next generation of ore deposits in frontier areas to sustain Australia's mineral exports.[205]

3.183 The NTMC argued that the provision of geoscience data by the NT Government is 'extraordinary and it is very highly regarded by industry.'[206] Nonetheless, the NTMC also argued that the Territory and Commonwealth Governments should work together to encourage the search for new deposits.[207]

3.184 Jindalee Resources and Southern Gold also spoke highly of the survey data provided by the NT Government and GA:

> It is sensational. It is great stuff. The state governments will now give you all of their geophysical surveys on disk. You can get them for just about nothing. The Northern Territory government is sensational with that. Instead of repeating the work that somebody else did five years ago you can get all of this on file now.[208]

3.185 In its previous report on the impediments to increasing Australia's exploration investment, the Committee made several recommendations pertaining to precompetitive geoscientific data, including that the Australian Government provide additional funds to enable GA to accelerate data acquisition programs.[209]

3.186 The Committee notes that in the 2005 progress report on the implementation of recommendations from the MEAA, the implementation group also recommended that:

> … a new national geoscience program should be implemented to address the deficiencies in modern coverage. A new program should specifically focus on pioneering new techniques and methods for revealing the potential of Australia's prospectivity under sedimentary cover, and at depth.[210]

3.187 The MEAA implementation group repeated the recommendation that new precompetitive geoscience information, particularly geophysical data, be provided for frontier areas.

3.188 The Committee welcomes the announcement in August 2006 of an addition $59 million for GA to pioneer the application of innovative, integrated geoscientific research designed to identify on-shore energy sources. Nonetheless, the Committee calls for additional funding for GA to develop and deploy new techniques to assist in the discovery of new world-class uranium deposits.

Recommendation 2

> **The Committee recommends that Geoscience Australia be granted additional funding to develop and deploy new techniques, including airborne electromagnetics, to provide precompetitive geoscience of prospective areas, in order to assist in the discovery of new world-class uranium and other mineral deposits located under cover and at depth.**

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Conclusions

3.189 The Committee was pleased to note record uranium production and exports for Australia in calendar year 2005. Production across the three operational mines (Ranger, Olympic Dam and Beverley) was 11 222 t U_3O_8 and exports were 12 360 t U_3O_8. Uranium exports also earned a record $573 million in 2005.

3.190 Australia is rightly regarded as a low-cost and reliable supplier of uranium. The Committee agrees that there is great potential for Australia to expand production and become the world's premier supplier of uranium. Specifically, the Committee looks forward with interest to the outcomes of BHP Billiton's PFS and feasibility studies for the possible expansion of Olympic Dam. Should the proposed expansion proceed, Olympic Dam could be producing some 20 per cent of world uranium mine output by 2013. If this were to eventuate, national production would be double the current level and Australia would become by far the world's largest uranium producer. The Committee would welcome this development.

3.191 In addition, the Committee notes that sxr Uranium One, owners of the Honeymoon deposit in SA which has already been granted a mining lease and an export license, have announced that the company expects to proceed with construction in the second half of 2006. Australia's second ISL mining operation is expected to commence production in 2008.

3.192 Although the Committee appreciates that ISL mining is applicable in very specific geological conditions, it notes that this mining method has numerous advantages over traditional excavation techniques, including minimal environmental impacts. The Committee was extremely impressed with the Beverley operation, its minimal surface disturbance and its advanced instrumentation. Committee members were convinced that once production has ceased at Beverley and the infrastructure has been removed, there will be virtually no indication that a mine ever existed at the site at all and the rehabilitation process will be relatively simple.

3.193 The Committee was also pleased to note Heathgate Resources' claim that Beverley is not only the largest but also the most technologically advanced ISL operation in the world. The Committee hopes that the Australian uranium industry will continue to lead the world in this area of expertise.

3.194 The Committee notes that Australia possesses 36 per cent of the world's RAR of uranium recoverable at low cost and 43 per cent of the world's low cost Inferred Resources. Australia has some 85 uranium deposits scattered across the country and these contain a total of over 2 Mt U_3O_8. Australia also possesses the world's largest quantity of thorium resources, which could be used as nuclear fuel.

3.195 Almost all of Australia's Identified Resources of uranium are contained in six deposits—Olympic Dam, Ranger Jabiluka, Koongarra, Kintyre and Yeelirrie. Olympic Dam, the world's largest uranium orebody, dwarfs all others and contains an estimated overall resource of 1.46 Mt of U_3O_8. Olympic Dam contains 26 per cent of the world's entire RAR recoverable at low cost.

3.196 The Committee notes that improvements in the recoveries of uranium from brannerite mineralisation, which have the potential to significantly increase Australia's recoverable resources (mainly at Olympic Dam and the Mt Isa deposits) would, in turn, have important ramifications for Australia's uranium mining industry. Given its importance for the industry as a whole, the Committee encourages an increased research and development effort to achieve improved uranium recoveries.

3.197 Notwithstanding the size of Australia's resources, the Committee notes that some 10 per cent of Australia's low cost uranium resources are deemed inaccessible to mining. Aside from those deposits in the NT that are surrounded by the Kakadu National Park, these resources include the deposits that cannot be developed in WA and Qld due to state government prohibitions on uranium mining. State government restrictions have also impeded exploration investment and activity in these states as mining companies have gone elsewhere to explore.

3.198 While there has been a trend of increasing exploration expenditures since 2003, there was relatively little exploration for uranium over the previous two decades and Australia's known uranium resources generally reflect exploration efforts that took place 30 years ago. As exploration expenditures declined from 1980 onwards, only four new uranium deposits were found and only one, Kintyre in WA, contains RAR recoverable at low cost. It follows that the size of Australia's known uranium resources significantly understates the potential resource base.

3.199 The Committee concludes that there are a number of regions that are highly prospective for uranium and there is great potential for new discoveries in various geological settings across Western Australia, South Australia, the Northern Territory and Queensland. Regrettably, there has been no exploration for uranium in Victoria and NSW since these states legislated to prohibit uranium mining in the 1980s.

3.200 Reflecting a trend which is occurring across the minerals industry, junior companies are now conducting much of the exploration activity for uranium. With the withdrawal of major mining companies, there are now calls for increased government support for juniors. The Committee repeats the recommendation contained in its previous report that a flow-through share scheme for companies conducting eligible minerals exploration activities in Australia be introduced.

3.201 The Committee is aware that there has been a significant turn-around in uranium exploration expenditure in recent years and a key obstacle to further uranium exploration is opposition to uranium mining in some states. Other impediments to juniors are discussed in chapter 11.

3.202 Submitters pointed to the need for a new national geoscience program to address current deficiencies. It was argued that future discoveries of uranium will require more sophisticated geochemical and geophysical technologies in order to see through the regolith to discover the deeper deposits. The Committee recommends that GA be funded to develop and deploy techniques to provide precompetitive geoscience of prospective areas, in order to assist in the discovery of new uranium (and other mineral) deposits located at depth.

3.203 In the following chapter, the Committee considers the potential implications for global greenhouse gas emission reductions from the further development and export of Australia's uranium resources.

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Footnotes

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Last reviewed 14 March 2007 by Committee Secretariat

Australia’s uranium — Greenhouse friendly fuel for an energy hungry world

A case study into the strategic importance of Australia’s uranium resources for the Inquiry into developing Australia’s non-fossil fuel energy industry

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Chapter 4 Greenhouse gas emissions and nuclear power

> *Responsible and balanced policy would strive for a mix of low-greenhouse energy sources: CO2-free nuclear for baseload power in countries with high ambient power demand; low-CO2 coal, because coal is abundant; natural gas for peaking loads; hydro, wind, tidal, solar where suitable and appropriate. Achieving better energy efficiency in product design and use and reducing excessive consumption in the developed world through better electricity pricing are also important strategies. There is no single panacea, but no likely remedy should be arbitrarily rejected. Windmills and reactors each have parts to play.*[1]

> *… I am a Green and I entreat my friends in the movement to drop their wrongheaded objection to nuclear energy. Even if they were right about its dangers, and they are not, its worldwide use as our main source of energy would pose an insignificant threat compared with the dangers of intolerable and lethal heat waves and sea levels rising to drown every costal city in the world. …civilisation is in imminent danger and has to use nuclear — the one safe, available, energy source — now or suffer the pain soon to be inflicted by our outraged planet.*[2]

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Key messages —

- **Electricity generation is the largest and fastest growing contributor to global carbon dioxide (CO_2) emissions, responsible for 40 per cent of global emissions in 2003—10 billion tonnes of CO_2.Emissions from electricity are projected to contribute approximately 50 per cent of the increase in global CO_2 emissions to 2030.**
- **Nuclear power is a CO_2-free energy source at point of generation.**
- **Over the whole fuel cycle, nuclear power emits only 2–6 grams of carbon (or up to 20 grams of CO_2) per kilowatt-hour of electricity produced. This is two orders of magnitude less than coal, oil and natural gas, and is comparable to emissions from wind and solar power.**
- **A single nuclear power plant of one gigawatt capacity offsets the emission of some 7–8 million tonnes of CO_2 each year if it displaces coal. A nuclear plant will also offset the emission of sulphur dioxide, nitrous oxide and particulates, thereby contributing significantly to air quality.**
- **Nuclear power currently avoids the emission of 600 million tonnes of carbon per year. If the world were not using nuclear power, CO_2 emissions from electricity generation would be at least 17 per cent higher and 8 per cent higher for the energy sector overall. By 2030, the cumulative carbon emissions saved due to the use of nuclear power could exceed 25 billion tonnes.**
- **Australia's uranium exports currently displace at least 395 million tonnes of CO_2 per year, relative to use of black coal. This is equivalent to 70 per cent of Australia's total greenhouse gas emissions for 2003. Australia's total low cost uranium reserves could displace nearly 40 000 million tonnes of CO_2 if it replaced black coal electricity generation.**
- **The capacity of uranium to mitigate production of greenhouse gases depends on the extent to which nuclear power displaces carbon-based energy sources in electricity generation. In the future, nuclear power may also have the capacity to reduce emissions from the transport sector through the production of hydrogen.**
- **For the generation of continuous, reliable supplies of electricity on a large scale, the only alternative to fossil fuels is nuclear power.**
- **Nuclear power is cost competitive with gas and coal-fired electricity generation in many industrialised countries. Nuclear plants offer very low operating costs, security of energy supply and electricity price stability.**

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Introduction

4.1 This chapter addresses the greenhouse gas emissions avoided by the use of nuclear power, emissions across the whole nuclear fuel cycle, the contribution from renewable energy sources, and the relative economic attractiveness of nuclear power for baseload power generation.

4.2 In turn, the Committee considers:

- the nature of the enhanced greenhouse effect and the potential consequences of climate change;
- projections for global energy and electricity demand and associated carbon dioxide emissions; and
- the contribution that nuclear power makes to the mitigation of greenhouse gas emissions, the quantity of emissions displaced by export of Australia's uranium, and the possible future emission savings from expanded use of nuclear power.

4.3 The Committee then considers arguments critical of nuclear's greenhouse gas mitigation potential, including claims about emissions across the whole nuclear fuel cycle compared to other electricity generation chains, the energy used to enrich uranium and the energy required to extract uranium as ore grades decline. The Committee then addresses arguments associated with the claim that nuclear power is too limited, slow and impractical to 'solve' climate change. Discussion follows on the limitations of renewables and efficiency measures, and the need for a mix of low-emission energy sources.

4.4 The chapter concludes with an overview of the economics of nuclear power and its competitiveness relative to other baseload alternatives and renewables.

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The enhanced greenhouse effect

4.5 The greenhouse effect is the term used to describe the retention of heat in the Earth's lower atmosphere. The enhanced greenhouse effect refers to the rise in the Earth's surface temperature (global warming) which is considered likely to occur because of the increasing concentration of certain gases in the atmosphere due to human activities. These gases are referred to as greenhouse gases.[3]

4.6 Greenhouse gases absorb infrared radiation reflected back from the Earth's surface and trap heat in the atmosphere. The principal greenhouse gases are carbon dioxide (CO_2), methane, halocarbons and nitrous oxide. While some greenhouse gases exist in nature, such as water vapour, CO_2 and methane, others are exclusively human-made, such as gases used for aerosols.

4.7 Atmospheric concentrations of greenhouse gases have increased significantly during the last century and most of this increase is attributed to human sources; that is, of anthropogenic origin. Human activities that generate greenhouse gases include burning fossil fuels (coal, oil and natural gas), agriculture and land clearing.[4]

4.8 Carbon dioxide is considered the most significant anthropogenic greenhouse gas (GHG) and fossil fuel combustion is known to be responsible for the largest share of global anthropogenic GHG emissions, accounting for 80 per cent of emissions in industrialised countries in 2003. The second largest source of GHG emissions is agriculture, which contributes seven per cent (mainly methane and nitrous oxide).[5]

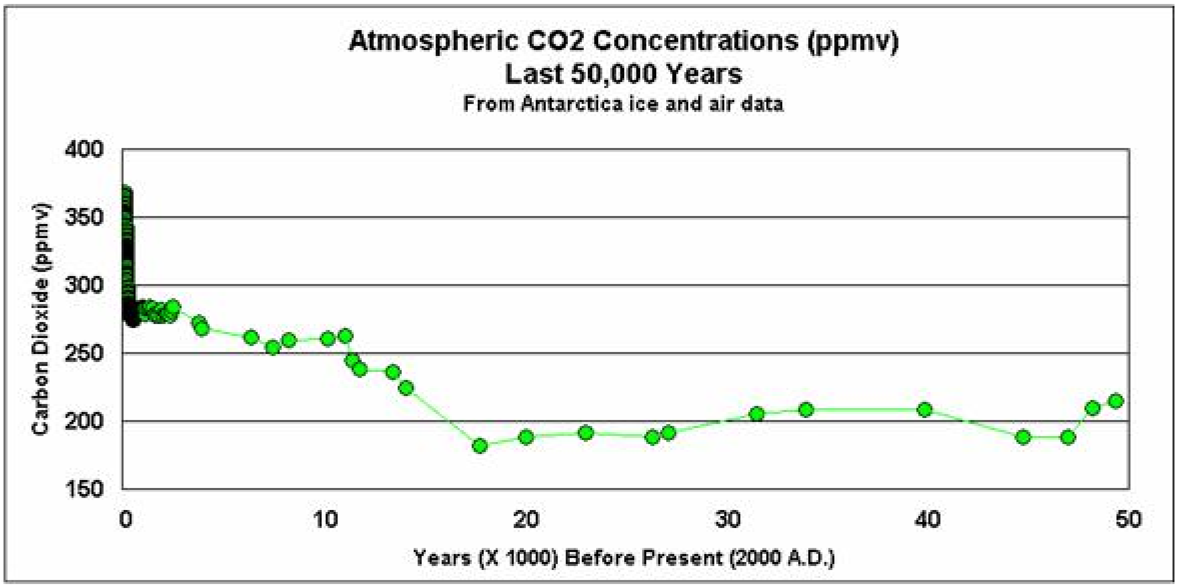
4.9 The atmospheric concentration of CO_2 is now at 380 part per million by volume (ppmv), which is the highest level for at least 420 000 years, and possibly the highest concentration for 20 million years.[6]

4.10 In addition to historically high concentrations, the rate of increase is also unprecedented during at least the past 20 000 years.[7] Evidence emphasised that 'of the non-catastrophic sources of quick CO_2 emissions into the atmosphere, it appears that the rate of change in the last 150 years has been greater than that previously witnessed.'[8] That is, although major volcanic events such as Krakatoa have introduced large volumes of CO_2 into the atmosphere in shorter time frames, the current rise is the fastest increase of anthropogenic origin.

4.11 The increase in atmospheric concentrations of CO_2 during the past 250 years is depicted in figure 4.1. Over the period from 50 000 years ago to the last hundred years, concentrations remained in the range of 200 to 270 ppmv. However, the Australian Nuclear Science and Technology Organisation (ANSTO) argued that since the industrial revolution CO_2 concentrations have increased dramatically.[9] In 1750, CO_2 concentrations were approximately 280 ppmv, but by 2000 they had risen to 370 ppmv —an increase of 32 per cent.[10]

4.12 The rate of increase has been pronounced even over the span of a few decades. In 1959, CO_2 concentrations were 316 ppmv, but had risen to 375 ppmv by 2003—an 18.8 per cent increase over just 44 years.[11]

Figure 4.1 Atmospheric concentrations of CO 2 over the last 50 000 years (parts per million by volume)



Source ANSTO, *Exhibit no. 74, Presentation by Dr Ron Cameron and Dr Ian Smith* , p. 17.

4.13 The Committee's inquiry was concerned with the potential implications for global GHG emission reductions from the further development of Australia's uranium resources. Comment was not explicitly sought on the link between GHG emissions and global warming, or the possible severity of climate change. Nevertheless, most submitters were convinced that 'carbon dioxide is driving … global climate change. The greenhouse effect is real' and global warming will have 'potentially catastrophic consequences.'[12]

4.14 Drawing on findings published by the International Panel on Climate Change (IPCC), it is widely reported that the global average surface temperature increased by about 0.6 degrees Celsius (°C) over the past one hundred years (0.7 °C in Australia).[13] Carbon dioxide is estimated to contribute some 60 per cent of the warming effect.[14]

4.15 In its Third Assessment Report (2001), the IPCC concluded that 'there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.'[15] According to all IPCC emissions scenarios, CO_2 concentrations, global average temperature and sea-level rise are all projected to increase in the coming decades without additional mitigation action.

4.16 ANSTO commented that the world cycles between glacial and warmer inter-glacial periods over about 100 000 years. During each cycle, sea level changes by about 120 metres and the temperature changes by approximately five or six degrees. A change in cycle is thought to be triggered by about 180 ppmv CO_2 to 260 ppmv CO_2. As noted above, atmospheric concentrations are now at about 380 ppmv and are projected to rise to at least 450 or even 550 ppmv. ANSTO argued that:

> ... the world is now into a cycle that has been going on for a period of 150 years. We are making the kinds of change in CO_2 level that triggered that change happening in just 100-odd years.[16]
>
> That is, climatic changes that would previously have been experienced over a 100 000 year glacial-interglacial cycle are projected to occur in a mere 100 years.

4.17 In addition to global temperature change and sea level rise, ANSTO noted that increased CO_2 concentrations acidify the oceans which will have potentially disastrous effects on coral reefs and marine life.[17]

4.18 The potential consequences of global warming were emphasised by the Chief Scientific Adviser to the British Government, Sir David King, who attributed half of the severity of the 2003 heatwave in Europe, which killed 30 000 people, to global warming with a 90 per cent statistical certainty.[18]

4.19 While the Committee notes that there are uncertainties in the science of climate change, the Australian Government reports that climate models, based on a range of emission scenarios, indicate that increasing atmospheric concentrations of greenhouse gases could cause average global temperatures to rise by between 1.4 and 5.8 °C by 2100.[19] The consequences of a temperature rise of this magnitude could be dramatic:

> This rate and magnitude of warming are significant in the context of the past 400,000 years. History has shown us that a warming of 1–2 °C can have dramatic consequences. Even the 0.6 °C warming in the past 100 years has been associated with increasing heat waves and floods, fewer frosts, more intense droughts, retreat of glaciers and ice sheets, coral bleaching and shifts in ecosystems. A further warming of 1.4 to 5.8 °C could challenge the adaptive capacity of a range of human and natural systems.[20]

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The global energy situation and carbon dioxide emissions

4.20 Global primary energy demand is projected to grow at a rate of 1.6 per cent per year in the period 2003 to 2030. This would see demand for energy increase by 52 per cent over the period and reach 16.3 billion tonnes of oil equivalent (toe) by 2030.[21]

4.21 Fossil fuels are expected to continue to meet the overwhelming bulk of the world's energy needs. Oil, natural gas and coal are expected to account for 83 per cent of the increase in world energy demand over 2003–30 and account for 81 per cent of energy demand in 2030 (up slightly from 80 per cent in 2003).[22]

4.22 Electricity consumption, which uses some 40 per cent of the world's primary energy supply, is forecast to grow at a faster rate than overall energy demand. Electricity consumption is projected to grow at an annual rate of 2.5 per cent and rise from 15 000 terawatt-hours (TWh) currently, to 24 000 TWh by 2025.[23] The growth in demand is likely to be driven by the industrial modernisation of India and China.[24]

4.23 In 2003, fuel for world electricity production was provided 39.9 per cent by coal, 19.2 per cent by natural gas, 6.9 per cent by oil (for a total of 66 percent from burning fossil fuels), 16.3 per cent by hydro, 1.2 per cent by combustible renewables (such as biomass), and 0.7 per cent from geothermal, solar and wind combined. Nuclear was the fourth largest fuel source for electricity generation at 15.7 per cent.[25] It is anticipated that the majority of the growth in electricity consumption will be fuelled by coal.[26]

4.24 World CO_2 emissions from fossil fuel combustion reached 25 billion tonnes (gigatonnes, Gt) in 2003, an increase of 20 per cent on the 1990 level of 20.7 Gt. Of these emissions, around 38 per cent comes from coal, 21 per cent from gas and 41 per cent from oil.[27] Energy-related CO_2 emissions are projected to increase by 1.6 per cent annually between 2003 and 2030, reaching 37 Gt of CO_2 emitted annually by 2030—an increase of 52 per cent over the 2003 level.[28]

4.25 According to the IEA, the largest and fastest growing contributor to global CO_2 emissions is the electricity and heat sector, which contributed 40 per cent of world CO_2 emissions in 2003—10 Gt of CO_2. Emissions from electricity generation grew by 44 per cent over the 13 years to 2003 and are projected to contribute approximately 50 per cent of the increase in global emissions to 2030. Other major contributors to world CO_2 emissions are the transport sector (24 per cent) and manufacturing and construction (18 per cent). Transport will contribute a quarter of the emissions increase to 2030.[29]

4.26 While industrialised countries have been overwhelmingly responsible for the build-up in fossil fuel-related CO_2 concentrations to date, much of the future increase in emissions is expected to occur in the developing world, where economic development and energy demand is predicted to be supplied primarily with fossil fuels. Developing countries' emissions are expected to grow above the world average at 2.7 per cent annually to 2030. Developing countries will be responsible for 73 per cent of the increase in global CO_2 emissions to 2030 and surpass the OECD as the leading contributor to global emissions in the early 2020s. The increase in emissions from China alone will exceed the increase in all OECD countries and Russia combined.[30]

4.27 ANSTO amplified the significance of the forecast growth in energy demand in developing countries, explaining that during the last 30 years some 31 per cent of the growth in energy production was in the OECD, with 59 per cent in the developing world. In the next 30 years however, there is predicted to be only three per cent growth in the OECD, but 85 per cent growth in the developing countries:

> If you take Nigeria, for instance, the average electricity consumption per person is 70 kilowatt hours per year. If you want to quantify it, that is the equivalent of leaving your television set on stand-by for the year. The average use in Europe is 8,000 kilowatt hours per person. So as these people develop, we are going to have a greater energy demand.[31]

4.28 The IEA also notes that in 2003 some 1.6 billion people were without access to electricity. If future energy demand is met by fossil fuels, the implications for CO_2 emissions are dramatic, as indicated in the forecasts above.[32]

4.29 With these forecasts in mind, a number of submitters argued that nuclear power will be essential to reduce emissions from electricity generation. For example, Cameco argued that:

> Numerous studies have noted the generation of electricity from fossil fuels, notably coal and natural gas, is a major and growing contributor to the emissions of carbon dioxide – a greenhouse gas that contributes significantly to global warming. There is a scientific consensus that these emissions must be reduced, and a growing opinion the increased use of nuclear power is one of only a few realistic options for reducing carbon dioxide emissions from electricity generation.[33]

4.30 Similarly, Areva argued that stabilising emissions will require mitigation policies. It was noted that in order to stabilise emissions at a target of 550 ppm of CO_2 will require that emissions be limited to 10 billion tonnes of carbon (GtC) per year by 2050. Achieving this target will require avoiding about 6 GtC per year from the current trend by 2050 and even more after that. Areva argued that human adaptation systems to climate change will need to be developed but that this capacity is limited, particularly in developing countries: 'We thus need to implement mitigation policies to avoid unbearable costs for economies.'[34]

4.31 The Committee now turns to a consideration of the GHG emissions from use of nuclear power and the extent to which nuclear power mitigates emissions from other sources.

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Nuclear power's contribution to greenhouse gas mitigation

4.32 Most submitters to the inquiry who expressed a view on this issue argued that the use of nuclear power reduces GHG emissions and that 'the export of uranium helps reduce greenhouse emissions in other countries to the extent that nuclear power produced replaces higher emission sources.'[35] A sample of the observations made on this issue follows:

- 'Realistic assessment shows that nuclear energy is indispensable in abating the intensification of greenhouse gases resulting from the inexorable rise of global energy consumption.'[36]
- 'There is incontrovertible evidence that from an emission standpoint uranium is a clean fuel.'[37]
- 'Nuclear power plants are the single most significant means of limiting increased greenhouse gas emissions while enabling access to economic electricity and providing for energy security.'[38]
- 'Nuclear power is mankind's single greatest opportunity to combat the looming environmental threat of global warming.'[39]
- 'Nuclear power is essential to attaining the goal of reducing the emission of greenhouse gas while at the same time maintaining access to electricity.'[40]
- 'Nuclear energy appears to be the only source which can provide safe, reliable and substantial base-load power without producing large quantities of greenhouse gases.'[41]
- 'Nuclear power is the only proven large scale technology for baseload power supply which does not release substantial amounts of carbon dioxide.'[42]

4.33 Nuclear power produces no GHG emissions during electricity generating operations. A nuclear power plant does not emit combustion gases when producing steam and therefore 'a nuclear power plant is a CO_2-free energy source at point of generation.'[43]

4.34 On a fuel basis, coal releases some four tonnes of CO_2 for every tonne of oil equivalent burned, oil releases some 3.2 tonnes of CO_2 for every tonne burned and natural gas releases 2.3 tonnes of CO_2 for every tonne of oil equivalent burned. Nuclear plants emit no CO_2.[44]

4.35 Uranium is also a highly concentrated source of energy when compared to fossil fuels. Uranium contains some 10 000 times more energy per kilogram of fuel than traditional fossil fuel sources. The typical energy output per kilogram of various fuels are listed in table 4.1.

Table 4.1 Energy output per kilogram of various fuels

Rank	Fuel source	Energy output per kilogram of fuel (megajoules)
1	Uranium	500 000
2	Crude oil	45
3	Natural gas	39*
4	Black coal	30
5	Firewood	16
6	Brown coal	9

Source Arafura Resources NL, *Submission no. 22* , p. 4. * per cubic metre

4.36 Fuel derived from one tonne of natural uranium can produce more than 45 000 megawatt-hours (MWh) of electricity. To produce this amount of electricity from fossil fuels would require burning 20 000 tonnes of black coal, 80 000 barrels of oil or 13 million cubic metres of gas.[45] However, burning one tonne of black coal emits approximately 2.75 tonnes of CO_2. Hence, to generate the same amount of electricity that can be produced with one tonne of uranium, a coal-fired station would emit some 55 000 tonnes of CO_2. To operate a typical coal-fired power plant with 1 000 megawatts electrical (MWe) capacity requires some 3 million tonnes (Mt) of black coal, which emits some 7–8 Mt of CO_2 per year.[46]

4.37 According to the Minerals Council of Australia (MCA) and other submitters, every 22 tonnes of uranium (equivalent to 26 tonnes of uranium oxide—U_3O_8) used in generating electricity saves the emission of one million tonnes of CO_2, relative to using coal with current technologies.[47]

4.38 While precise estimates of the global emissions avoided due to the use of nuclear power vary, submitters generally agreed that nuclear energy avoids more than 600 million tonnes of carbon emissions or some 2.5 billion tonnes of CO_2 per year.[48] That is, nuclear power currently saves about 10 per cent of total CO_2 emissions from world energy use.[49] The World Nuclear Association (WNA) estimates that the emissions avoided are equivalent to approximately one half of the CO_2 emitted by the world's motor vehicles.[50]

4.39 If the electricity currently generated by nuclear power were instead generated by fossil fuels, the increase in global CO_2 emissions would be dramatic. AMP Capital Investors Sustainable Funds Team (AMP CISFT), which is opposed to the use of nuclear power, conceded that:

> If modern fossil fuelled plants produced the electricity that is currently generated by nuclear power plants, then CO_2 emissions would be 8% higher from the energy sector and 17% higher from the electricity generation sector.[51]

4.40 Evidence also revealed that countries with a higher proportional share of nuclear energy in their electricity generation mix are the world's lowest emitters of greenhouse gasses.[52]

4.41 In relation to electricity generation in the US specifically, ANSTO noted that if that country had *not* adopted nuclear power, total emissions of CO_2 would be 29 per cent higher than they currently are. That is, the US nuclear program is saving the equivalent of almost 30 per cent of the country's total emissions.[53]

4.42 ANSTO observed that of the emission-free energy sources in the US; that is, sources that produce little or no CO_2, nuclear produces some 72 percent of the total, hydro about 26 per cent, with small amounts contributed by wind, geothermal and solar. For ANSTO, this means that 'if you take the fossil fuel side out of it then nuclear forms a big part of the ability to have emission-free generation.'[54]

4.43 These conclusions have also been reached in international fora. The International Ministerial Conference, *Nuclear Power for the 21 st Century*, held in Paris during March 2005, noted that:

> The health of the planet's environment, including action to reduce air pollution and address the risk of global climate change, is a serious concern that must be regarded as a priority by all Governments.[55]
>
> The Conference affirmed that nuclear power could make a contribution to meeting energy needs and sustaining the world's development in the 21 st Century because nuclear 'does not generate air pollution or greenhouse gas emissions'.[56]

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Australia's uranium exports displace global emissions

4.44 In terms of the emission savings attributable to Australia's uranium exports, the Australian Government Department of the Environment and Heritage (DEH) noted that Australia's uranium exports of 9 593 t U_3O_8 in 2002–03 could have produced some 413 640 gigawatt-hours (GWh) of electricity. If this amount of electricity was produced from black coal generation, more than 395 Mt of CO_2 would be emitted and 'this represents around 70% of Australia's total greenhouse gas emissions for 2003'.[57]

4.45 Assuming that Australia's uranium does not displace uranium sourced from other countries, DEH estimated that:

> Australia's total inferred, low cost, uranium reserves could displace nearly 40,000 Mt CO2e if it replaced black coal electricity generation. This represents almost 5 years of emissions from world public electricity and heat production at 2002 levels ...[58]

4.46 To place these GHG displacement estimates in the context of specific uranium mine production, Heathgate Resources (owners of Beverley, Australia's smallest uranium mine) submitted that its annual production generates the same amount of electricity as 16 Mt of coal and thereby avoids 33 Mt of CO_2 that would be emitted by coal-fired plants.[59]

4.47 Paladin Resources argued that Australia's uranium industry complements the coal industry because uranium exports 'neutralise' the carbon content of Australia's thermal coal exports, 'by generating in our customer countries an amount of carbon-free electricity to balance the inevitable carbon emissions of burning the coal equivalent.'[60] Moreover, Paladin Resources suggested that 'a good argument can be made that uranium exports should earn credits against CO2 taxes imposed on coal combustion in some jurisdictions.'[61]

4.48 DEH noted however that under current international arrangements, the emissions from producing uranium would be attributed to Australia, but the emissions savings from its consumption in electricity generation would accrue to the country that uses it. Nonetheless, as Nova Energy argued, 'the growth of uranium exports will contribute to global greenhouse gas and CO_2 emissions reductions.'[62]

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Future emission savings from use of nuclear power

4.49 To the extent that uranium is used in nuclear power plants which are constructed instead of fossil fuel plants, further export of Australia's uranium will prevent additional emissions of greenhouse gasses.[63]

4.50 As noted above, evidence stated that use of nuclear power avoids the emission of approximately 600 million tonnes of carbon per year (MtC).[64] This estimate is based on the assumption that, in a hypothetical non-nuclear world, all non-nuclear sources would expand their contributions proportionately, with the exception of hydropower which is more constrained than other sources of electricity.[65]

4.51 The IAEA stated in its 2003 study, *Nuclear Power and Climate Change*, that compared with the carbon avoidance promised by the Kyoto Protocol, which will reduce annual carbon emissions in 2010 by less than 350 MtC:

> ... nuclear power *already* contributes reductions more than twice the likely reductions from the Kyoto Protocol seven years down the road.[66]

4.52 In terms of the quantity of carbon that will be avoided by use of nuclear power in the future, estimates vary depending on forecasts for the future evolution of the electricity generating mix and the likely reductions in the carbon intensity of different generation options. For its projections, the IAEA adopted the conservative assumptions of the IEA in its *World Energy Outlook 2002* report; that no new nuclear plants will be constructed beyond those currently being built or seriously planned, and that reactors will be retired as previously scheduled. If the world develops along this path, by 2030 cumulative carbon emissions avoided that are attributable to nuclear power could be some 17 billion tonnes (GtC).[67]

4.53 If nuclear power expands its contribution to world energy supplies in the future, rather than contracts as in the IEA scenario presented above, then emissions avoided that are attributable to nuclear power could be far greater. Adopting the emissions scenarios developed by the IPCC, the IAEA has estimated that cumulative carbon emissions avoided by nuclear power will exceed 20 GtC by 2030 under all scenarios.[68] This amounts to some 74 Gt of CO_2 avoided due to use of nuclear power.

4.54 Cameco observed that i n some emissions scenarios, the cumulative carbon savings from nuclear over the three decades to 2030 will actually exceed 25 GtC.[69]

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Nuclear power's other environmental benefits

4.55 In addition to displacing emissions of CO_2, it was argued that nuclear power relieves general air and surface pollution. Several submitters emphasised that the environmental impacts of coal and gas-fired power stations are significantly greater than those of nuclear power plants.[70] A comparison between coal, gas and nuclear plants of equal capacity follows.

4.56 A coal-fired power station with a capacity of 1 300 MWe will consume approximately 3.3 Mt of black coal per year and require a transport component of 82 500 rail cars each of 40 tonnes capacity. The land use requirement for a plant of this size, including fuel storage and waste disposal, will be around 415 hectares. Depending on the quality of the coal and other factors, the emissions will be in the order of 10 Mt of CO_2, 2 300 tonnes of particulates, 200 000 tonnes of sulphur dioxide and 7 000 tonnes of nitrous oxide. The plant would also produce some 250 000 tonnes of fly ash containing toxic metals including arsenic, cadmium, mercury, organic carcinogens and mutagens and naturally-occurring radioactive substances.[71]

4.57 A gas combined cycle plant of the same capacity will consume 1.9 billion cubic metres of gas per year and emit 5 Mt of CO_2, 30 tonnes of sulphur dioxide, 12 700 tonnes of nitrous oxide and 410 tonnes of methane.[72]

4.58 In contrast, a 1 300 MWe nuclear power plant, which requires a land area of some 60 hectares, will consume some 32 tonnes of enriched uranium per year, produced from around 170 tonnes of natural uranium in the form of uranium oxide concentrate. The plant would produce some 4.8 cubic metres of used fuel per year.[73] The wastes produced in the operation of nuclear power plants and in the various stages of the fuel cycle are further described in chapter five.

4.59 In comparing the environmental consequences of using fossil fuels with nuclear power, Cameco restated British environmentalist Sir James Lovelock's suggestion that people try to imagine they are a government minister required to decide what fuel to use for a new power station being built to supply half a large city:

> Every year, there are the following environmental consequences: using coal requires a 1,000 kilometre line of railway cars filled with coal which will emit billions of cubic feet of greenhouse gases, creates dust and more than 500,000 tonnes of toxic ash; using oil needs four or five-super tanker loads of heavy oil imported from unstable parts of the world, emits nearly as much greenhouse gases as coal plus huge volumes of sulphur and other deadly compounds that turn into acid rain; importing natural gas over long distances by ships and pipelines prone to accidents and leaks, emissions are highly polluting and the gas supply is vulnerable; or about two truckloads of cheap and plentiful uranium with essentially no emissions.[74]

4.60 While natural gas emits less CO_2 than coal, several submitters expressed reservations about its expanded use for baseload power generation on the grounds that there are relatively small global resources and these are said to be poorly located relative to centres of high potential economic growth. AMEC also raised concerns about the opportunity cost in using gas for large-scale electricity generation and inter-generational equity.[75]

4.61 The Committee also received evidence suggesting that nuclear power causes virtually the least environmental damage of all major energy technologies. Based on estimates of the unit cost of various pollutants (carbon dioxide, lead, nitrous oxide, particulates, sulphur dioxide and so on) in US dollars per tonne, Lucent Technologies have determined the damage to the environment per kilowatt-hour in dollar terms for a range of energy technologies. These environmental damage costs are listed in table 4.2. According to this estimate, wind power causes the least environmental damage, followed by nuclear power. Fossil fuel energy sources cause by far the most environmental damage in dollar terms.[76]

Table 4.2 Life cycle damage cost from major energy technologies (1999)

Technology	Damage cost (USc/kWh)
Wind	0.005 – 0.008
Nuclear	0.04
Hydro	0.073
Solar PV	0.231 – 0.376
Natural gas	1.04
Coal	1.59 – 6.02

Source ANSTO, *Exhibit no. 74, Presentation by Dr Ron Cameron and Dr Ian Smith* , p. 34.

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A moral responsibility to export uranium?

4.62 As noted in the discussion of energy demand above, forecast levels for energy use would trigger a significant increase in CO_2 emissions, with the IEA predicting that energy-related CO_2 emissions will reach 37 Gt annually by 2030—an increase of 52 per cent over the 2003 level.

4.63 Arafura Resources explained that while world economic growth to 2010 is forecast to average 3.5 per cent, India and China are forecast to grow at 6 per cent and 9.5 per cent respectively. Combined, these countries currently have some 37.5 per cent of the world's population. However, Arafura argued that India and China:

> … already have environmental conditions that are approaching crisis point. China has 9 out of the 10 most polluted cities in the world. Approximately 70% of China's energy needs come from brown coal, the least efficient and dirtiest fossil fuel for energy generation.[77]

4.64 Summit Resources also spoke of the imperative for countries like China to have their energy requirements supplied by non fossil fuel sources:

> … what we have to face is that China's economy is growing and they want to improve their standard of living. The biggest thing that the Chinese are going to consume is not KFC and not Coca-Cola but energy. If we sit here and just keep letting them build more coal-fired power stations, we are all going to suffer.[78]

4.65 For Nova Energy, nuclear power is a means for these and other developing nations not bound by the Kyoto Protocol, to meet their energy demands in a way which reduces their reliance on fossil fuels:

> Australia's uranium is, potentially, a way to meet the energy demands of these developing countries that obviates their need to depend on fossil fuels and delivers a positive global outcome—more energy for less carbon.[79]

4.66 Similarly, Compass Resources argued that:

> … the only realistic alternative available to meet the increased energy demand is coal or nuclear. Despite likely improvements to coal power plant emissions through geosequestration, use of coal will increase greenhouse gas emissions as the industry is asked to fill the world's energy needs.[80]

4.67 Noting that nuclear electricity has the lowest CO_2 emissions per kilowatt hour of the alternatives for baseload power generation, the Australian Nuclear Forum (ANF) argued that:

> In those countries that are serious about global warming, nuclear will expand and will need fuel. We think that the greatest contribution Australia can make to the global reduction of CO_2 is to maximise the export of uranium to responsible countries.[81]

4.68 AMEC submitted that the Federal 'government now has a moral responsibility to contribute to reducing global greenhouse emissions' and that 'Australia is well placed to make a significant contribution to greenhouse gas emission reduction targets through increased production and supply of uranium.'[82]

4.69 Cameco was also emphatic that given nuclear power's value as a carbon-free electricity supply technology, the further exploration and development of Australia's uranium resources should be supported and 'Australia should throw the world a climate lifeline.'[83]

4.70 In view of the potential greenhouse benefits, Professor Ralph Parsons argued that 'Australia should encourage those of our major trading partners which currently produce large quantities of greenhouse gases to use uranium rather than carbon based fuels wherever possible.'[84]

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Prominent environmentalists support nuclear power

4.71 The Committee was also informed that a number of prominent environmentalists, who were foundational figures in the environment movement and previously adamantly opposed to nuclear, now support use of nuclear power to avert global environmental calamity. These individuals include Dr Patrick Moore, Bishop Hugh Montefiore and Sir James Lovelock. Excerpts from their writings cited in evidence follow:

- Dr Patrick Moore, one of the co-founders of Greenpeace in 1971 and subsequently its president, has argued that 'nuclear energy is the only non greenhouse gas-emitting power source that can effectively replace fossil fuels and satisfy global [energy] demand.'[85] Dr Moore has also argued that environmental activists who oppose nuclear power have 'abandoned science in favour of sensationalism'.[86]

- Sir James Lovelock, an independent scientist and author of the Gaia hypothesis, has argued that:

- … by all means, let us use the small input from renewables sensibly, but only one immediately available source does not cause global warming and that is nuclear energy. Opposition to nuclear energy is based on irrational fear fed by Hollywood-style fiction, the Green lobbies and the media. These fears are unjustified, and nuclear energy from its start in 1952 has proved to be the safest of all energy sources. We have no time to experiment with visionary energy sources; civilisation is in imminent danger and has to use nuclear — the one safe, available, energy source — now or suffer the pain soon to be inflicted by our outraged planet.[87]

- Bishop Hugh Montefiore, a trustee of Friends of the Earth (FOE) for two decades and chairman of the organisation between 1992 and 1998, argued that:

- The dangers of global warming are greater than any others facing the planet. In the light of this I have come to the conclusion that the solution is to make more use of nuclear energy … Nuclear energy provides a reliable, safe, cheap, almost limitless form of pollution free energy. The real reason why the government has not taken up the nuclear option is because it lacks public acceptance, due to scare stories in the media and the stonewalling opposition of powerful environmental organisations. Most, if not all, of the objections do not stand up to objective assessment.[88]

4.72 For Cameco, the reason these environmentalists have taken this stance is that they rightly recognise that the enhanced greenhouse effect poses a far more serious threat to humankind than the risks associated with use of nuclear energy, notably its relatively small quantities of waste.[89] Indeed, Sir James Lovelock has argued that:

> … I am a Green and I entreat my friends in the movement to drop their wrongheaded objection to nuclear energy.
>
> Even if they were right about its dangers, and they are not, its worldwide use as our main source of energy would pose an insignificant threat compared with the dangers of intolerable and lethal heat waves and sea levels rising to drown every costal city in the world.[90]

4.73 Similarly, the Australian Nuclear Association (ANA) argued that while the perception of risks may vary, 'the cost is that the greenhouse gas problem could be more dangerous in the future … than the risks of radioactive waste if we use nuclear power.'[91]

4.74 The significance of prominent environmentalists taking pro-nuclear positions was disputed by FOE, who argued that most environmentalists remain opposed to use of nuclear power.[92] Similarly, the Environment Centre of the Northern Territory (ECNT) argued that:

> They are still only a tiny, tiny proportion of the people who have ever considered themselves to be, or have been called, environmentalists. The environment groups around the world are extremely solid in saying that we should not be wasting our time going back to nuclear; we should be going forward to renewable energy and energy efficiency.[93]

4.75 In response to the environment movement's continued opposition to nuclear power, Dr Moore argued before the US Senate Committee on Energy and Natural Resources in April 2005 that:

> I believe the majority of environmental activists, including those at Greenpeace, have now become so blinded by their extremism that they fail to consider the enormous and obvious benefits of harnessing nuclear power to meet and secure America's growing energy needs. These benefits far outweigh the risks. There is now a great deal of scientific data showing nuclear power to be an environmentally sound and safe choice.[94]

4.76 Despite media reports of a shift in perspective by WWF Australia, several environmental groups in Australia that submitted to the Committee's inquiry remain opposed to uranium mining and use of nuclear power.[95] The following section summarises the range of criticisms of nuclear power's contribution to GHG emission mitigation.

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Arguments critical of nuclear's contribution to greenhouse gas mitigation

Emissions across the whole nuclear fuel cycle

4.77 While it was widely conceded that nuclear power emits virtually no CO_2 at point of generation, numerous submitters argued that the balance of emissions across the whole nuclear fuel cycle is significant. That is, by adding the emissions produced from all other fuel cycle stages—mining and milling, enrichment, fuel fabrication, transport, plant construction, plant decommissioning and waste disposal—to the electricity generation stage, nuclear power produces a relatively large quantity of GHG emissions.

4.78 Examples of statements by submitters making this argument follow:

- 'Nuclear power also contributes to global carbon dioxide production. Huge quantities of fossil fuel are expended for the "front end" of the nuclear fuel cycle, to construct the massive reactor buildings and cooling towers, and to mine, mill, and enrich the uranium fuel.'[96]
- 'While the production of steam in a nuclear reactor is essentially greenhouse-free, the same is not the case for, the mining, transport and enrichment of the uranium concentrate and the decommissioning of the plant … The amount of fossil fuel required in the mining, enrichment, construction and decommissioning stages ruins the argument that nuclear power is a valid answer to climate change.'[97]
- 'Nuclear power, despite being depicted as "clean and green" by its advocates, is neither. Throughout the exploration and mining phases, the milling and processing, the transporting of processed ore, the building of reactors, the global movement of spent and treated fuel rods, the passage of radioactive wastes … and the final decommissioning of reactors past their use-by date, fossil fuels are extensively used.'[98]
- 'The case for presenting nuclear power as an alternative source of power generation that is less likely to contribute to global warming is very flawed as it does not take into account the whole nuclear power cycle.'[99]
- 'While nuclear power is "environmentally greener" than any other current energy resource, the infrastructure needed to access and mine the ore plus the construction of reactors and waste disposal sites might result in increased levels of greenhouse gas, cancelling the good effects at the power production level.'[100]

4.79 Life cycle emissions analysis presented in evidence refuted these claims. While estimates of the quantity of emissions released from electricity generation sources across their life cycles vary, it is clear that nuclear power emits orders of magnitude *less* CO_2 than fossil fuels and is equivalent to renewables in most cases:

> Nuclear power creates the lowest amount of CO_2 emissions compared with coal (highest), gas, solar photovoltaic, and in some cases wind. The only rival to nuclear is hydro.[101]

4.80 Several estimates of the emissions from electricity generation chains were submitted in evidence and some of these are listed below. Life cycle emissions are generally quoted in terms of grams of carbon dioxide emitted per kilowatt-hour of electricity produced (gCO_2/kWh). The range of estimates are comparable:

- UIC estimated that nuclear emits some 20 gCO_2/kWh, while black coal emits 950 gCO_2/kWh and gas emits 500 gCO_2/kWh.[102]
- Areva estimated that nuclear emits 12 gCO_2/kWh, while lignite emits 1.1kg of CO_2/kWh, coal emits 932 gCO_2/kWh, oil emits 777 gCO_2/kWh, gas emits 439 gCO_2/kWh, hydro (dam) emits 12.5 gCO_2/kWh, wind emits 9 gCO_2/kWh and

hydro (river) emits 5.1 gCO_2/kWh.[103]

- Geoscience Australia (GA) estimated that nuclear emits 5 gCO_2/kWh.[104]
- CSIRO estimated that nuclear emits less than 40 gCO_2/kWh, compared to 760 gCO_2/kWh from a 'state-of-the-art pulverised fuel fired station firing black coal at around 41 per cent overall thermal efficiency.'[105]
- Australian Institute of Nuclear Science and Engineering (AINSE) estimated that nuclear, hydro and wind emit under 10 gCO_2/kWh, while solar emits approximately 100 gCO_2/kWh.[106]

4.81 These various estimates suggest that fossil fuels emit between 18 and 92 times the CO_2 of nuclear power across the full electricity production chains, while nuclear is comparable to—and in some cases less than— renewables.

4.82 Groups critical of nuclear power cited other studies, such as those published by the German Oko Institut, which were said to have found that nuclear emits between 34–60 gCO_2/kWh over its full fuel cycle, while wind emits approximately 20 gCO_2/kWh. Similarly, the Medical Association for the Prevention of War (Victorian Branch) argued that on a full life cycle basis nuclear produces between 1.5 and 3 times as much CO_2 as wind generation.[107]

4.83 The Australian Conservation Foundation (ACF) and Dr Helen Caldicott cited research by Jan Willem Storm van Leeuwen and Philip Smith claiming that nuclear power emits only three times less GHG than modern natural gas power stations.[108]

4.84 Some environmental groups conceded that nuclear power is far less carbon intensive than fossil fuel alternatives. For example, FOE stated that electricity from fossil fuels is far more greenhouse intensive than nuclear. However, it was argued that nuclear power emits more GHG than most renewables, but again FOE conceded that the difference is small.[109]

4.85 AMP CISFT, which argued that nuclear power is not environmentally sustainable, conceded that nuclear's major benefit is that it 'is one of the least carbon intensive generation technologies.'[110] AMP CISFT estimated that nuclear emits between 9.2–20.9 gCO_2/kWh, compared to 385g–1.3kg CO_2/kWh for fossil fuel chains and 9.2–278.7 gCO_2/kWh for renewables.[111]

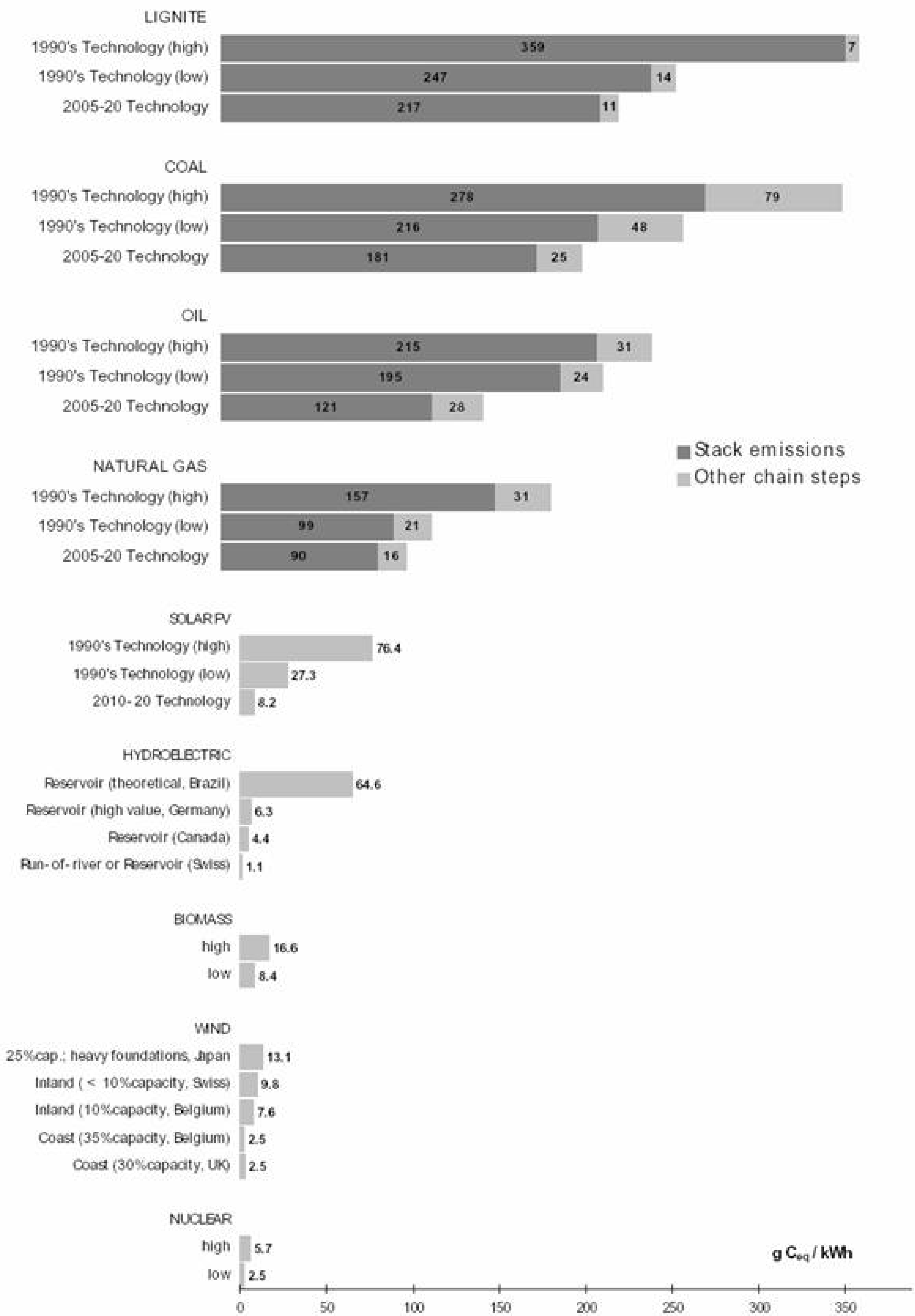
4.86 The range of greenhouse gas emissions emitted across electricity production chains for different sources of electricity as determined by the IAEA are depicted in figure 4.2. As with the estimates above, these figures include emissions across the entire nuclear power chain—from mining uranium ore to nuclear waste disposal and reactor construction. Emissions range from 366 grams of carbon equivalent per kilowatt-hour (gC_{eq}/kWh) for lignite, to between 2.5 and 5.7 gC_{eq}/kWh for nuclear power. Wind ranges between 2.5 and 13.1 gC_{eq}/kWh, and solar photovoltaics between 8.2 and 76.4 gC_{eq}/kWh. The IAEA has concluded that:

> The complete nuclear power chain, from resource extraction to waste disposal including reactor and facility construction, emits only 2-6 grams of carbon equivalent per kilowatt-hour. This is about the same as wind and solar power including construction and component manufacture. All three are two orders of magnitude below coal, oil and natural gas.[112]

4.87 Studies have also been made of the carbon emissions by fuel source for specific countries. Table 4.3 lists the life cycle emissions for various sources of electricity generation and fuel types in Japan, Sweden and Finland—countries which have produced authoritative figures. The variation in emission levels for nuclear across the three countries reflects the method of uranium enrichment used (gaseous diffusion or gas centrifuge) and whether the power for enrichment comes from nuclear sources or from fossil sources.

4.88 The data reveals that, other than hydro, nuclear power emits the least CO_2 of all generation methods in each of the countries. Nuclear emits less than one-hundredth of the CO_2 of fossil fuel based generation in Sweden .

Figure 4.2 The range of total greenhouse gas emissions from electricity production chains
(measured in grams of carbon equivalent per kilowatt-hour of electricity generated)



Source Hans-Holger Rogner , et. al., *Nuclear Power: Status and Outlook* , IAEA, Vienna , 2002, p. 5.

4.89 The ANA argued that emissions from nuclear are below wind in Japan and marginally above wind in Sweden and Finland. The reasons for this are that wind and solar are diffuse sources of energy and they have a low capacity factor. In addition, solar and wind both produce CO_2 during the construction process for the towers, turbines and [113] generators.

Table 4.3 Grams of carbon dioxide emitted per kilowatt-hour of electricity produced by different generation methods in Japan, Sweden and Finland

Generation method	Japan	Sweden	Finland
Coal	975	980	894
Gas Thermal	608	1170	—
Gas Combined Cycle	519	450	472
Solar photovoltaic	53	50	95
Wind	29	5.5	14
Nuclear	22	6	10 – 26
Hydro	11	3	—

Source ANSTO, *Exhibit no. 74, Presentation by Dr Ron Cameron and Dr Ian Smith* , p. 32. UIC, *Submission no. 12* , p. 15.

4.90 GA submitted the life cycle emissions data contained in table 4.4, which lists the GHG emissions for different sources of electricity generation and fuel types for France and other European countries. The table lists the emissions released at the point of generation or operation, emissions across the remainder of the electricity production chains and the total for each source of electricity.

4.91 In this data, natural gas releases 182 times more CO_2 over its full electricity production chain than nuclear, and coal releases over 200 times more CO_2 than nuclear. Nuclear and hydro have the same life cycle emissions per unit of electricity produced and wind is marginally lower.

Table 4.4 Greenhouse gas emissions for different sources of electricity generation and fuel types, typical for France and other European countries (2004)

Energy source	**Operation** grams of CO_2 equivalent per kW hour	**Remainder of cycle** grams of CO_2equivalent per kW hour	**Total** grams of CO_2 equivalent per kW hour
Coal 600 MWe	892	111	1 003
Fuel oil	839	149	988
Gas turbine	844	68	912
Diesel	726	159	895
Hydro-pumped storage	127	5	132
Photovoltaic	0	97	97
Hydroelectric	0	5	5
Nuclear energy	0	5	5
Wind generation	0	3	3

Source Geoscience Australia , *Submission no. 42* , p. 26.

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Enrichment and declining uranium ore grades

4.92 Critics of nuclear power's GHG mitigation potential raised the issues of the energy required to power uranium enrichment plants and the additional energy that may be required to mine and mill uranium as ore grades decline. That is, as higher grade ores are exhausted, a greater amount of energy may need to be expended for extraction and processing, and hence overall CO_2 emissions may increase.

4.93 In relation to uranium enrichment, which is discussed further in chapters seven and twelve, there are currently two enrichment technologies in large scale commercial use: gaseous diffusion and newer gas centrifuge enrichment plants. There are currently two of the older gaseous diffusion plants remaining in operation—one in France (operated by Areva) and another in the US (operated by the US Enrichment Corporation, USEC). These plants account for approximately 40 per cent of world enrichment capacity.[114]

4.94 It was argued that enrichment plants consume enormous quantities of electricity and emit large quantities of chlorofluorocarbons (CFCs), which are ozone depleting as well as being significant greenhouse gases.[115]

4.95 Silex confirmed that the first generation gaseous diffusion enrichment technology consumes large amounts of electricity. The gaseous diffusion plant in Paducah, Kentucky, consumes one-half of one per cent of all electricity generated in the US. The Paducah plant also operates with CFCs and has a dispensatory license allowing it to do so. Areva and USEC have indicated their intention to phase out these plants.[116]

4.96 ANA stated that while gaseous diffusion plants consume a large amount of electricity, these are being replaced by centrifuge enrichment plants which use less than one-tenth of the electricity previously required.[117] Whereas a gaseous diffusion plant would use 2 500 kWh per unit of production (a separative work unit, SWU), a centrifuge plant would only require between 50 and 100 kWh per SWU.[118]

4.97 Mr Keith Alder, formerly the General Manager and then a Commissioner of the Australian Atomic Energy Commission, also dismissed arguments critical of the energy balance in relation to enrichment plants, arguing that centrifuge technology has dramatically reduced the amount of energy required, down by a factor of 20 compared to gaseous diffusion plants.[119]

4.98 GA observed that the whole of life cycle emission rate for nuclear power in France listed in table 4.4 (5 gCO_2/kWh) is lower than the industry average cited by the UIC (20 gCO_2/kWh) because nuclear reactors are used to power the enrichment plants in France, whereas in other countries the electricity for enrichment is supplied by coal-fired power stations.[120]

4.99 The ANA agreed, noting that the gaseous diffusion plant in France, which is to be replaced by centrifuge technology, is powered by four dedicated nuclear power plants and so the enrichment process in that country emits no CO_2 .[121] The gaseous diffusion plant operating in the US is powered by coal. However, the ANA and Silex estimated that within ten years all existing gaseous diffusion plants will be replaced by centrifuge enrichment plants. There are now four of the newer plants worldwide, with two currently in operation, and there are plans to build more.

4.100 The UIC observed that while enrichment can be greenhouse intensive, it still accounts for a small share of carbon emissions:

> [Enrichment] can also account for the main greenhouse gas impact from the nuclear fuel cycle if the electricity used for enrichment is generated from coal. However, it still only amounts to 0.1% of the carbon dioxide from equivalent coal-fired electricity generation if modern gas centrifuge plants are used, or up to 3% in a worst case situation.[122]

4.101 It was also argued that over coming decades increased energy inputs will be required to extract and process lower grade uranium ores, and that the energy required to extract uranium will rise to the extent of making the net energy yield from nuclear power very small. It was argued that as energy inputs increase, CO_2 emissions will rise to near fossil fuel levels.

4.102 A number of submitters advanced this argument. For example, DEH argued that the GHG emission benefit of nuclear power may indeed diminish as the quality of uranium ores decline: 'The lower the quality of the ore, the more greenhouse gas intensity increases.'[123] Similarly,
Dr Gavin Mudd claimed that:

> If you look at Olympic Dam, both its current operations and its future operations, and Ranger et cetera, there will be at least one millions tonnes of CO_2 released a year. If those operations expand, that figure will

> obviously increase. One of the issues is that to get the uranium out in the future is going to require more energy, so there will be more relative CO_2 emissions.[124]

4.103 The argument was also made by other witnesses, including FOE, ACF, the Public Health Association (PHA), MAPW and Greenpeace who issued a joint statement, *Nuclear Power: No Solution to Climate Change*. This statement claimed that:

> … the mining of lower grade ores is likely to have significant implications in relation to energy usage and greenhouse gas emissions. The energy required to extract uranium from low grade ores may approach the energy gained from the uranium's use in power reactors. Likewise, the increased greenhouse gas emissions from mining and milling low grade ores will narrow nuclear's greenhouse advantage in relation to fossil fuels, and widen nuclear power's deficit in comparison to most renewables energy sources.[125]

4.104 The argument draws again on a study by Storm van Leeuwen and Smith (SLS), now comprehensively critiqued, which purports to compare the energy inputs and outputs for nuclear power, and asserts that mining and milling uranium are major energy costs. SLS argue that although the production of electricity leads to 'considerably less' CO_2 emissions than fossil fuels:

> In the course of time, as the rich ores become exhausted and poorer and poorer ores are perforce used, continuing use of nuclear reactors for electricity generation will finally result in the production of more CO_2 than if fossil fuels were to be burned directly.[126]

4.105 The UIC, WNA and academics from the School of Physics at the University of Melbourne, among others, have published detailed responses to the SLS study and emphatically rebutted the claims made.[127] In brief, the UIC argued that the SLS 'assertions ignore hard data and misunderstand the concept of mineral resources.'[128]

4.106 It was argued that a typical life cycle analysis of nuclear energy shows that total energy inputs are only about two per cent of outputs (which is comparable to wind generation), or less.[129] An audited life cycle analysis of the Forsmark nuclear power plant in Sweden showed that energy inputs are in fact 1.35 per cent of output. It was argued that if uranium with much lower ore grades is used, the total energy inputs rise to only about 2.5 per cent of outputs.

4.107 Similarly, the Melbourne University physicists group have argued that the SLS paper 'grossly over estimates the energy cost of mining low-grade ores'.[130] Employing the SLS calculations, the group predicted that the energy cost of extracting Olympic Dam's annual uranium production would require the energy equivalent to almost two one-gigawatt power plants running for a full year (two gigawatt-years). In fact, this is larger than the entire electricity production of South Australia and an order of magnitude more than the measured energy inputs for the mine.[131]

4.108 The UIC argued that the energy costs of uranium mining and milling are well known and published. The energy cost are said to form a small part of the overall total and 'even if they were ten times higher they would still be insignificant overall.'[132]

4.109 The UIC also argued that by suggesting the need to mine low grade ores is imminent, SLS misunderstand the nature of mineral resources:

> We can be confident that known economic resources of uranium (as of other metal minerals) will increase in line with exploration effort. While ore grades may well decline to some extent, the energy required to utilise them will not become excessive.[133]

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Nuclear power 'too limited, slow and impractical to solve climate change'

4.110 Environment groups argued that nuclear power cannot solve climate change because it is too limited, slow and impractical. Nuclear was said to be a limited response to climate change because nuclear power is used almost exclusively for power generation, which is claimed to be 'responsible for less than a third of global greenhouse gas emissions.'[134] As noted above, other anthropogenic sources of GHG emissions include transport and agriculture, and thus:

> Switching the entire world's electricity production to nuclear would still not solve the problem. This is because the production of electricity is only one of many human activities that release greenhouse gases.[135]

4.111 MAPW also argued that the IPCC has concluded that CO_2 emissions must be reduced by at least 70 per cent over the next century to stabilise atmospheric CO_2 concentrations at 450 ppm. It was therefore argued that:

> Reducing CO_2 emissions from electricity generation by itself would be insufficient to achieve this target; thus even massive expansion of nuclear power could not by itself be sufficient.[136]

4.112 ACF argued that to reduce emissions by the public energy sector according to the targets of the Kyoto Protocol would require that 72 medium sized nuclear power be built in the EU-15 nations by the end of the first commitment period, 2008–12:

> Leaving aside the huge costs this would involve, it is unlikely that it is technically feasible to build so many new plants in such a short time, given that only 15 new reactors have been built in the last 20 years.[137]

4.113 FOE also argued that a 'nuclear solution to climate change' was impractical because for nuclear to account for 70 per cent of electricity by 2100 would allegedly require 115 reactors to be built each year. In any case, it was claimed that this would 'result in emission reductions relative to fossil fuels of just 16 per cent.'[138]

4.114 FOE and People for Nuclear Disarmament NSW asserted that a doubling of nuclear power output by 2050 would reduce global greenhouse emissions by about 5 per cent, allegedly 'less than one tenth of the reductions required to stabilise atmospheric concentrations of greenhouse gases.'[139]

4.115 Research provided by Dr Helen Caldicott argued that, in addition to being a limited response to climate change, nuclear power is also 'about the slowest option to deploy (in capacity or annual output added)'.[140] It was argued that efficiency gains combined with decentralised sources of energy 'now add at least ten times as much capacity per year as nuclear power.'[141]

4.116 Professor Richard Broinowski expressed scepticism that nuclear power could even be part of the solution to the greenhouse emissions problem:

> The most compelling reasons are that: firstly, electricity generation accounts for only approximately one-third of greenhouse gas emissions; secondly, at least 1,000 nuclear reactors of at least 1,000 megawatts each would have to be constructed, beginning immediately, to make any dent on the contribution power generation makes to global warming; and, thirdly, these would in turn generate enormous quantities of hydrocarbon emissions in the mining and enrichment of the additional uranium, rapidly exhaust economically significant deposits of uranium and significantly increase the problems of disposal of spent nuclear fuel.[142]

4.117 In terms of emissions currently avoided, FOE argued that nuclear avoids some 312 Mt CO_2 per year in the EU countries, relative to use of fossil fuels. However, FOE argued that the savings drop to half if the comparison is with natural gas cogeneration and zero if compared with hydroelectricity. There are allegedly net costs if nuclear is compared with investment in energy efficiency measures and renewables such as wind generation.[143]

4.118 ACF argued that nuclear is not an answer to the climate change problem because of the 'very long lead time and the high capital investment that is required for nuclear options.'[144] ACF also pointed to the significant opportunity cost involved for countries that choose to build or expand nuclear power. Because resources are finite, countries would necessarily have to forgo other options should it choose to adopt nuclear power. ACF also stressed that the economic competitiveness of renewables would improve over the next 10 to 15 years.

4.119 Similarly, MAPW (WA Branch) pointed to the long-lead times for the construction of nuclear power plants:

> The 10 years needed to plan and build a nuclear power plant, together with the high capital cost, makes the nuclear response to accelerating global warming particularly inappropriate. In fact, I think it would be a recipe for disaster because of the greenhouse gases produced in building those power stations.[145]

4.120 Critics of nuclear power argued that nuclear cannot solve the climate change problem. For example, FOE argued that 'nuclear power is being promoted as *the* solution to climate change, but it is no such thing.'[146] However, no witness or submitter—particularly those from industry—presented evidence to the Committee alleging that nuclear power *alone* could 'solve' climate change, or that nuclear power *alone* could reduce emissions sufficient to prevent further global warming.

4.121 Industry presented a consistently measured response in relation to nuclear power's potential to assist in reducing GHG emissions. For example, the ANA argued that:

> … if you are operating 400 or so nuclear power stations around the world, you are producing less CO_2 per unit of electricity than if you were operating coal or gas stations. Nuclear power, in that sense, can contribute to reducing the greenhouse effect but … nuclear power is not the solution to the greenhouse problem because it can only contribute a small amount as one of several energy resources. In general, we in the world are unfortunately very reliant on fossil fuels. We cannot possibly phase them out over a short period, and possibly not even over 20 to 50 years. We will be dependent on them, but we can do everything possible to conserve electricity and use more efficient end-use applications. We can conserve it in that sense and we can supplement it with new baseload and distributed generation from nuclear and renewables which have much lower contributions. That is the point.[147]

4.122 Areva also argued that:

> No-one will ever suggest, and we certainly would not, that nuclear should be the only fuel source, but there is no doubt that it is the most efficient and one of the cleanest sources of energy …
>
> Nuclear power is just one of the many aspects. In a relative sense it is a clean fuel. It does not produce CO_2 which … is creating global warming … Nuclear power will help to reduce that, but there have to be other ways as well. It is not going to stop it, but it will help to reduce it.[148]

4.123 Similarly, BHP Billiton argued that:

> No, [nuclear power] is not the solution, because I do not think there is one solution. I think more efficient carbon capture, better use of fossil fuels, more use of renewables as appropriate and more use of nuclear fuels are all part of the case.[149]

4.124 Heathgate Resources stated that nuclear power is 'one part of the answer' and the ANF argued that nuclear power is 'not going to solve [the climate change] problem by itself', but that 'by having nuclear reactors you certainly could do something to ameliorate it.'[150] Similarly, Nova Energy stated that nuclear 'is only part of that solution.'[151]

4.125 Nonetheless, BHP Billiton noted that while the energy used to mine uranium in Australia is carbon based, a global perspective is needed and use of Australia's uranium makes a significant contribution to GHG mitigation worldwide:

> You have to take a global picture … about 40 per cent of Australia's current greenhouse gas emissions are saved, if you like—internationally, not in Australia—by virtue of the amount of uranium produced. So it is a major contributor … and a legitimate part of the greenhouse gas debate, but there is no magic solution.[152]

4.126 In terms of the emissions avoided by use of nuclear compared to those saved by renewables, in testimony before the US Senate Committee on Energy and Natural Resources Dr Patrick Moore argued that 'in 2002, carbon emissions avoided by nuclear power were 1.7 times larger than those avoided by renewables.'[153]

4.127 While it was conceded that nuclear power currently avoids emissions in the electricity and heat sector, which contributes 40 per cent of global CO_2 emissions, submitters also argued that nuclear power has the potential to significantly reduce emissions in the transport sector, which is the second largest CO_2 contributor at 24 per cent of the global total.[154]

4.128 Paladin Resources and Cameco, among others, pointed out that nuclear power, particularly reactors currently being developed, could play a significant role in producing hydrogen which may eventually have widespread use in transport and for desalination:

> Looking ahead there is an expectation that hydrogen will play a more important role in energy supply, especially as a transportation fuel to replace greenhouse gas-emitting petrol. Industrial-scale production of hydrogen by electrolysis will require large amounts of electricity, which itself must be generated by a CO_2-free source if the total greenhouse loading is to be reduced. Large nuclear power plants obviously have a key role in future hydrogen manufacture. Nuclear power plants are also ideally suited for large scale water desalination plants which may become necessary in some parts of the world as water resources become severely over taxed by social demand.[155]

4.129 CSIRO also observed that:

> … large-scale nuclear energy production allows you an easy route to electrolysis of water to produce oxygen and hydrogen, without producing greenhouse gas emissions in any significant way and without the need, as you do in the similar production of hydrogen from coal, to sequester the CO_2.[156]

4.130 The Final Statement from the International Ministerial Conference, *Nuclear Power for the 21 st Century*, also observed that nuclear power could make a valuable contribution to sustainable development through the production of hydrogen and potable water (desalination).[157]

4.131 ANSTO informed the Committee that the US Department of Energy (DOE) is moving towards a concept of producing hydrogen by nuclear power through a 'Nuclear Hydrogen Initiative'.[158] The aim of the Initiative is to:

> … demonstrate the economic commercial-scale production of hydrogen using nuclear energy by 2015, and thereby make available a large-scale, emission-free, domestic hydrogen production capability to fuel the approaching hydrogen economy.[159]

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Renewables and energy efficiency measures

4.132 Submitters opposed to the use of nuclear power argued that the world's energy needs can be met and major reductions in GHG emissions can be achieved by promoting the use of renewable energy sources, decentralising power generation, adopting energy efficiency measures and significantly reducing energy consumption per capita in industrialised countries.[160] In particular, ACF, FOE, MAPW (WA Branch) and others drew on a study by Keepin and Kats, published in 1988, to argue that:

> … energy efficiency demand management is the most cost effective way of addressing greenhouse gas emissions … for every dollar invested in energy efficiency … realises seven times more savings in energy and in greenhouse gas emissions than if the same single dollar had been invested in a nuclear proposal.[161]

4.133 Keepin and Kats assert that:

> Opportunities for efficiency gains are so compelling that they suggest that global warming can best be avoided by concentrating on efficiency rather than on a rapid expansion of nuclear power.[162]

4.134 FOE cited a number of alternative studies which assert that energy efficiency and conservation measures, in combination with use of renewables, can deliver reductions in emissions required to stabilise atmospheric concentrations of greenhouse gasses. FOE also argued that reducing growth in energy demand will be essential to reduce emissions, regardless of whether there is a large expansion of nuclear power or renewables. It was argued that the choice of which renewable energy source to deploy (for example, solar or wind) would vary depending on the circumstances of the particular country.[163]

4.135 In the Australian context, FOE and the ECNT cited two studies which propose methods to achieve 'deep cuts' in Australia's GHG emissions:

- Clean Energy Future Group (2004), which concludes that Australia can meet its energy needs from various commercially proven fuels and technologies while cutting greenhouse emissions by 50 percent by 2040 in the stationary energy sector; and an
- Australia Institute study (2002), which claims to show how Australia can reduce greenhouse emissions by 60 per cent by 2050, through a combination of:

> … a major expansion of wind power, modest growth in hydroelectricity, significant use of biomass, niche applications for solar photovoltaics, and a shift away from large-scale thermal generators isolated from load centres towards distributed cogeneration of electricity and heat.[164]

4.136 The ECNT argued that:

> … there are more immediate, cost-effective and environmentally and socially sustainable options that can be pursued, rather than wasting time, money and resources heading off towards the nuclear dead end.[165]
>
> It was argued that nuclear should be replaced by efficient combined cycle gas as a transition away from fossil fuels to generate baseload power.[166]

4.137 The ECNT also argued that it would:

> … be negligent of the committee to endorse an expansion of uranium

> exports to, say, China, without conducting a thorough examination of the opportunities for, and benefits of, renewable energy technologies and energy efficiency measures, both in Australia and overseas. Indeed, we would go further and encourage the committee to recommend the redirection of Commonwealth funding currently aimed at facilitating the expansion of the coal and uranium sectors towards the renewable sector as well as into reducing baseload electricity demand.[167]

4.138 The Uniting Church in Australia (Victorian and Tasmanian Synod) also recommended that the Australian Government should assist in transferring renewable technologies to developing countries to assist with their greenhouse gas emission reductions and to significantly increase the provision of subsidies for research, development and implementation of renewables.[168] The ECNT also alleged that Australia was 'getting left behind' by failing to export renewable technologies to China.[169]

4.139 In a project of potential significance in Australia, Geodynamics described the GHG displacement potential of the company's 'hot fractured rock' geothermal resources in the Cooper Basin, which could enable Australia to avoid some 38 Mt of CO_2 per year relative to fossil fuelled plants and generate baseload power (estimated at 3 500 MWe). It was argued that the company's geothermal energy project is unique within the renewable sector 'because it can produce low cost, baseload power on a large scale'.[170]

Nuclear power — an essential component in a low-emission energy mix

4.140 Industry argued that nuclear power can make a significant contribution as part of a low-emission energy mix, which should also include renewables and clean coal technologies:

> Australia's uranium producers do not say that nuclear is the only answer to the world's energy needs but they do say that it needs to be regarded as an important part of the mix, which should also include renewable sources where they are available, economic and efficient. We also support the coal industry's endeavours to dramatically reduce carbon dioxide emission from the use of their product and to achieve this economically.[171]

4.141 Energy Resources of Australia (ERA) emphasised that:

> … nuclear power is an essential component of any mix of low-emission power generation technologies required to reduce greenhouse gas production.[172]

4.142 Paladin Resources stated that:

> Responsible and balanced policy would strive for a mix of low-greenhouse energy sources: CO_2-free nuclear for baseload power in countries with high ambient power demand; low-CO_2 coal, because coal is abundant; natural gas for peaking loads; hydro, wind, tidal, solar where suitable and appropriate. Achieving better energy efficiency in product design and use and reducing excessive consumption in the developed world through better electricity pricing are also important strategies. There is no single panacea, but no likely remedy should be arbitrarily rejected. Windmills and reactors each have parts to play.[173]

4.143 Likewise, Ms Pepita Maiden, a former employee of British Nuclear Fuels, argued that:

> … nuclear power should not necessarily be embraced as the sole solution to climate change issues, it should be accepted and supported as an important part of the world's energy mix.[174]

4.144 The Committee notes that while the IEA has emphasised the key role of energy efficiency measures in reducing global emissions, the Agency has argued that there is no one technology or policy which can stabilise atmospheric GHG emission concentrations. The IEA has concluded that the global energy mix for a sustainable future will require a 'portfolio approach' to policy, technology development and R&D in which nuclear power plays an important part.[175]

4.145 In a similar vein, the Final Statement from the International Ministerial Conference, *Nuclear Power for the 21 st Century*, noted that:

> A diverse portfolio of energy sources will be needed in the 21st century to allow access to sustainable energy and electricity resources in all regions of the world. Efforts will be needed as well to improve energy efficiency, while limiting air pollution and greenhouse gas emissions.[176]

4.146 Emphasising the importance of a mix of energy sources, the World Energy Council concluded at its World Energy Congress held in Sydney in September 2004 that:

> All energy options must be kept open and no technology should be idolised or demonised. These include the conventional options of coal, oil, gas, nuclear and hydro (whether large or small) and the new renewable energy sources, combined of course with energy efficiency.[177]

4.147 The view that the optimum energy supply mix must include nuclear power was also supported by Wind Prospect, a wind energy developer, constructor and operator, working in Australia, UK, Hong Kong and Ireland, who submitted that:

> It is our belief that the optimum energy supply solution, both for Australia and internationally, involves a mix of many energy sources, and that there exists a place for nuclear energy as a source of baseload electricity.[178]

4.148 The MCA emphasised that nuclear power should not be seen as a substitute for coal, renewables or other energy sources because the rate of growth of energy demand globally requires a contribution from all energy sources and, second, the required reductions in greenhouse emissions will not be achieved by energy efficiency measures alone:

> The rate of growth in demand of energy is increasing and, particularly in the industrialised and urbanising countries of China and India and other parts of Asia, there is going to be demand for all sources of energy. We are not looking at uranium as a substitute for coal or other sorts of energy, we are looking across the board and that includes some of the variable load capacity of renewables and maybe also the baseload of hydro … because we are not going to get within a bull's roar of what the scientists are telling us we have to do in terms of [greenhouse gas emission] reductions just through energy efficiency …[179]

4.149 However, research cited by Dr Helen Caldicott disputed the argument that a mix of energy options is required or even possible:

> The claim that 'we need all energy options' has no analytic basis and is clearly not true; nor can we afford all options. In practice, keeping nuclear power alive means diverting private and public investment from the cheaper market winners—cogeneration, renewables, and efficiency—to the costlier market loser.[180]

4.150 The IEA concludes that to meet global energy demand and stabilise CO_2 concentrations will require unprecedented technology changes during this century.[181] Potential strategies to avoid one billion tonnes of CO_2 per year (a three per cent difference) as posited by the IEA are listed in table 4.5. For example, to avoid one billion tonnes of CO_2 would require the replacement of 300 conventional 500 MW coal power stations with 1 000 Sleipner carbon sequestration plants (currently being deployed in the North Sea at a cost of US$59/tonne), the installation of 200 times the current US wind generation, or the construction of 1 300 times the current US solar generation. Alternatively, 140 one-gigawatt nuclear power stations would need to be constructed. Dr Ian Smith, Executive Director of ANSTO, argued that 'I believe you have to do all those things; you cannot do just one of those things.'[182]

Table 4.5 Strategies to avoid one billion tonnes of carbon dioxide per year

Coal	Replace 300 conventional, 500-MW coal power plants with 'zero emission' power plants, or …
CO_2 Sequestration	Install 1 000 Sleipner CO_2 sequestration plants
Wind	Install 200 times the current US wind generation in lieu of unsequestered coal
Solar PV	Install 1 300 times current US solar generation in lieu of unsequestered coal
Nuclear	Build 140 1-GW power plants in lieu of unsequestered coal plants

Source Claude Mandil , *International Ministerial Conference, Nuclear Power for the 21 st Century, March 2005*
cited in ANSTO, *Exhibit no. 74, Presentation by Dr Ron Cameron and Dr Ian Smith* , slide no. 30.

4.151 Silex Systems argued that potential solutions to climate change include a combination of the following:

- decreasing fossil fuel consumption;
- increasing reliance on nuclear power;
- increasing reliance on renewables, at least for peak load power;
- accelerating the hydrogen economy via nuclear power, particularly to replace fossil fuels in transportation; and
- improving energy efficiency.[183]
- Silex argued that no one option will solve the greenhouse problem:

We believe that an integrated mix of nuclear, renewables, hydrogen and energy efficiency measures is required and is inevitable.[184]

4.152 Moreover, in relation to the development of clean coal technologies, development of uranium reserves and renewables/hydrogen, Silex argued that Australia needs a 'bipartisan energy strategy for there to be a coherent and forceful approach. A unique opportunity for political leadership exists'.[185]

4.153 DEH, the MCA and the ANA stressed the importance of addressing GHG emissions by focussing on clean coal technologies given Australia's comparative advantage in coal and the likelihood that the world will remain reliant on fossil fuels, particularly coal, for decades to come:

> … in the longer term the world is going to be reliant on fossil fuels. There is no doubt about that; it is the dominant fuel … So it does make sense to look at technologies by which you can clean up that use of coal in terms of greenhouse emissions.[186]

4.154 DEH emphasised that while uranium exports can reduce emissions if they displace high-intensity sources, Australia has a keen interest in technologies that can produce low emissions from coal and so 'it is in Australia's interests not to set them against each other but to talk about the contribution both can make.'[187] Furthermore, in addition to clean coal technology, it was submitted that Australia has a comparative advantage in solar photovoltaics and hot dry rocks (geothermal) and is best able to contribute in these areas of technology.

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The limitations of renewable energy sources

4.155 While industry welcomed the contribution that renewable energy sources can make and readily conceded that nuclear power alone could not 'solve' climate change, it was consistently argued that nuclear power is the only low-emission alternative to fossil fuels capable of providing baseload supply of electricity on a large scale. For example, the UIC submitted that:

> While the UIC has a positive view of the role of wind and solar power in the overall electricity supply, we wish to emphasise that the main demand in any urbanised country is for continuous, reliable supply on a large scale, and these intermittent renewables simply cannot meet that, let alone on an economic basis. Nor is there any prospect of them doing so.[188]

4.156 The capacity of nuclear power to provide baseload power with low emissions was emphasised as being particularly important in the context of rapidly growing global energy demand. For example, Paladin Resources argued that:

> It is difficult to see how the world's voracious appetite for energy, and particularly electricity, will be met without compromising greenhouse gas limits unless there is an increasing reliance on nuclear power for baseload, high volume electricity production.[189]

4.157 Similarly, AINSE argued that:

> … of the methods of power generation which contribute least to CO_2 emissions nuclear fission is the only one suited to the provision of a stable baseload … The projected increase in energy demands requires a solution now. Nuclear fission will be one component of multiple strategies, including renewables.[190]

4.158 AMEC also observed that nuclear power is part of the answer to the energy demand and GHG emission problem for the medium term:

> With the growing demand for energy and the dangers that global warming presents … at least in the short to medium term we have to develop uranium deposits throughout this country.[191]

4.159 It was emphasised that renewable energy sources and energy efficiency measures are limited and will not be sufficient to meet growing energy demand and reduce emissions. The SIA argued that the limitations of renewables need to be acknowledged:

> Yes, we must achieve better efficiencies. We must maximise the use of renewable energy—wind, solar and hot rocks—and clean up coal, but we have to be realistic about the risks, the costs and the real limitations of some of these measures. These measures alone will not suffice. The paradox for me is that the very people who would protect the environment have caused and continue to cause such damage by their blind rejection of the realities.[192]

4.160 On the potential for renewables to address global GHG emissions, replace fossil fuels and nuclear power, and meet the growing global demand for energy, CSIRO argued that:

> The question is can renewable technology keep pace with the increasing need for energy? At the moment it does not appear that the technology is advancing at a rate and at a scale that allows it to replace existing fossil fuel and nuclear fuel based energy production … The scenario planning that

> CSIRO has done so far projects out 50 years or so, and that has fossil fuel based sources of energy still in the mix at that point. At the end of the day, the models must take into account the economic situation as well as the demand situation. It projects increases in electricity production requirements of the order of two per cent growth a year, and we just cannot keep pace with that with any silver bullet technology that might come in.[193]

4.161 Submitters noted that the proportion of world energy demand that will be supplied by renewable sources in the future is highly contested. Nova Energy asserted that without resolving a series of technical challenges, 'there is general acceptance that it will not be possible to meet all future energy demands from renewable energy sources.'[194]

4.162 In general, it was argued that renewable energy sources cannot provide the baseload capacity required by industrial societies and large cities, such as the emerging 'megacities' of Asia.[195] Renewables, such as solar, wind and wave power, were said to be intermittent, provide fluctuating supply and present energy storage issues.[196]

4.163 Nova Energy argued that while renewables are certainly required to complement other energy sources, it is not possible to derive sufficient electricity or liquid fuels from renewables to sustain the present high per capita rates of consumption, let alone additional growth requirements. The reasons cited for these limitations were:

- Large fluctuations in energy production, for example variability and intermittency of wind energy or limited solar energy efficiency caused by winter solar incidence or night time.
- Need to store energy to cope with timing inconsistencies of supply and demand, for example storage of solar energy for night use. Large storage volumes are required to store significant quantities of energy.
- Significant loss factors during the process, including on transmission, inversion from DC to AC current and conversion for storage.
- Many potential locations from where renewable energy, such as wind, hydro and thermal, may be sourced are significant distances from power grids making transport difficult and expensive.
- Infrastructure requirements are expensive to install and maintain.
- Low efficiency rates, for example solar energy generated compared to actual energy falling on solar panels.
- Current technology requires large amounts of land to house infrastructure.
- It is difficult to extend the use of renewables on a large scale unless significant government policies are implemented, for example reducing carbon-emitting energy sources on the environment and subsidies.
- Renewable energy is not expected to compete economically with fossil fuels in the mid-term forecasts.[197]

4.164 Nova Energy argued that the limitations of wind power are clearly demonstrated by the German experience, which now has over 17 000 wind turbines with capacity exceeding 14 350 MW—the largest installed wind capacity in the world. In 2003, the turbines were said to provide just four percent of Germany's demand for electricity. The operator of Germany's transmission grid, E.ON Netz GmbH, has pointed out that periods of maximum demand often coincide with periods of minimum wind power (for example, summer heatwaves). E.ON estimates that 80 per cent back-up power (nuclear or carbon-based) is required to meet demand at all times. Thus, wind power reduces fossil fuel consumption but does not remove the need for conventional baseload power sources.[198]

4.165 Similarly, Deep Yellow submitted that:

> Evidence to date is that wind, wave and solar power cannot provide the scale of electricity required without a backup facility powered by reliable fossil fuels. Geothermal energy is not yet proven on large scales.[199]

4.166 Mr Keith Alder also welcomed the contribution being made by renewables but argued that their limitations needed to be better understood:

> There is a lot of urging that the use of [renewables] be increased—looking for subsidies, of course—from the present one or two per cent up to about 20 per cent … That figure of 20 per cent is one of the limits, I believe. I do not think you can put more than about 20 per cent of renewable energy such as solar and wind into a major electricity grid, for the simple reason that it is unreliable … If the wind does not blow … your wind generator drops out and, if the sun does not shine—and it certainly does not shine at night—you lose your solar energy. There is a natural limit to what the grid can stand. If it drops out and you do not want blackouts, then something else has to pick up the load. No electricity generating authority in the world which believes it can supply reliable energy will tolerate more than about 20 or maybe 30 per cent, at the most, of its input in one piece of machinery. This is why there is a natural limit on the renewables ...[200]

4.167 Mr Alder argued that the key question is:

> … where we get the other 80 per cent. That is where uranium comes into the picture. As far as I can see, there are only two possible ways to generate that 80 per cent, or the baseload—which is more than half and, more likely, 70 per cent—of that 80 per cent. The two alternatives are coal and nuclear; there is nothing else. It is an absolutely inescapable fact that you have to burn coal or use nuclear reactors to generate baseload electricity. You can use oil or gas, but they are both very desirable resources to be retained for other purposes.[201]

4.168 Although opposed to use of nuclear power, AMP CISFT conceded that that renewables cannot meet baseload power requirements, either in Australia or internationally.[202]

4.169 CSIRO submitted that while considerable research is going into energy storage devices for renewables, aside from geothermal there are no renewable sources of energy that provide inherent baseload power.[203] In surveying the range of future renewable electricity generation options, including photovoltaics, Dr Rod Hill observed that:

> There is certainly a significant research effort in these longer term technologies, but the reality of it is that we need to make the existing dependence on coal more efficient and we need to make sure that people feel comfortable about nuclear, because they are the short-term options.[204]

4.170 The MAPW (WA Branch), who promoted use of renewables such as wind and solar, also conceded that energy storage is a problem for wider deployment of renewables.[205] The ANA also argued that intermittent renewable sources—solar, wind and wave—will not be able to make a major contribution until electricity storage systems are developed to produce a 'smooth, efficient source at reasonable cost. That is the key to renewables.'[206] In the meantime, the ANA expressed support for the Australian Government's efforts to develop clean coal technologies.

4.171 Dr Gavin Mudd observed that geothermal has potential as a future renewable baseload energy source, but being remote from population centres means that significant energy losses can be expected in transmission.[207]

4.172 In summary, Nova Energy argued that:

> … to develop systems in which the majority of energy is sourced from

> renewables, provision must be made for large fluctuations in energy production and for the need to store large quantities of energy. These problems make a significant difference to the viability of renewables due to the impact on efficiencies and costs.[208]

4.173 Nova Energy also argued that even if renewables could supply baseload power needs, the capital investment that would be required would be 'absolutely enormous'.[209] The UIC also noted that to conform with current German policy, another 30 000 MWe of renewable capacity will need to be added by 2020, which will cost some €80 billion.[210]

4.174 Heathgate Resources pointed to the impracticality of providing baseload power via renewables by comparing the fuel requirements to generate 1 000 MW, the typical size of a single nuclear reactor, which would require 150 tonnes of natural uranium per year. Given the low energy densities of renewables, to generate this amount of electricity would require 60 to 150 square kilometres of solar panels (in France), 150 to 450 square kilometres of wind mills in a favourable area, 6.2 Mt of garbage, or 4 000 to 6 000 square kilometres of biomass plantations. The fuel requirements for an equivalent capacity fossil fuel plant, discussed above, are 2.3 Mt of coal, 1.9 Mt of oil or 1.4 billion cubic metres of natural gas.[211]

4.175 Concern about the potential of renewables is shared by Dr Mohamed ElBaradei, Director General of the IAEA, who has stated that while nuclear and renewable sources could both have larger roles to play in meeting rising energy demands over coming decades:

> The problem is that no 'renewable' source has been demonstrated to have the capacity to provide the 'baseload' amounts of power needed to replace large fossil fuel plants. Wind power, for example, may be an excellent choice for sparsely populated rural economies, particularly if they lack modern electrical infrastructure; on the other hand, it seems unlikely that wind power will be able to support the electricity needs of tomorrow´s mega-cities.[212]

4.176 Compass Resources argued that as oil production eventually declines, 'the only realistic alternative to meet the increased energy demand is coal or nuclear.'[213] However, it was suggested that despite geosequestration and other improvements, coal is likely to increase greenhouse emissions as demand grows. SIA also argued that geosequestration is 'perhaps 10 years off' and that 'the technical and economic viability have yet to be demonstrated.'[214]

4.177 In addition to comparing the life cycle emissions of electricity generation chains, assessing the contribution that nuclear power can make to GHG abatement necessarily involves an analysis of the costs of generating nuclear power. Although the Committee did not request evidence on this matter, information was provided by some submitters and the Committee presents an overview of this evidence in the section which follows.

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The economics of nuclear power

4.178 A central consideration in assessing nuclear power's viability as a GHG emission mitigation option relates to the economic attractiveness of nuclear generation of electricity relative to other baseload alternatives.

4.179 The OECD Nuclear Energy Agency (OECD-NEA) states that the economics of nuclear power are characterised by high capital investment costs; low fuel, operating and maintenance costs; insensitivity to variations in fuel prices; and long operational life but significant regulatory costs.[215]

4.180 The costs of producing nuclear electricity are typically broken down into three major categories:

- capital investment costs, including plant construction, major refurbishment and decommissioning;

- operation and maintenance (O&M) costs, including staff costs, training, security, health and safety, and cost of managing low and intermediate level operational waste; and
- fuel cycle costs, including the cost of the uranium, its conversion and enrichment, fuel fabrication, used fuel disposal and reprocessing.[216]

4.181 Capital costs account for approximately 60 per cent or more of the total costs of nuclear electricity production, with O&M and fuel cycle costs accounting for some 20 per cent each of the total cost.[217]

4.182 Compared to nuclear power, coal-fired plants are said to be characterised by mid-range capital and fuel costs, while natural gas-fired plants are characterised by low capital investment costs but significant fuel costs. Renewable sources of energy, such as wind and hydropower, are similar to nuclear in having high capital and low generating costs per unit of power produced.[218]

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Studies of the comparative costs of generating electricity

4.183 There have been several respected studies of the economics of nuclear power published in recent years, including the following:

- IEA and OECD-NEA (2005), *Projected Costs of Generating Electricity*[219]
- University of Chicago (2004), *The Economic Future of Nuclear Power*[220]
- Royal Academy of Engineering (2004), *The Cost of Generating Electricity*[221]
- Canadian Energy Research Institute (CERI) (2004), *Levelised Unit Electricity Cost Comparisons of Alternative Technologies for Baseload Generation in Ontario*[222]
- General Directorate for Energy and Raw Materials (DGEMP) of the French Ministry of the Economy, Finance and Industry (2003), *Reference Costs for Power Generation*[223]
- Massachusetts Institute of Technology (MIT) (2003), *The Future of Nuclear Power*[224]

4.184 While these studies come to differing conclusions about the costs of generating nuclear power, in the main they reveal that nuclear power is economically competitive with other baseload alternatives in many countries. This accords with the argument advanced by the MCA, Areva, UIC and others that: 'In many industrialised countries, nuclear energy is cost competitive with coal-fired electricity and gas–fired generation'.[225] The Committee makes observations about the possible economic competitiveness of nuclear power in the Australian context in chapter 12.

4.185 The most recent study, published by the IEA and OECD-NEA, estimated the costs of generating electricity by baseload power plants that are expected to be commercially available by 2015 or earlier. Ten countries submitted data on nuclear plants which were compared with coal and gas generation in the same countries. Some data was also collected on renewable energy generation options.

4.186 The principal findings, which include the average plant construction costs, average construction times and levelised electricity generation costs for the electricity generation options employed in the survey countries are listed in table 4.6. The levelised generation cost figures incorporate capital, O&M and fuel costs relevant to each technology. The levelised cost is the price needed to cover both the operating (fuel and O&M) and annualised capital costs of a plant. The calculations do not include costs of transmission and distribution, or costs associated with residual emissions including greenhouse gases from coal and gas-fired plants.

Table 4.6 Construction costs, construction time and levelised costs of electricity generation

Generating technologies	**Construction costs** (per plant, US$/kWe)	**Construction time** (years)	**Levelised generation costs** (US$/MWh @ 5% discount rate)	**Levelised generation costs** (US$/MWh @ 10% discount rate)
Coal-fired	1 000 – 1 500	4	25 – 50	35 – 60
Gas-fired	400 – 800	2 – 3	37 – 60	40 – 63
Nuclear	1 000 – 2 000	5	21 – 31	30 – 50
Wind (onshore)	1 000 – 2 000	1 – 2	35 – 95	45 – >140*
Solar	2 775 – 10 164	1	~150	>200
Hydro	1 500 – 7 000	3	40 – 80	65 – 100

Source IEA and OECD-NEA, *Projected Costs of Generating Electricity: 2005 Update*
* Does not include specific costs associated with wind or other intermittent renewable energy source for power generation, such as the need for backup power to compensate for the low average availability factor

4.187 The study found that despite relatively high capital costs, nuclear power is competitive with fossil fuels for electricity generation in many countries. Construction costs for nuclear power plants range from US$1 000 per kW in the Czech Republic to $2 500 per kW in Japan. Coal-fired plants range from $1 000 to $1 500 per kW and gas-fired plants are significantly less costly at between $400 and $800 per kW.[226]

4.188 At the five per cent discount rate, nuclear power is revealed to be generally the lowest cost option with costs ranging from US$21 to $31 per MWh. Nuclear is cheaper than coal in seven of the ten countries and cheaper than gas in nine. The lowest costs for nuclear production were recorded in Korea, the Czech Republic, Canada and France and the highest in Japan. At the 10 per cent discount rate, the levelised costs for nuclear range from $30 to $50 per MWh. Despite this, nuclear is cheaper than coal in five of the ten countries and cheaper than gas in eight.[227]

4.189 DEH expressed some reservations about the cost estimates, cautioning that the study fails to specify the level of finance allocated to decommissioning (although the estimates do explicitly incorporate decommissioning costs). The study was also criticised for not including complete insurance risk and the cost of permanent waste storage, which it was argued 'may raise the levelised cost considerably'.[228]

4.190 The IEA and OECD-NEA make clear that although the cost estimates do not substitute for detailed economic evaluations required by investors and utilities at the stage of project decision and do not take business risks in competitive markets adequately into account, nonetheless they 'provide a robust, transparent and coherent set of cost estimates … and may be used to assess alternative options at the stage of screening studies.'[229]

4.191 The IEA and OECD-NEA concluded that the generating technology preferred in each country will depend on the specific circumstances of each project. Further, the ranking of technologies in each country is sensitive to the discount rate employed and the projected prices of natural gas and coal.[230]

4.192 DEH also argued that the cost of electricity from nuclear compared to coal will vary according to 'the generation plant's proximity to its fuels source, the quality of fuel and the age of competing infrastructure.'[231]

4.193 The UIC and the MCA observed that the comparative costs of nuclear and coal depends on the locality of the proposed plant. If a power station is far removed from sources of coal and global transport is required then nuclear becomes more attractive.[232] Similarly, AMEC observed that nuclear is competitive with other forms of electricity generation, except where local access to low cost fossil fuels exist.[233]

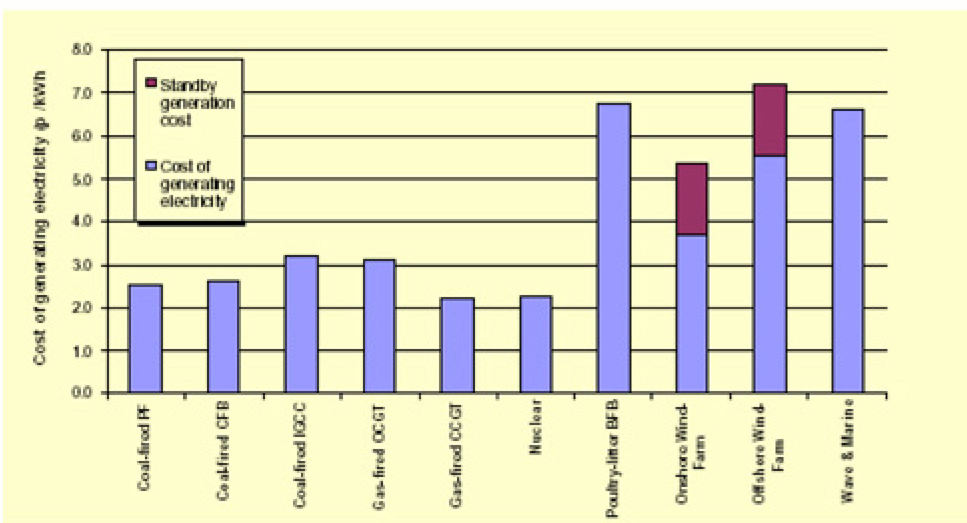
4.194 The study by the Royal Academy of Engineering (2004), *The Costs of Generating Electricity*, compared the present day costs of generating electricity in the UK from available technologies, including coal, oil, gas, nuclear, wind and biomass. The study considered what was regarded as best estimates of what it costs to build, maintain and operate various power stations. That is, the study incorporated the costs of construction, O&M and fuel for each plant. It also included an estimate of decommissioning costs for nuclear plants, but assumed that decommissioning costs for other plants are neutral. The study's findings are depicted in figure 4.3.

4.195 The study concluded that for baseload operation, generating costs are 2.2 pence per kWh for combined-cycle gas turbine (CCGT) plants, 2.3 pence per kWh for nuclear plants and between 2.5 and 3.2 pence per kWh for coal plants.[234]

4.196 Renewable energy sources, which offer intermittent power, were found to be markedly more expensive, with onshore wind generation costing 3.7 pence per kWh and offshore wind costing 5.5 pence per kWh. However, when the additional cost of standby generation was added, the costs became 5.4 and 7.2 pence per kWh respectively.[235] The effect of including standby generation costs is also depicted in figure 4.3.

4.197 The Academy's study also examined the sensitivity of electricity generation costs to variations in fuel prices and emission costs. As the cost of carbon emissions increases, nuclear and renewables become more competitive and the gap between CCGT plants and coal-fired technologies widens (because of the greater level of carbon found in coal compared with natural gas and the lower efficiency of steam plant). It was found that if fuel prices rise by 20 per cent or carbon taxes are introduced, nuclear becomes the cheapest option to deploy.[236]

Figure 4.3 Cost of generating electricity (pence per kWh) in the UK



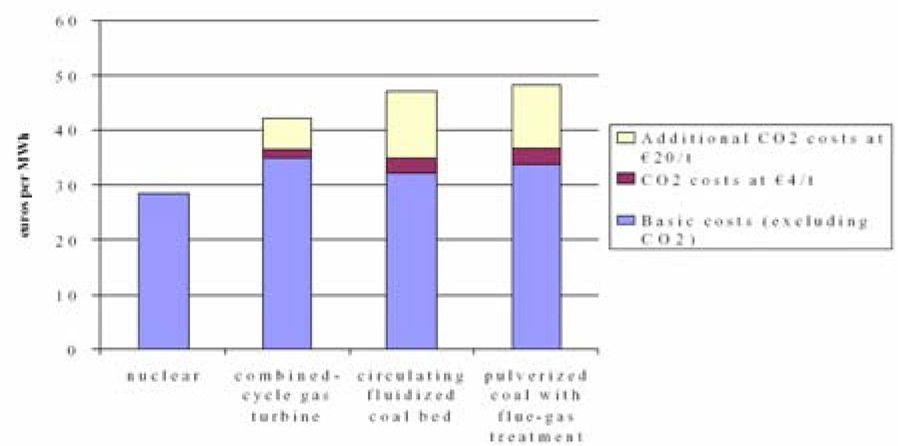
Source The Royal Academy of Engineering , *The Costs of Generating Electricity* , p. 4.

4.198 The University of Chicago (2004) study, *The Economic Future of Nuclear Power*, which was sponsored by the US DOE, found that new nuclear plants coming online in the next decade will initially have a levelised cost of electricity of US$47 to $71 per MWh. In comparison, coal plants will be in the range of $33 to $41 per MWh and gas-fired plants will be in the range of $35 to $45 per MWh. However, it was found that once early costs are absorbed, levelised costs for nuclear plants will fall to the range of $31 to $46 per MWh.[237] Thus, the DOE concluded that 'the future cost associated with nuclear power production is comparable with gas and coal-based energy generation', and that 'nuclear power can be a competitive source of energy production in the future and will help meet our environmental goals.'[238]

4.199 The CERI (2004) study, *Levelised Unit Electricity Cost Comparisons of Alternative Technologies for Baseload Generation in Ontario,* found that in the majority of scenarios considered, coal-fired generation is the most attractive option. However, if CO_2 emission costs of C$15 per tonne are included, deployment of 'first of a kind' nuclear technology (the twin ACR-700 reactor) becomes either the least-cost generating option or competitive with coal-fired generation depending on financing assumptions. For later deployments of the technology, cost savings are expected to reduce the levelised cost so that nuclear is competitive with coal even in the absence of CO_2 emission costs. Given forecast increases in the price of natural gas, gas-fired generation for baseload supply was found to be uncompetitive in most scenarios considered.[239]

4.200 The DGEMP study (2003), *Reference Costs for Power Generation*, found that using an eight per cent discount rate, nuclear power will be the cheapest option at 2.84 euro cents per kWh, followed by coal plants at 3.37 euro cents per kWh and the CCGT at 3.50 euro cents per kWh. At higher discount rates, nuclear's advantage is reduced. Nuclear power's competitiveness improves even further if CO_2 emission costs are included. Figure 4.4 illustrates the main conclusions of the study, showing the basic costs of the technologies estimated for 2015 and the effect of additional CO_2 costs.[240]

Figure 4.4 Costs (including tax) of baseload alternatives in France in 2015, based on an 8 per cent discount rate and showing CO_2 costs



Source DGEMP, *Reference Costs for Power Generation* , p. 1.

4.201 In contrast to the generally positive assessments of nuclear power's economic competitiveness in the studies summarised above, the MIT study (2003), *The Future of Nuclear Power,* found nuclear power to be an unattractive option. The study, which used construction and financing cost assumptions the industry considers demanding for nuclear, found the levelised cost for nuclear power to be US6.7 cents per kWh, compared to 3.8 to 5.1 cents per kWh for gas and 4.2 cents per KWh for coal.[241]

4.202 Even with the imposition of a cost for CO_2 emissions of US$50 per tonne of carbon (tC), nuclear power was still found to be uncompetitive against gas and coal in a base case scenario. With carbon taxes in the range of $100/tC to $200/tC, nuclear power would be an economic baseload option.[242]

4.203 DEH stated that, as with the IEA and OECD-NEA study, it was unclear whether MIT accounts for the costs of decommissioning, insurance risk and permanent waste disposal. Again, these factors could raise the levelised cost considerably.[243]

4.204 Notwithstanding its conclusion that nuclear 'is just too expensive', particularly in regions where electricity suppliers have access to natural gas or coal, the MIT study concluded that:

> If in the future carbon dioxide emissions carry a significant 'price' … nuclear power could be an important—indeed vital—option for generating electricity … *we believe the nuclear option should be retained, precisely because it is an important carbon-free source that can potentially make a significant contribution to future electricity supply*.[244]

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Reducing capital costs

4.205 In relation to the high capital costs for nuclear plants, ANSTO observed that efforts are now being made, for example through the 'Nuclear Power 2010' initiative in the US, to reduce capital costs, including by establishing more efficient licensing and approvals processes.[245]

4.206 Technological developments in reactor designs are also promising to reduce construction costs and construction times. For instance, ANSTO noted that 'pebble bed' reactors, which are fourth generation designs, are intended to be modular; that is, of various sizes from, say, 180 MW upwards. The costs for these reactors, which are thought to be appropriate for desalination and to supply power in remote communities, will be a fraction of the cost of a large 1 000 MW reactor, roughly proportional to the amount of power they produce. Thus, a 100 MW reactor would cost in the order of $250 million to construct.[246]

4.207 According to information published by academics from the School of Physics at the University of Melbourne, Westinghouse claims that its advanced reactor, the AP1000, will cost US$1 400 per KWh for the first reactor and fall to $1 000 for subsequent reactors. It is also claimed that the AP1000 would take only three years to construct. For the Melbourne University group:

> If the AP1000 lives up to its promise of $1000 per KW c onstruction cost and 3 year construction time, it will provide cheaper electricity than any other Fossil Fuel based generating facility, including Australian Coal power, even with no sequestration charges.[247]

4.208 In addition to new and simpler reactor designs and more predictable licensing processes, the WNA has suggested that other areas of potential capital cost reductions include: replicating several reactors of one design on one site, which can bring major unit cost reductions; standardisation of reactors and construction in series; and larger unit capacities which provide substantial economies of scale.[248]

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Low operating costs

4.209 ANSTO and the AMP CISFT argued that one of nuclear power's clear advantages is low operating (i.e. fuel and O&M) costs. For example, in the US operating costs for nuclear plants continue to decline and in 2004 were US1.72 c per kWh, slightly lower than coal at 1.8c per kWh and substantially lower than oil at 5.53c per kWh and gas at 5.77c per kWh. The operating costs for oil and gas were said to have increased substantially in recent times.[249]

4.210 Cameco also observed that 'from a cost perspective, nuclear power has been the lowest cost generator of electricity in the United States for four years running, marginally under coal, with one exception—that is, hydro-generated electricity'.[250]

4.211 Table 4.7 lists the comparative operating costs for nuclear, coal and gas generation for a range of countries projected for 2010 onwards, produced by the IEA and OECD-NEA. The data forecasts that costs of nuclear power will be below those for coal and gas in all countries, except the US and Korea where the cost of nuclear will exceed that of coal by a small margin. Costs for coal and gas generation in Australia have been included for an indicative rather than direct comparison. ANSTO observed that operating costs vary depending on whether a country has indigenous supplies of the particular fuel, the cost of importation and the cost of a country's regulatory systems.

4.212 A key factor in nuclear power's improved competitiveness has been a steady increase in nuclear plant availability and productivity. In particular, nuclear generating capacity has improved markedly in recent years. In 1990, nuclear plants on average were generating electricity 71 per cent of the time, but by 2005 reactor capacity reached a record average of 91.5 per cent in the US.[251] According to the IAEA, the global increase in generating capacity over the past 15 years represents 'an improvement in productivity equal to adding more than 25 new 1 000 megawatt nuclear plants—all at relatively minimal cost.'[252]

Table 4.7 Comparative electricity production cost projections for 2010 onwards (US 2003 cents per kWh)

Country	Nuclear	Coal	Gas
Finland	2.76	3.64	—
France	2.54	3.33	3.92
Germany	2.86	3.52	4.90
Switzerland	2.88	—	4.36
Netherlands	3.58	—	6.04
Czech Republic	2.30	2.94	4.97
Slovakia	3.13	4.78	5.59
Romania	3.06	4.55	—
Japan	4.80	4.95	5.21
Korea	2.34	2.16	4.65
USA	3.01	2.71	4.67
Canada	2.60	3.11	4.00
Australia*	—	3.00 – 3.50 (black coal) 3.60 – 4.00 (brown coal)	3.50 – 4.50

Source ANSTO, *Exhibit no. 74, Presentation by Dr Ron Cameron and Dr Ian Smith* , slide 12; ANSTO, *Submission no. 29.1* , p. 3.
US 2003 cents/kWh, Discount rate 5%, 40 year lifetime, 85% load factor
* Australian cents per kWh in 2010.

4.213 Additional generating capacity has also been obtained through up-rating the power output of nuclear reactors, by up to 15–20 per cent in some cases. This has been a particular focus in the US, Sweden and Eastern European countries. Owners of nuclear plants are also seeking to obtain permission from regulatory authorities to extend the operational life of their plants, thereby generating additional output per plant. In the US, 30 nuclear plants have already been granted 20-year life extensions.[253]

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Electricity price stability

4.214 In general, fuel costs represent a relatively large proportion of fossil fuel-based generating costs that are, as a result, sensitive to fuel price variations. Areva submitted that this is one of nuclear power's main advantages over other baseload alternatives: nuclear power has low fuel costs as a proportion of the overall cost of the electricity production, which means that the price of nuclear electricity is insensitive to fuel price rises and therefore relatively stable:

> … unlike its fossil fuel competitors, nuclear power is relatively immune to changes in fuel prices, which represent approximately 15% of its production cost. Based on current prices, natural uranium itself represents approximately 5% of the cost of nuclear electricity.[254]

4.215 Drawing on a Finnish study published in 2004, Areva argued that:

> … a 50% increase in the cost of natural uranium would raise the cost of nuclear generated electricity from €23.70 to €24.30. A 50% increase in the cost of natural gas or coal would raise the cost of electricity produced with these sources of energy from €31.20 to €42.40 for natural gas and from €32.90 to €41.85 for coal.[255]

4.216 Similarly, the AMP CISFT argued that:

> … doubling the price of uranium would increase the cost of [nuclear] power plant electricity by 20%. Doubling the price of coal would increase coal power plant electricity by 58%. The figure is 90% for gas power plants.[256]

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External costs — carbon dioxide emissions, waste management and decommissioning

4.217 The UIC explained that external costs are those which are actually incurred in relation to the health and the environment but not paid directly by the electricity producer or consumer.[257] For fossil fuel plants these externalities include the unpriced costs of carbon dioxide emissions into the atmosphere.

4.218 It was argued that, unlike nuclear power, the environmental costs of fossil fuel power generation are not factored into the cost of the electricity produced.[258] Thus, if the external costs of carbon emissions into the atmosphere were internalised in fossil-fuel electricity generation through the imposition of a carbon tax, the economic competitiveness of nuclear power could improve significantly.[259]

4.219 Several of the studies cited above noted that the introduction of a cost of carbon emissions (e.g. carbon taxes) would raise the levelised cost of fossil fuel electricity generation and thereby enhance the competitiveness of nuclear power, rendering nuclear the lowest cost option in many cases.

4.220 The UIC argued that international pressure will continue for limits to be imposed on carbon emissions and for costs of carbon to be internalised:

> Inevitably, international pressure will continue for limits to be imposed. In the context of the Kyoto Protocol, a carbon cost of at least one US cent per kWh needs to be factored for coal generation, and at least half that for gas (on the basis of various proposals and European Union Emissions Trading Scheme transactions). This would effectively increase costs by 20 to 30%. By comparison, nuclear energy has zero cost for carbon emissions.[260]

4.221 ANSTO noted that studies of the effects of carbon emissions trading on electricity generating costs in Finland have rendered nuclear power far more competitive than gas and coal, with the costs of nuclear approximately €20 per MW compared to more than €40 per MW for coal. This calculation was said to be significant in Finland's decision to proceed with a nuclear power program.[261]

4.222 The UIC also cited a major study of the other external costs of various fuel cycles published by the European Commission in 2001. The study found that if other external costs were included, the price of electricity from coal would double and the price of electricity from gas would increase by 30 per cent.[262]

4.223 AMP CISFT argued that without imposing a substantial cost of carbon, nuclear power will remain uneconomic.[263] However, from the industry's perspective, the UIC and WNA argued that nuclear power is already economically competitive in many countries, even without factoring in a cost of carbon or considering nuclear's advantages of price stability and security of supply:

> In most industrialised countries today, new nuclear power plants offer the most economical way to generate base-load electricity—even without consideration of the geopolitical and environmental advantages that nuclear energy confers.[264]

4.224 The UIC argued that the cost of waste management (including eventual disposal) and decommissioning old reactors are internalised in power prices charged by nuclear utilities during the operational life of each plant. The back-end of the nuclear fuel cycle, including used fuel storage or disposal in a repository, contributes some 10 per cent of the overall cost of the electricity generated. Decommissioning plants is said to cost approximately 5 per cent of the total generating cost.[265]

4.225 As discussed further in the following chapter, the costs of nuclear waste disposal and decommissioning are funded by a levy on nuclear utilities which is set at 0.1 to 0.2 cents per kWh in the US and at similar levels in European countries. To date, more than US$28 billion has been committed to the US Nuclear Waste Fund by nuclear utilities.[266]

4.226 In contrast, the AMP CISFT argued that the operating costs of nuclear power plants do not include the costs for 'acceptable' waste disposal of the low and high level wastes produced. AMP CISFT claimed that the impact of waste disposal costs on the economics of nuclear power is illustrated in the UK where, it is asserted, British Energy (BE) is in financial difficulty due to the need to pay £300 million per year to British Nuclear Fuels (BNFL) for fuel reprocessing. Furthermore, it was argued that BE is unable to pay for plant decommissioning by internal sources, which is estimated to cost some £14 billion over future years. Similarly, AMP CISFT argued that the US Government is paying US$58 billion to develop the Yucca Mountain nuclear waste storage facility, but that 'it will take … 50 years before the nuclear power industry will collect enough to pay for the Yucca Mountain site.'[267]

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Opportunity costs

4.227 Submitters that were critical of nuclear power cited studies which claimed that 'alternative energy sources [are] three to four times less costly as a means of reducing carbon dioxide than nuclear power.'[268] These submitters asserted that investment in nuclear power would reduce the amount of investment available for renewables and efficiency measures, and therefore worsen climate change because of the alleged opportunity cost this would involve.[269] For example, People for Nuclear Disarmament NSW argued that:

> In theory, nuclear expansion could proceed in tandem with concerted efforts in the areas of energy efficiency and renewable energy sources. In practice, nuclear expansion would most likely divert social and economic resources away from efficiency and renewables.[270]

4.228 Research cited by Dr Helen Caldicott emphasised that use of nuclear power to address climate change would involve opportunity costs, asserting that nuclear power is the most costly option for prevention of climate change. It was argued that nuclear power has a higher cost per unit of CO_2 abated than its 'decentralised rivals', which 'means that every dollar invested in nuclear expansion will *worsen* climate change by buying less solution per dollar.'[271] That is, investment in nuclear power involves significant opportunity costs:

> Specifically, every $0.10 spent to buy a single new nuclear kilowatt-hour … could instead have bought 1.2 to 1.7 kWh of windpower … 0.9 to 1.7+ kWh of gas-fired industrial or ~2.2–6.5+ kWh of building-scale cogeneration …, an infinite number of kWh from waste-heat cogeneration …, or at least several, perhaps upwards of ten, kWh of electrical savings from more efficient use. In this sense of 'opportunity cost'—any investment foregoes other outcomes that could have been bought with the same money—nuclear power is far *more* carbon-intensive than a coal plant.[272]

4.229 AMP CISFT also argued that to address greenhouse gas emissions, on an opportunity cost basis, funds should be invested in alternative energy industries rather than nuclear power.[273]

4.230 In contrast, the studies cited above concluded that renewables, particularly wind, have consistently higher generation costs than nuclear plants. These costs are even higher if the necessity for standby generation is included (because of the intermittent nature of renewable electricity). The UIC stated that:

> Wind power, the main no-carbon alternative to nuclear, typically costs significantly more per kWh generated with its unpredictable availability requiring additional investment in back-up capacity.[274]

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Subsidies

4.231 Critics of nuclear power argued that the industry is heavily subsidised. For example, the MAPW (Victorian Branch) argued that:

> Nuclear power is one of the most protected and heavily-subsidised industries in the world, and many cost estimates from proponents fail to take these into account. In the mid-1990s, governments worldwide were subsidizing fossil fuels and nuclear power to the tune of US$250-300 billion per annum. While several transitional and developing country governments have since reduced energy subsidies substantially, global subsidies for conventional (fossil fuel and nuclear) energy remain many magnitudes higher than those for benign alternatives such as efficiency and renewables.[275]

4.232 Similarly, the AMP CISFT argued that the nuclear power industry is subsidised by government for its negative externalities, discussed above, of waste disposal and decommissioning. An example cited was the British Government's payments to BE, via an emergency loan, for waste disposal costs in the order of £184 million a year:

> If you do the calculation, you find that is equivalent to a subsidy of about £2.50 per megawatt hour produced, or about $A5. The industry—BNFL—in its publication say that the cost of waste disposal is only £0.80, so already there is an inconsistency between what is required for the government to subsidise waste disposal as opposed to what a proponent of the industry says is required.[276]

4.233 Research cited by Dr Helen Caldicott asserts that the US*Energy Policy Act 2005* is 'festooned with lavish subsidies and regulatory short cuts for favoured technologies that can't compete unaided.'[277] It is argued that the Act contains some US$13 billion in subsidies to support nuclear expansion, including loan guarantees, research and development support, licensing-cost subsidies, public insurance against regulatory delays, an increase in operating subsidies, tax breaks for decommissioning funds and a cap on liability payments in case of accidents.[278]

4.234 The ECNT alleged that during the first 15 years of development in the US, the nuclear power industry received subsidies amounting to $15.30 per kWh, while the wind industry received 46c per kWh in its first 15 years of operation. It was argued that 'these huge imbalances towards dangerous, polluting and greenhouse intensive fuels need to be urgently addressed.'[279]

4.235 However, the WNA has flatly rejected that the nuclear power industry requires subsidies to be viable:

> Nuclear power does not, as critics often allege, depend on subsidies to be economically sustainable. Fossil fuels benefit from direct subsidies in some countries (like coal in Germany) or from hidden subsidies in the form of pollution and other external costs not taken into account.[280]

4.236 As noted above, some submitters, including the ECNT and Uniting Church in Australia (Victoria and Tasmanian Synod) urged the Australian Government to significantly increase the provision of subsidies for research, development and implementation of renewables. However, the ANA and other submitters observed that renewables currently require large subsidies in order to increase adoption.[281] The AMP CISFT conceded that without subsidies, investments in renewables would not be attractive.[282]

4.237 The UIC noted that renewable capacity in Germany has risen to 17 GWe due to generous subsidies, with the actual cost of wind generation 7–9 Euro cents per kWh (double the cost of nuclear and coal) and requires a 6.2c per kWh average subsidy through a feed-in tariff.[283]

4.238 The UIC observed that if subsidies and other government incentives are provided to renewables in order to achieve lower carbon emissions, then these incentives:

> … should be applied to anything which achieves low carbon emissions and not … discriminating against nuclear power. In other words, if subsidies are available for wind in Australia, on the basis of carbon reduction, they should be equally available to nuclear.[284]

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Conclusions

Greenhouse gas mitigation

4.239 The Committee concludes that nuclear power unquestionably makes a significant contribution to the mitigation of GHG emissions—nuclear power plants currently save some 10 per cent of total CO_2 emissions from world energy use. This represents an immense saving of GHG emissions that would otherwise be contributing to global warming. If the world were not using nuclear power plants, emissions of CO_2 would be some 2.5 billion tonnes higher per year.

4.240 Australia's uranium exports displace some 395 million tonnes of CO_2 each year, relative to black coal generation, and this represents some 70 per cent of Australia's total GHG emissions for 2003. Evidence suggests that the cumulative carbon savings from nuclear power over the three decades to 2030 will exceed 25 billion tonnes.

4.241 In addition to its GHG mitigation benefits, nuclear power also offsets the vast emissions of sulphur dioxide, nitrous oxide and particulates which are produced by fossil fuelled plants.

4.242 The Committee notes the support shown for nuclear power by several foundational figures of the environment movement. These individuals now perceive that the risks of expanded use of nuclear power are insignificant in comparison to the threat posed by the enhanced greenhouse effect and global warming. The Committee notes calls by some in industry that, in view of the energy demands from heavily populated developing nations, Australia in fact has a moral responsibility to contribute to reducing global GHG emissions through the increased production and supply of uranium.

4.243 It was claimed that nuclear power will not solve climate change because it only reduces emissions from the electricity sector, which is only one source of anthropogenic GHG emissions. The Committee notes, however, that no representative of the uranium industry ever claimed that nuclear power alone could 'solve' climate change. In fact, it was repeatedly stated that nuclear power is one, albeit significant, part of the solution to global warming.

4.244 Although nuclear power has the potential to reduce emissions in the transport sector through the production of hydrogen, nuclear's greenhouse mitigation contribution is currently limited to the electricity sector. However, electricity generation, which is already the largest contributor of CO_2 emissions at 40 per cent of the global total, is also the fastest growing. It is imperative that emissions from this sector be reduced.

4.245 The Committee finds that over its whole fuel cycle nuclear power emits very small quantities of CO_2—orders of magnitude less than fossil fuels and quantities similar to, or less than, renewable such as wind.

4.246 Evidence suggests that renewables and energy efficiency measures alone have no prospect of meeting rapidly growing demands for energy and abating greenhouse emissions to the degree required. The weight of evidence points to the need for a mix of low-emission energy sources and technologies, in which nuclear power will continue to play a significant part.

4.247 In the context of rapidly growing energy demand, particularly from developing nations, nuclear power represents the only means of limiting increased emissions while meeting the world's voracious appetite for energy. While the Committee recognises that there is a role for renewables and certainly for greater use of efficiency measures, renewables are limited in their application by being intermittent, diffuse and pose significant energy storage problems. Renewables also require substantial backup generation, which needs to be provided by conventional baseload power sources. Promised baseload contributions from geothermal, which will be welcome, are yet to be developed on any scale.

4.248 The Committee believes that the nuclear versus renewables dichotomy, which is explicit in some submissions, is a false debate and misses the point: while renewables have a contribution to make, other than hydro and (potentially) geothermal, they are simply not capable of providing baseload power on a large scale. The relevant comparison, if one needs to be made, is between baseload alternatives. On this issue the evidence is clear—nuclear power is the only proven technology for baseload power supply which does not release substantial amounts of CO_2.

4.249 The Committee also recognises that given its comparative advantage in fossil fuels and the world's projected continued reliance on fossil fuels, Australia has a strong economic interest in supporting technologies that reduce the greenhouse intensity of these fuels. The Committee agrees that nuclear power should not be seen as competing with or substituting for clean coal technologies, and indeed renewables such as photovoltaics in which Australia has expertise.

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Economics

4.250 A vital consideration in assessing nuclear power's viability as a GHG emission mitigation option relates to the economic competitiveness of nuclear power relative to other baseload alternatives. Evidence suggests that nuclear power plants have higher capital/construction costs than either coal or gas plants, which are characterised by mid-range and low capital costs respectively. However, nuclear plants have low fuel, operating and maintenance costs relative to the fossil fuel alternatives.

4.251 A range of recent studies have concluded that, in many industrialised countries, nuclear power is competitive with gas and coal-fired electricity generation, even without incorporating an additional cost for the carbon emissions from the fossil fuelled plants. Factors that influence the suitability of deploying nuclear plants in a particular situation include the projected prices of natural gas and coal, the discount rate employed, proximity and access to fuel sources such as low cost fossil fuels, and the quality of fuel sources.

4.252 Although nuclear plants generally have higher capital costs, the Committee notes there are developments which promise to reduce the construction costs and construction times for new plants, including possible regulatory reforms in the US and new plant designs. It seems clear that replicating several reactors of one design, or standardising reactors, reduces levelised generating costs considerably.

4.253 Although again the Committee does not wish to enter into a nuclear versus renewables debate, evidence suggests that renewables, particularly wind, have consistently higher generating costs than nuclear plants. These costs are even higher if the necessity for standby generation is included.

4.254 The Committee concludes that, in addition to security of energy supply and near-zero GHG emissions, nuclear power offers at least three economic advantages relative to other baseload energy sources:

- price stability, because the price of nuclear generated electricity is largely insensitive to variations in fuel prices;
- very low operating costs—consistently lower even than coal in the US; and
- internalisation of costs that are not incorporated in the cost of other sources of electricity, notably waste management.

4.255 Although the Committee is not in a position to assess the veracity of claims about subsidies received by the industry, claims by some submitters that the cost of decommissioning and waste disposal are not included in economic assessments of nuclear power or the price of its electricity are entirely mistaken. Unlike its fossil fuel alternatives, nuclear utilities are required to set aside funds to cover decommissioning and final waste disposal. While the adequacy of the funds set aside may be queried, there can be no question that these costs are internalised in the price of the electricity generated.

4.256 The Committee notes that if fossil fuel plants were required to internalise the environmental costs of their emissions (for example, if a cost of carbon were imposed), this would undoubtedly effect the cost of the electricity generated and could significantly improve the economic competitiveness of nuclear power, even in countries with plentiful supplies of low cost fossil fuels.

4.257 The issue of waste management is further addressed in the next chapter which, along with chapters six, seven and eight, discusses the three key objections to an expansion of uranium mining and use of nuclear power worldwide—waste, safety and proliferation of nuclear weapons.

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Footnotes

1 Paladin Resources Ltd, *Submission no. 47*, p. 7. Back

2 Sir James Lovelock , 'Nuclear Power is the only green solution', *The Independent*, 24 May 2004 , viewed 15 May 2006 , <http://comment.independent.co.uk/commentators/article61727.ece>. Back

3 Uranium Information Centre (UIC), *Global Warming*, Nuclear Issues Briefing Papers No. 24, UIC, Melbourne , 2003, viewed 11 May 2006 , < http://www.uic.com.au/nip24.htm>. Back

4 Australian Greenhouse Office (AGO), *Climate Change Science—Questions Answered*, Australian Government Department of the Environment and Heritage, Canberra, 2005, p. 5, viewed 12 January 2006, <http://www.greenhouse.gov.au/science/qa/index.html>. Back

5 International Energy Agency (IEA), *CO_2 Emissions from Fossil Fuel Combustion 1971–2003*, OECD/IEA, Paris , 2005, p. xvii. Back

6 B Pittock (ed), *Climate Change: An Australian Guide to the Science and Potential Impacts*, AGO, Canberra , 2003, p. 23. Back

7 Nova Energy Ltd, *Submission no. 50*, p. 18. Back

8 Dr Rod Hill (CSIRO), *Transcript of Evidence*, 19 August 2005 , p. 8. Back

9 Dr Ian Smith (ANSTO), *Transcript of Evidence*, 13 October 2005 , p. 5. Back

10 Dr Michael Goldsworthy (Silex Systems Ltd), *Transcript of Evidence*, 9 February 2006 , p. 2. In addition, nitrous oxide levels have increased by 17 per cent and methane concentrations have more than doubled. See also: AGO, *op. cit*., p. 6. Back

11 Nova Energy Ltd, *loc. cit*. Back

12 Dr Michael Goldsworthy , *loc. cit*; Nova Energy Ltd, *op. cit*., p. 19. Back

13 B Pittock, *op. cit*., p. 3; AGO, *op. cit*., p. 4. Back

14 UIC, *loc. cit*. Back

15 Cited in IEA, *op. cit*., p. xviii. Back

16 Dr Ian Smith , *op. cit*., p. 6. Back

17 *ibid*. Back

18 *ibid*. Back

19 AGO, *op. cit*., p. 5; Nova Energy, *op. cit.*, p. 19. Media reports claim that the IPCC's

Fourth Assessment Report, to be issued in 2007, will find that temperature rises will be between 2 and 4.5°C by 2100. See: M Warren , 'Science tempers fears on climate', *The Australian*, 2–3 September 2006, p. 1. **Back**

20 AGO, *loc. cit*. **Back**

21 IEA, *World Energy Outlook 2005*, OECD/IEA, Paris , 2005, p. 80. **Back**

22 *ibid* .; ANSTO, *Exhibit no. 74, Presentation by Dr Ron Cameron and Dr Ian Smith* , p. 26. **Back**

23 IEA, *Electricity Information 2005*, OECD/IEA, Paris , 2005, p. I.4; UIC, *Submission no. 12*, p. 7; Summit Resources Ltd, *Submission no. 15*, p. 27; Heathgate Resources Pty Ltd, *Exhibit no. 57, Energy for the World—Why uranium?,* p. 2. **Back**

24 Dr Michael Goldsworthy (Silex Systems Ltd), *Transcript of Evidence*, 9 February 2006 , p. 2; UIC, *loc. cit*. **Back**

25 IEA, *Electricity Information 2005*, *op. cit*., pp. I.39, I.43. See also: World Nuclear Association (WNA), *Sustainable Energy—Uranium, electricity and greenhouse*, March 2006, viewed 16 March 2006, <http://world-nuclear.org/education/ueg.htm>; Cameco Corporation, *Submission no. 43*, p. 6; Mr Bernie Delaney (BHP Billiton Ltd), *Transcript of Evidence*, 2 November 2005 , p. 26. **Back**

26 Dr Michael Goldsworthy , *loc. cit*. Association of Mining and Exploration Companies (AMEC), *Submission no. 20*, p. 7. **Back**

27 WNA, *Sustainable Energy—Uranium, electricity, and greenhouse*, March 2006, viewed 16 May 2006 , <http://world-nuclear.org/education/ueg.htm>. **Back**

28 IEA, *CO_2 Emissions from Fossil Fuel Combustion 1971–2003, op. cit*., p. xxiii; IEA, *World Energy Outlook 2005*, *op. cit*., p. 92. **Back**

29 IEA, *CO_2 Emissions from Fossil Fuel Combustion 1971–2003*, *op. cit.,* pp. xxiii, xxviii; IEA, *World Energy Outlook 2005, loc. cit.* **Back**

30 ANSTO, *Exhibit no. 74, Presentation by Dr Ron Cameron and Dr Ian Smith* , p. 28; IEA, *World Energy Outlook 2005, op. cit.*, pp. 92, 93. **Back**

31 Dr Ian Smith , *op. cit*., p. 7. **Back**

32 IEA, *CO_2 Emissions from Fossil Fuel Combustion 1971–2003*, *op. cit.*, p. xvii. **Back**

33 Cameco Corporation, *op. cit.*, p. 7. **Back**

34 Areva, *Submission no. 39*, p. 4. **Back**

35 Minerals Council of Australia (MCA), *Submission no. 36*, p. 10. See also: ANSTO, *Submission no. 29*, p. 8. Some 30 submitters expressed this view. See for example: Mr Robert Elliott , *Submission no. 1*, p. 1; Mr John Reynolds , *Submission no. 5*, p. 3; Summit Resources Ltd, *Submission no. 15*, p. 25; Deep Yellow Ltd, *Submission no. 16*, p. 2; Australian Nuclear Association, *Submission no. 19*, p. 3; Submarine Institute of Australia, *Submission no. 21*, p. 7; Mr Robert Parsons, *Submission no. 24*, p. 2; Anonymous, *Submission no. 25*, p. 1; Mr Alan Parker, *Submission no. 35*, p. 12; CSIRO, *Submission no. 37*, p. 10; Heathgate Resources Pty Ltd, *Submission no. 49*, p. 1; Southern Gold Ltd, *Submission no. 54*, p. 4; Energy Resources of Australia Ltd, *Submission no. 46*, p. 4. **Back**

36 Cameco Corporation, *op. cit.*, p. 9. **Back**

37 Compass Resources NL, *Submission no. 6*, p. 3. **Back**

38 UIC, *Submission no. 12*, p. 14. **Back**

39 Arafura Resources NL, *Submission no. 22*, p. 1. **Back**

40 Areva, *Submission no. 39*, p. 2. **Back**

41 Mr Robert Parsons , *Submission no. 24*, p. 2. **Back**

42 AMEC, *loc. cit*. **Back**

43 Paladin Resources Ltd, *Submission no.47*, p. 5. See also: Australian Government Department of the Environment and Heritage (DEH), *Submission no. 55*, p. 5; Geoscience Australia (GA), *Submission no. 42*, p. 26. **Back**

44 Cameco Corporation, *op. cit*., p. 8. **Back**

45 See for example: UIC, *Submission no. 12*, pp. 10, 21; Cameco Corporation, *loc. cit*.

AMP Capital Investors Sustainable Funds Team provided a similar estimate in *Exhibit no. 65, The Nuclear Fuel Cycle Position Paper*, p. 13. The amount of energy produced depends on the type of reactor and the enrichment level of the fuel. Back

46 AMEC, *op. cit*., p. 7. Back

47 Mr Mitch Hooke (MCA), *Transcript of Evidence*, 5 September 2005 , p. 20. See also: Southern Gold, *Submission no. 54*, p. 9; AMEC, *op. cit*., p. 8. Back

48 UIC, *op. cit*., p. 14. See also: Compass Resources NL, *Submission no. 6*, p. 3; Nova Energy Ltd, *op. cit*., p. 19; Professor Leslie Kemeny , *Exhibit no. 7, Nuclear Energy and the Greenhouse Problem*, p. 1; AMEC, *loc. cit*; Cameco Corporation, *op. cit*., p. 9. Cameco estimates savings of 2.2 Gt of CO_2 per year, while AMEC estimates savings of 2.3 Gt. Back

49 Professor Leslie Kemeny , *ibid*. Back

50 WNA, *The environment needs nuclear*, viewed 14 May 2006 , <http://www.worldnuclear.org/pdf/The_Environment_Needs_Nuclear.pdf>. Back

51 AMP CISFT, *Exhibit no. 65, The Nuclear Fuel Cycle Position Paper*, p. 13. See also: The Hon Alexander Downer MP , *Submission no. 33*, p. 6. Back

52 Nova Energy Ltd, *op. cit*., p. 20. Back

53 Dr Ron Cameron (ANSTO), *Transcript of Evidence*, 13 October 2005 , p. 5. See also: Northern Land Council, *Submission no. 78*, p. 4. Back

54 Dr Ron Cameron , *op. cit*., p. 2. Back

55 Cited in the Hon Alexander Downer MP, *loc. cit*. Back

56 *ibid* . Back

57 DEH, *loc. cit*. See also: Dr Clarence Hardy (ANA), *Transcript of Evidence*, 16 September 2005 , p. 53. Back

58 *ibid* . Back

59 Heathgate Resources Pty Ltd, *Exhibit no. 57, loc. cit*. Back

60 Paladin Resources Ltd, *op. cit*., p. 4. Back

61 *ibid* ., p. 5. Back

62 Nova Energy Ltd, *loc. cit*. Back

63 ANSTO, *Submission no. 29*, p. 8. Back

64 The Hon Alexander Downer MP, *loc. cit*. This is the elemental carbon component of carbon dioxide. Back

65 H Rogner, *Nuclear Power and Climate Change*, IAEA, Paris , 2003, p. 4. Back

66 *ibid* ., p. 8. Emphasis in original. Cameco Corporation, *loc. cit*. Back

67 *ibid* ., p. 6. Back

68 *ibid* ., p. 8. Back

69 Cameco Corporation, *loc. cit*. Back

70 Mr John Reynolds , *Submission no. 5*, p. 5; Energy Resources of Australia Ltd, *Exhibit no. 82, Ranger overview presentation*, p. 16; Southern Gold Ltd, Submission no. 54, pp. 9–10. Back

71 Professor Leslie Kemeny , *op. cit*., p. 3. See also: Professor Leslie Kemeny , *Exhibit no. 28*, *Renewable energy debate makes little sense*; Energy Resources of Australia Ltd, *loc. cit*. Precise quantities of emissions would depend on the coal quality, power plant design, thermal efficiency, effectiveness of the abatement system and the operational performance of the plant. Back

72 Professor Leslie Kemeny , *Exhibit no. 7*, *op. cit*., p. 4. Back

73 *ibid* ., p. 3. Maintenance of a nuclear reactor of this size would also produces some 531 cubic metres of low level waste and 47 cubic metres of intermediate level waste per year. Back

74 Cameco Corporation, *loc. cit*. Back

75 Arafura Resources NL, *op. cit*., p. 5; AMEC, *op. cit*., p. 6; Mr Keith Alder, *Transcript of Evidence*, 16 September 2005, p. 80. Back

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77 Arafura Resources NL, *Submission no. 22*, p. 2. Back

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79 Nova Energy Ltd, *op. cit*., p. 19. Back

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81 Mr James Brough (ANF), *Transcript of Evidence*, 16 September 2005 , p. 42. Baseload power generation is defined as that part of electricity demand that is continuous and requires reliability. Back

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96 Ms Janet Marsh , *Submission no. 2*, p. 2. Back

97 Wind Prospect Pty Ltd, *Submission no. 4*, p. 3. Back

98 Medical Association for the Prevention of War—WA Branch, *Submission no. 8*, p. 8. Back

99 Mr John Schindler , *Submission no. 10*, p. 2. Back

100 Ms Caroline Pembroke , *Submission no. 81*, p. 2. Back

101 Paladin Resources Ltd, *op. cit*., p. 5. Back

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Dr Helen Caldicott, *Transcript of Evidence*, 16 September 2005, p. 15. See also: Mr Justin Tutty , *Submission no. 41*, p. 2; Wind Prospect Pty Ltd, *op. cit*., p. 3. For a critique of the van Leeuwen and Smith study see: UIC, *Energy Analysis of Power Systems*, Nuclear Issues Briefing Paper No. 57, UIC, Melbourne, 2006, viewed 18 May 2006, <http://www.uic.com.au/nip57.htm>. Back

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127 For detailed critiques of the Storm van Leeuwen and Smith studies see: UIC, *Energy Analysis of Power Systems*, Nuclear Issues Briefing Paper No. 57, UIC, Melbourne, 2006, viewed 18 May 2006, <http://www.uic.com.au/nip57.htm>; and by physicists at Melbourne University available online at 'nuclearinfo.net', viewed 18 May 2006, <http://www.nuclearinfo.net/Nuclearpower/TheBenefitsOfNuclearPower>. Back

128 UIC, *Submission no. 12.1*, p. 1. Back

129 Compare UIC, *Submission no. 12.1*, p. 1, with Wind Prospect Pty Ltd, *loc. cit*. Back

130 See: Nuclearinfo.net, *loc. cit*. Back

131 *ibid* . Back

132 UIC, *Energy Analysis of Power Systems*, *loc. cit*. Back

133 UIC, *Submission no. 12.1*, *loc cit*. Back

134 FOE et. al., *Exhibit no. 71*, *op. cit*., section 2.1. As described in the section in this chapter entitled 'The global energy situation and carbon dioxide emissions' above, the IEA states that the electricity and heat sector contributes 40 per cent of global CO_2 emissions and is the fastest growing sector. FOE argued that electricity is responsible for less than a third of CO_2 emissions, while the ACF stated that electricity accounts for 39 per cent of emissions. Back

135 ACF, *op. cit*., p. 13.; PHA, *Submission no. 53*, p. 3.; Ms Jo Vallentine , *Submission no. 73*, p. 2. Back

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138 Dr Jim Green , *op. cit.*, p. 60. Back

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142 Professor Richard Broinowski , *Transcript of Evidence*, 16 September 2005 , p. 17. Back

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148 Mr Stephen Mann (Areva), *Transcript of Evidence*, 23 September 2005 , pp. 1, 8. Back

149 Dr Roger Higgins (BHP Billiton Ltd), *Transcript of Evidence*, 2 November 2005 , p. 23. Back

150 Mr Mark Chalmers (Heathgate Resources Pty Ltd), *Transcript of Evidence*, 19 August 2005 , p. 105; Mr James Brough (ANF), *Transcript of Evidence*, 16 September 2005 , p. 50. Back

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156 Dr Rod Hill, *op. cit.*, p. 5. See also: Mr John Reynolds , *op. cit*., p. 7; ANF, *op. cit*., p. 4. Back

157 Cited in the Hon Alexander Downer MP, *op. cit*., p. 7. Back

158 Dr Ron Cameron, *op. cit.*, p. 10; ANSTO, *Exhibit no. 74,Presentation by Dr Ron Cameron and Dr Ian Smith*, p. 47. Back

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161 Mr David Noonan , *op. cit.*, p. 82. See also: Dr Gary Scott (ECNT), *Transcript of Evidence*, 24 October 2005, p. 4; MAPW (WA Branch), *op. cit*., p. 7; Ms Jo Vallentine , *Submission no. 73*, p. 2. Back

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