SOUTH AUSTRALIA'S NUCLEAR FUEL CYCLE ROYAL COMMISSION ISSUES

May 2015

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NUCLEAR FUEL CYCLE ROYAL COMMISSION
ISSUES

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7.4 Nuclear Power in Australia − How Much Waste?
7.5 Should South Australia Accept High Level Nuclear Waste from Overseas?

EXECUTIVE SUMMARY

The Conservation Council of South Australia (Conservation SA) is the peak environment group in the state, representing around 50 non-profit environmental organisations.

Conservation SA does not support an expansion of South Australia's role in the nuclear cycle.

Uranium mining in SA has a history of very significant environmental impacts that show no signs of abating. The nuclear industry has caused suffering and displacement of Aboriginal communities over many decades, from the toxic legacy of Maralinga nuclear testing, uranium mining operations and attempts to impose unwanted nuclear waste dumps.

All forms of energy generation have some environmental impact. To determine the lowest impact options, we need to assess each technology across its entire life cycle. Unfortunately, this is rarely done. Emissions from the nuclear fuel cycle will increase as relatively high-grade uranium ores are mined out and are replaced by the mining of lower-grade ores. Nuclear power brings with it a range of unavoidable risks to public health and safety that other energy options simply do not. Nuclear is also a high-cost option that has never been viable without generous taxpayer support.

The Royal Commission provides an opportunity for all of the impacts of the nuclear fuel cycle to be assessed, and Conservation SA will be actively participating to ensure that it does. This document outlines a summary of our thinking.

URANIUM MINING

From the mid-2000s until the Fukushima disaster, expectations of a significant global expansion of nuclear power drove a sharp increase in uranium exploration and the start-up of numerous mines. However nuclear power has maintained its long-standing pattern of stagnation. The uranium price is lower than the average cost of production − and well below the level that would entice mining companies to invest capital in new projects.

Australia's uranium production of 5,000 tonnes in 2014 was the lowest for 16 years. The industry generates less than 0.2 per cent of national export revenue and accounts for less than 0.02 per cent of jobs in Australia.

Governments and uranium companies routinely claim that 'strict' safeguards ensure peaceful use of Australian uranium. Those claims do not stand up to scrutiny. The Royal Commission needs to consider the vital issues of nuclear

safeguards and uranium export policy (e.g. sales to countries refusing to ratify the Comprehensive Test Ban Treaty).

The Royal Commission should investigate the repeated pattern of Aboriginal land rights and heritage protection laws being weakened or circumvented at the behest of the uranium industry. A 2003 report by the federal Senate References and Legislation Committee found "a pattern of under-performance and non-compliance" in the uranium mining industry and those ongoing patterns require thorough investigation.

URANIUM ENRICHMENT

The establishment of a uranium enrichment industry in SA is being promoted as a way to 'value add' to uranium exports. However the 2006 Switkowski Review concluded that "there may be little real opportunity for Australian companies to extend profitably" into enrichment. Conditions are no more conducive to the establishment of an enrichment industry now than they were in 2006. Former World Nuclear Association executive Steve Kidd noted in July 2014 that "the world enrichment market is heavily over-supplied".

FUEL LEASING

Fuel 'leasing' proposals could involve:

- uranium export, and the import and storage or disposal of high-level nuclear waste arising from the use of that uranium in power reactors overseas; or
- comprehensive 'front end' processes (uranium mining, conversion into uranium hexafluoride, enrichment, fuel fabrication) and 'back end' management of spent fuel (reprocessing and re-export, storage and/or disposal).

Among other problems and obstacles, the simpler of those options − uranium export and spent fuel take-back − would likely be unacceptable to at least some of Australia's major uranium customers. BHP Billiton said in its submission to the Switkowski Review said that its major customers have choices about where to acquire uranium and "these utilities generally regard their spent fuel as an asset − a resource for future reprocessing to produce more fuel input."

A comprehensive leasing scheme would involve entry into several markets − including uranium conversion, enrichment and fuel fabrication − which are already oversupplied, and which are technically challenging with high entry barriers and high entry costs. The improbability of such proposals is clearly spelt out in the 2006 Switkowski Review and in BHP Billiton's submission to the Switkowski Review − and they are no less improbable now than they were in 2006.

NUCLEAR POWER

Despite the promotion of a nuclear power 'renaissance' over the past decade, the number of 'operable' power reactors fell from 443 to 437 in the 10 years to January 2015.

In 2014, worldwide nuclear capacity increased by 2.4 gigawatts (GW). Approximately 100 GW of solar and wind power capacity were installed in 2014, up from 74 GW in 2013.

If there is any growth in global nuclear power capacity from 2015−2030, it is unlikely to exceed 2% annual growth. It is by no means certain that there will be any growth at all. That opinion is increasingly being voiced by nuclear industry 'insiders'.

Nuclear power is subject to a 'negative learning curve' − it is becoming more expensive over time. Even the large-scale, standardised French nuclear power program has been subject to a negative learning curve.

Nuclear power is heavily subsidised. Earlier promises not to subsidise new reactors in the UK have been abandoned. Construction cost estimates for two planned large reactors at Hinkley Point the UK range from A$30.6−46.8 billion. The UK government is guaranteeing payment of A$173.30 for every megawatt-hour generated by the Hinkley Point reactors, fully indexed for inflation, for 35 years. For comparison, that guaranteed payment is 2.7 times greater than typical wholesale electricity purchase costs in Australia.

Nuclear power could at most make a modest contribution to climate change abatement. The Switkowski Review stated that the construction of 12 power reactors from 2025−2050 would reduce Australia's greenhouse emissions by 8% relative to business as usual, assuming that nuclear power displaces coal. Emissions savings would be lower if the assumption is that nuclear power displaces gas. There would be no emissions savings whatsoever if nuclear power displaces those renewable energy sources that are less greenhouse intensive than nuclear power, or the many energy efficiency measures which are less greenhouse intensive than nuclear power.

The commercial deployment of Generation IV reactors is decades away. The International Atomic Energy Agency states: "Experts expect that the first Generation IV fast reactor demonstration plants and prototypes will be in operation by 2030 to 2040."

It is doubtful whether the purported benefits of Generation IV reactors will be realised. Whether Generation IV concepts deliver on their potential depends on a myriad of factors − not just the resolution of technical challenges.

NUCLEAR ACCIDENTS AND ATTACKS

In a 2010 paper, academic Benjamin Sovacool documented 99 accidents at nuclear power plants from 1952 to 2009 that resulted in the loss of human life and/or more than US$50,000 of property damage. Of the 99 accidents, 57 occurred since the Chernobyl disaster in 1986, and 56 were in the USA, refuting the notion that severe accidents are relegated to the past or to countries without modern US technology and oversight."

Claims that the safety of nuclear power is comparable to that of renewable energy sources do not stand up to scrutiny, for the following reasons (among others):

- Firstly, and most importantly, nuclear power is the only energy source with repeatedly-demonstrated connections to the proliferation of Weapons of Mass Destruction.
- Secondly, such claims ignore the long-term cancer death toll from major accidents, in particular Chernobyl and Fukushima.
- Thirdly, such claims ignore or downplay human radiation exposure from routine emissions from the nuclear fuel cycle.
- Fourthly, non-fatal impacts must be considered. For example, the relocation of 350,000 people in the aftermath of the Chernobyl disaster was associated with a great deal of trauma. Four years after the Fukushima disaster, around 80,000 people remain displaced specifically as a result of the nuclear accident.

A number of nuclear lobbyists claim that low-level radiation exposure is harmless. Informed scientific opinion holds otherwise.

RADIOACTIVE WASTE

The waste produced in nuclear reactors − called spent nuclear fuel − is orders of magnitude more radioactive than fresh uranium fuel. It takes around 200,000 years for the radioactivity of spent fuel to decline to that of the original uranium ore body.

Not a single repository exists anywhere in the world for the disposal of high level waste from nuclear power reactors. Only a few countries have identified a repository site.

Worldwide, there is one deep underground repository for long-lived intermediate-level nuclear waste − the Waste Isolation Pilot Plant (WIPP) in the US state of New Mexico. In February 2014, a heat-generating chemical reaction ruptured one of the barrels stored underground at WIPP, and this was followed by a failure of the filtration system which was meant to ensure that radiation did not reach the outside environment. Twenty-two workers were exposed to low-level radiation, the total cost to fix up the problems will exceed $500 million, and WIPP will be shut for at least four years. A troubling aspect of the WIPP problems is that complacency and cost-cutting set in just 10−15 years after the repository opened.

AUSTRALIAN EXPERIENCES WITH RADIOACTIVE WASTE

In the late-1990s, the Australian government carried out a clean-up of the Maralinga nuclear test site. It was done on the cheap and many tonnes of plutonium-contaminated debris remain buried in shallow, unlined pits in totally unsuitable geology. The government said the Maralinga clean-up was 'world's best practice' even though it breached Australian standards for the management of

long-lived nuclear waste. In 2011, a survey revealed that 19 of the 85 contaminated debris pits have been subject to erosion or subsidence.

From 1998−2004, the federal government attempted to impose a national radioactive waste repository in SA despite the clear opposition of the SA Parliament and the SA population. In 2003, the federal government used the Lands Acquisition Act 1989 to seize land for the dump. In the lead-up to the 2004 federal election, with the dump issue deeply unpopular, and the Federal Court having rejected the government's use of urgency provisions in the Lands Acquisition Act, the federal government decided to abandon the repository plan.

The federal government announced in 2005 that a national radioactive waste dump would be imposed in the Northern Territory. The federal government passed legislation allowing the imposition of a nuclear dump with no Aboriginal consultation or consent. A small group of Traditional Owners supported the dump but a much larger group were opposed and some initiated legal action in the Federal Court challenging the nomination of the Muckaty site by the federal government and the Northern Land Council (NLC). The Federal Court trial finally began in June 2014. After two weeks of evidence, the NLC gave up and the federal government acceded to the NLC's request not to proceed with the Muckaty nomination. Federal Industry Minister Ian Macfarlane characterised the Muckaty process as a "disaster".

Former Chair of the Board of the Australian Nuclear Science and Technology Organisation, Ziggy Switkowski, has been promoting the construction of 50 nuclear power reactors in Australia. Over a 50-year lifespan, 50 reactors would:

- be responsible for 1.8 billion tonnes of low level radioactive tailings waste (assuming the uranium came from Olympic Dam).
- be responsible for 430,000 tonnes of depleted uranium waste.
- produce 75,000 tonnes of high level nuclear waste (approx. 25,000 cubic metres).
- produce 750,000 cubic metres of low level waste and intermediate level waste.
- produce 750 tonnes of plutonium, enough for 75,000 nuclear weapons.

SHOULD SA ACCEPT HIGH-LEVEL NUCLEAR WASTE FROM OVERSEAS?

How much money might be made by taking nuclear waste from other countries? There is no precedent to base an estimate on. It is doubtful whether it would generate any more than a fraction of the revenue that some lobbyists claim it might. There are many constraints, such as the fact that some countries with significant nuclear power programs − such as Russia, France, and India − operate reprocessing plants so would be unlikely to want to send spent fuel to Australia.

Prof. John Veevers from Macquarie University wrote in *Australian Geologist* about the serious public health and environmental risks associated with a high-level nuclear waste repository: "Tonnes of enormously dangerous radioactive waste in the northern hemisphere, 20,000 kms from its destined dump in Australia where it

must remain intact for at least 10,000 years. These magnitudes − of tonnage, lethality, distance of transport, and time − entail great inherent risk."

Some argue that Australia has a moral responsibility to accept the high-level nuclear waste arising from the use of Australian uranium in power reactors overseas. However the responsibility for managing nuclear waste lies with the countries that make use of Australian uranium. There are no precedents for Australia or any other country being morally or legally responsible for managing wastes arising from the use of exported fuels.

1. INTRODUCTION

1.1 SA NUCLEAR FUEL CYCLE ROYAL COMMISSION

The SA government's Nuclear Fuel Cycle Royal Commission will consider uranium enrichment, nuclear power, and proposals for Australia to host an international high-level nuclear waste dump.

The Royal Commission website is: http://nuclearrc.sa.gov.au

The Terms of Reference for the Royal Commission are as follows:[1]

> ***Exploration, extraction and mining:***
> *1. The feasibility of expanding the current level of exploration, extraction and milling of minerals containing radioactive materials in South Australia, the circumstances necessary for such an increase to occur and to be viable, the risks and opportunities created by expanding the level of exploration, extraction and milling, and the measures that might be required to facilitate and regulate that increase in activity.*
> ***Further Processing and Manufacture***
> *2. The feasibility of further processing minerals, and processing and manufacturing materials containing radioactive and nuclear substances (but not for, or from, military uses), including conversion, enrichment, fabrication or re-processing in South Australia, the circumstances necessary for processing or manufacture to be viable, the risks and opportunities associated with establishing and undertaking that processing or manufacture, and the measures that might be required to facilitate and regulate the establishment and carrying out of processing or manufacture.*
> ***Electricity Generation***
> *3. The feasibility of establishing and operating facilities to generate electricity from nuclear fuels in South Australia, the circumstances necessary for that to occur and to be viable, the relative advantages and disadvantages of generating electricity from nuclear fuels as opposed to other sources (including greenhouse gas emissions), the risks and opportunities associated with that activity (including its impact on renewable sources and the electricity market), and the measures that might be required to facilitate and regulate their establishment and operation.*
> ***Management, Storage and Disposal of Waste***
> *4. The feasibility of establishing facilities in South Australia for the management, storage and disposal of nuclear and radioactive waste from the use of nuclear and radioactive materials in power generation, industry, research and medicine (but not from military uses), the circumstances necessary for those facilities to be established and to be viable, the risks and opportunities associated with establishing and operating those facilities, and*

[1] www.nuclearrc.sa.gov.au/files/terms-of-reference.pdf

the measures that might be required to facilitate and regulate their establishment and operation.

In inquiring into the risks and opportunities associated with the above activities, consideration should be given, as appropriate, to their future impact upon the South Australian:
a. economy (including the potential for the development of related sectors and adverse impacts on other sectors);
b. environment (including considering lessons learned from past South Australian extraction, milling and processing practices); and
c. community (incorporating regional, remote and Aboriginal communities) including potential impacts on health and safety.

1.2 THE NUCLEAR FUEL CYCLE

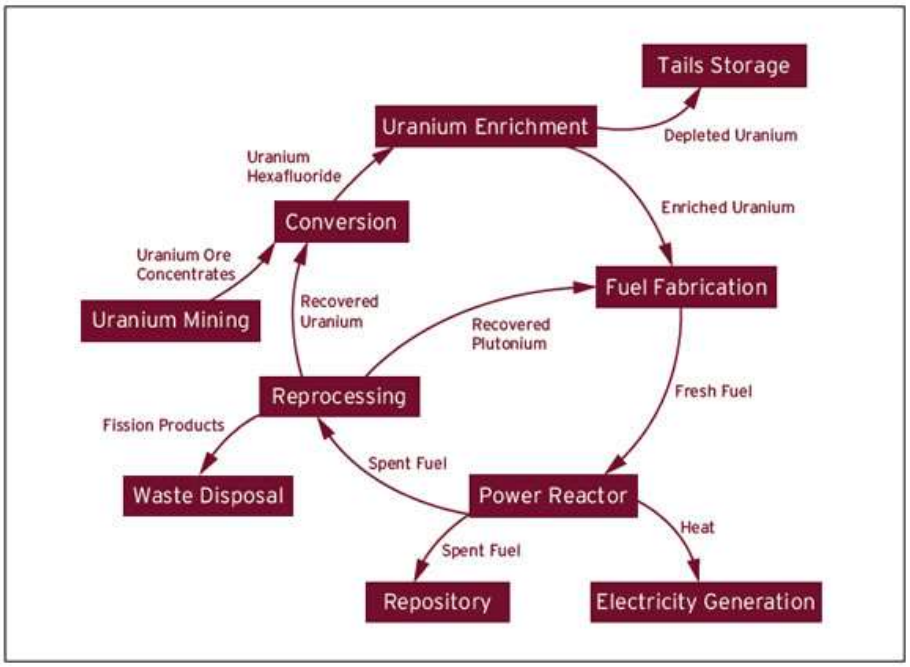
The nuclear fuel cycle for conventional uranium-fuelled reactors involves the following stages:

- Uranium mining (and milling): The most common methods are open cut (e.g. Ranger in the NT), underground (e.g. Olympic Dam in SA), or in-situ leach mining (e.g. Beverley Four Mile in SA). Heap leaching and other methods account for a small fraction of uranium mining. Australia's role in the nuclear fuel cycle is currently limited to uranium mining and milling.
- Conversion of uranium oxide to uranium hexafluoride, UF6.
- Enrichment: Natural uranium contains 0.7% of the uranium-235 isotope and 99.3% of the heavier uranium-238 isotope. Most nuclear power reactors use uranium fuel enriched to 3−5% uranium-235, hence the need for enrichment plants. (Further enrichment is required to produce enriched uranium suitable for weapons.)
- Fuel fabrication.
- Reactor operation.
- Spent fuel is either stored or reprocessed. There are no operating disposal facilities for spent fuel or for the high-level nuclear waste stream from reprocessing. With reprocessing, uranium can be extracted and reused as fuel although it is mostly stored; and extracted plutonium is either stored or used in mixed plutonium-uranium 'MOX' fuel.

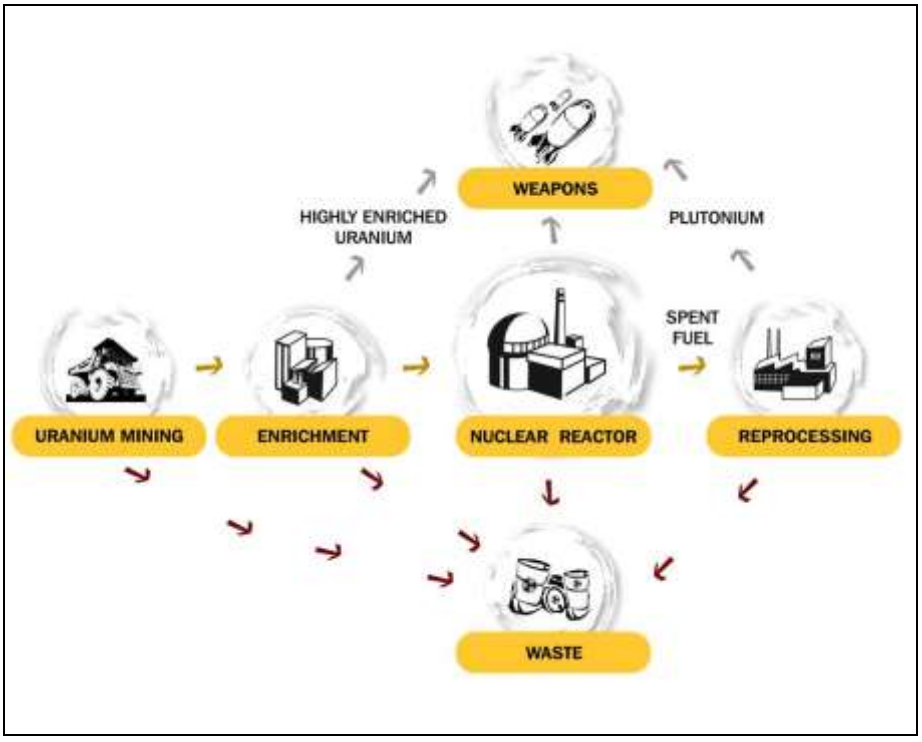
The following figures are typical for the annual operation of a 1000 megawatt (MW) nuclear power reactor[2]:
Mining: Anything from 20,000 to 400,000 tonnes of uranium ore
Milling: 230 tonnes of uranium oxide (containing 195 tonnes of uranium (tU))
Conversion: 288 tonnes uranium hexafluoride, UF6 (with 195 tU)
Enrichment: 35 tonnes enriched UF6 (containing 24 t enriched U) – balance is depleted uranium 'tails'
Fuel fabrication: 27 tonnes uranium oxide (with 24 t enriched U)

[2] www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Introduction/Nuclear-Fuel-Cycle-Overview/

Reactor operation: 8760 million kWh of electricity at full output; 22.3 tU per terrawatt-hour
Spent fuel: 27 tonnes containing 240 kg transuranics (mainly plutonium), 23 t uranium (0.8% U-235), 1100 kg fission products.



Above: Nuclear fuel cycle for conventional uranium-fuelled reactors.
Below: Key stages of the nuclear fuel cycle, illustrating weapons proliferation risks.



1.3 CONSERVATION COUNCIL SA POLICY BLUEPRINT

The Conservation Council of SA undertook an exhaustive consultation process with member groups resulting in its environmental policy document *South Australia in a Changing Climate: A Blueprint for a Sustainable Future*.[3] The relevant section of the document states:

The state government should legislate to prohibit the use and development of nuclear power, uranium processing, conversion and enrichment facilities and nuclear fuel fabrication, nuclear fuel leasing and nuclear fuel reprocessing. Uranium mining should be phased out and no further approvals be granted. If it is to continue, however, it must be managed for the 'least worst outcomes' and the state government must enforce policy standards for the 'strictest environmental conditions' to apply.

2. URANIUM MINING

The Royal Commission will consider the feasibility of expanding uranium mining and the circumstances necessary for such an increase to occur. It will not consider the option of reducing or ceasing the mining and export of uranium.

2.1 GLOBAL STATUS OF URANIUM MINING

From the mid-2000s until the Fukushima disaster in 2011, expectations of a significant global expansion of nuclear power drove a sharp increase in uranium exploration and the start-up of numerous mines. However nuclear power has maintained its long-standing pattern of stagnation. All of Japan's reactors (approx. 10% of the world's total) remain shut down. Some uranium mines have shut down, some are operating at a loss. Uranium exploration has sharply declined. The uranium price is lower than the average cost of production − and well below the level that would entice mining companies to invest capital in new projects.[4] China, Japan and some other countries have amassed large stockpiles of uranium − industry analyst David Sadowski said in March 2014 that "many utilities are sitting on near-record piles" of uranium.[5]

Energy consultants Julian Steyn and Thomas Meade wrote in *Nuclear Engineering International* in October 2014:
"The uranium market is characterised by oversupply, which is forecast to continue through most of the current decade. The oversupply situation has been exacerbated by the greater-than-initially-expected decline in demand following

[3] www.conservationsa.org.au/images/CCSA_Policy_Blueprint_2013_Final.pdf
[4] For general discussion on the uranium industry, see *Nuclear Monitor* #792, 2 Oct 2014, www.wiseinternational.org/node/4190
See also: 'Nuclear non-starter: Oversupplied, losing money and without a constituency', *Climate Spectator*, 16 Feb 2015, www.businessspectator.com.au/article/2015/2/16/energy-markets/nuclear-non-starter-oversupplied-losing-money-and-without
[5] 29 March 2014, 'Conjuring Profits from Uranium's Resurgence: Interview with David Sadowski', http://theenergycollective.com/streetwiser/360291/conjuring-profits-uraniums-resurgence-david-sadowski

Fukushima as well as the increase in primary supply during the same period. Existing production capacity and output from mines under development could cause total supply to exceed demand through the year 2020."[6]

Likewise, RBC Capital Markets analysts said in June 2014 that worldwide supply currently exceeds demand, and that it does not expect the uranium industry's situation to improve until at least 2021 because of accumulated inventories.[7]

China is the only country where significant nuclear growth can be anticipated in the coming 10−20 years. However, according to investment bank Macquarie, there are "serious question marks" about China's uranium requirements.[8] Macquarie believes that China has enough uranium stockpiled to meet demand for about seven years at forecast 2020 consumption rates − which is around three times greater than the current consumption rate.

Steve Kidd, an independent consultant and economist who worked for the World Nuclear Association for 17 years, wrote in *Nuclear Engineering International Magazine* in May 2014 that "the case made by the uranium bulls is in reality full of holes" and he predicts "a long period of relatively low prices, in which uranium producers will find it hard to make a living".[9]

Kidd states that most nuclear power growth to 2030 will be concentrated in China and Russia. But "uranium demand will almost certainly fall in the key markets in Western Europe and North America", and in Japan it will take a "long time to unwind the inventory accumulation". Only low-cost uranium mining operations will prosper while others "will struggle to stay in business and further mine closures ... are definitely on the horizon."[10]

2.2 AUSTRALIA'S URANIUM INDUSTRY

Politicians, academics and uranium industry representatives have drawn comparisons between the potential of Australia's uranium industry and Saudi oil revenue. The comparisons do not stand up to scrutiny. Australia would need to supply entire global uranium demand 31 times over to match Saudi oil revenue.[11]

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[6] Julian Steyn and Thomas Meade, 1 Oct 2014, 'Uranium market doldrums continue', www.neimagazine.com/features/featureuranium-market-doldrums-continue-4390747/
[7] Vicky Validakis, 6 June, 2014, 'Price collapse sees junior miner ditch uranium to focus on property development', www.miningaustralia.com.au/news/price-collapse-sees-junior-miner-ditch-uranium-to
[8] Rhiannon Hoyle, 17 Jan 2015, 'Uranium Rally Running Low on Juice', http://online.barrons.com/articles/uranium-rally-running-low-on-juice-1421462807
[9] www.neimagazine.com/opinion/opinionthe-future-of-uranium-higher-prices-to-come-4259437/
[10] www.neimagazine.com/opinion/opinionthe-future-of-uranium-higher-prices-to-come-4259437/
[11] ACF, 2013, 'Yellowcake Fever: exposing the uranium industry's economic myths', www.acfonline.org.au/resources/yellowcake-fever-exposing-uranium-industrys-economic-myths

Assuming a contract price of US$55 / lb U3O8 (typical in recent times), the value of annual global uranium requirements for power reactors is around US$10 billion − a tiny fraction of the global oil trade.

From 2011 to 2013, uranium was produced in 21 different countries, with Kazakhstan, Canada and Australia as the largest producers, accounting for approximately 63% of world production. Australia accounts for approximately 11% of global production, compared to its 2002−2011 average of 18.2%.[12]

Australia's uranium production of 5,000 tonnes in 2014 was the lowest for 16 years.[13] The industry generates less than 0.2 per cent of national export revenue and accounts for less than 0.02 per cent of jobs in Australia.[14]

The Ranger open-cut mine in the NT has been mined out and the planned Ranger 3 Deeps underground mine is subject to doubt and delay.[15] The uranium industry in the NT may come to an end when the last of the Ranger ore stockpile is milled in two years time.[16]

Energy Resources of Australia (ERA) has posted losses for each of the past five years, totalling $500 million. ERA has struggled with the political and economic impacts of a December 2013 leach tank collapse at Ranger resulting in the spillage of 1.4 million tonnes of radioactive slurry[17]; the collapse of a ventilation shaft in 2014[18]; and the revelations of a whistleblower published in the *Mining Australia* magazine in May 2014.[19]

In South Australia, the planned open-pit expansion of the Olympic Dam copper-uranium mine was cancelled in 2012, BHP Billiton disbanded its Uranium Division, and hundreds of Olympic Dam workers have been retrenched since then.[20]

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[12] ACF, 2013, 'Yellowcake Fever: exposing the uranium industry's economic myths', www.acfonline.org.au/resources/yellowcake-fever-exposing-uranium-industrys-economic-myths
[13] World Nuclear Association, 23 Jan 2015, Weekly Digest, http://us1.campaign-archive1.com/?u=140c559a3b34d23ff7c6b48b9&id=e08ac096b6&e=ae5ca458a0
[14] ACF, 2013, 'Yellowcake Fever: exposing the uranium industry's economic myths', www.acfonline.org.au/resources/yellowcake-fever-exposing-uranium-industrys-economic-myths
[15] Peter Ker, 9 Feb 2015, 'Standard & Poor's suggests Rio Tinto should limit its generosity', www.smh.com.au/business/mining-and-resources/standard--poors-suggests-rio-tinto-should-limit-its-generosity-20150206-13862d.html
[16] Matthew Stevens, 2 April 2015, 'Rio Tinto worried about ERA's Ranger uranium mine', www.afr.com/business/mining/uranium/rio-tinto-worried-about-eras-ranger-uranium-mine-20150402-1mctl1
[17] Gundjeihmi Aboriginal Corporation, 17 April 2014, 'Held To Ransom: Rio Tinto's radioactive legacy at Kakadu', www.mirarr.net/media_releases/held-to-ransom-rio-tinto-s-radioactive-legacy-at-kakadu
[18] Ben Hagemann, 12 May 2014, 'Shaft collapse brings new setbacks to Ranger 3 Deeps uranium operation', www.miningaustralia.com.au/news/shaft-collapse-brings-new-setbacks-to-ranger-3-dee
[19] Ben Hagemann, 5 May 2014, 'Running amok at Ranger Uranium Mine', www.miningaustralia.com.au/features/running-amok-at-ranger
[20] Simon Evans, 30 Jan 2015, 'Up to 300 jobs to go at BHP's Olympic Dam mine', www.smh.com.au/business/mining-and-resources/up-to-300-jobs-to-go-at-bhps-olympic-dam-mine-20150130-1327kb.html

Just months after first production at the Honeymoon uranium mine in 2011, project partner Mitsui announced its decision to withdraw as it "could not foresee sufficient economic return from the project". In 2013, the mine owner − a subsidiary of Russia's Rosatom − put the mine into care-and-maintenance because it was running at a loss.[21]

Beverley Four Mile started production in 2014, at the same time as the nearby Beverley mine was put into care-and-maintenance. *The Advertiser* reported: "South Australia's newest mine will lose money and won't create any jobs."[22] Alliance Resources, which holds a 25% stake in Beverley Four Mile, is seeking to sell out of the project.[23]

In November 2013, Marathon Resources gave up on the uranium sector, stating that the "risks were more likely to exceed rewards".[24]

2.3 URANIUM EXPORT POLICY AND NUCLEAR SAFEGUARDS

Governments and uranium companies routinely claim that 'strict' safeguards ensure peaceful use of Australian uranium. Those claims do not stand up to scrutiny[25] and the issue should be thoroughly investigated by the Royal Commission.

During his tenure as the Director-General of the International Atomic Energy Agency from 1997−2009, Dr. Mohamed El Baradei said that the Agency's safeguards system suffers from "vulnerabilities" and "clearly needs reinforcement"; that efforts to improve the system have been "half-hearted"; and that the safeguards system operates on a "shoestring budget ... comparable to that of a local police department".

Moreover, the Australian government is further compromising the safeguards system. The government has signed a uranium sales agreement with India that weakens safeguards standards in many respects. The agreement is currently before the Australian Parliament's Joint Standing Committee on Treaties. In its current form, the agreement has been strongly opposed by, among others, a former Director-General of the Australian Safeguards and Non-Proliferation Office (John Carlson), a former Chair of the Board of Governors of the International Atomic Energy Agency (Ronald Walker), a former Assistant Director of the US Arms

[21] Reuters, 13 Nov 2013, 'Russia's Rosatom to mothball uranium mine expansion projects', www.reuters.com/article/2013/11/13/russia-rosatom-idUSL5N0IY1E720131113
[22] Chris Russell, 26 June 2014, 'Mining company Quasar opens Four Mile uranium mine near Arkaloola', www.adelaidenow.com.au/business/mining-company-quasar-opens-four-mile-uranium-mine-near-arkaloola/story-fni6uma6-1226966919583?nk=33cc12265a6414070d671f9c7d758200
[23] ABC, 26 June 2014, 'Four Mile uranium mine becomes Australia's newest', www.abc.net.au/news/2014-06-25/four-mile-becomes-newest-uranium-mine/5549648
[24] AAP, 21 Nov 2013, 'Explorer says uranium project unviable', www.heraldsun.com.au/business/breaking-news/explorer-says-uranium-project-unviable/story-fni0xqe4-1226765298924
[25] www.choosenuclearfree.net/safeguards/

Control and Disarmament Agency (Prof. Lawrence Scheinman), and an Australian nuclear arms control expert (Crispin Rovere).[26]

John Carlson, who headed Australia's safeguards office for 21 years, argues that the agreement with India "represents a serious weakening of Australia's ... safeguards conditions" and that weaknesses in the agreement "mean Australian material could be used in support of India's nuclear weapon program."[27]

If the uranium agreement is approved, there will be sustained pressure for Australia to apply equally inadequate standards to other countries. Moreover, other nuclear and uranium exporting countries will follow Australia's lead and weaken their safeguards requirements.

Australia's uranium sales agreement with Russia highlights serious inadequacies.[28] The Joint Standing Committee on Treaties rejected the agreement to sell uranium to Russia when it learnt that International Atomic Energy Agency (IAEA) safeguards inspections in Russia are nearly non-existent. The committee said it is "essential that actual physical inspection by the IAEA occurs at any Russian sites that may handle" Australian uranium and that uranium exports "should be contingent upon such inspections being carried out." The major parties in Canberra simply ignored the recommendation.

The Royal Commission should investigate why South Australian uranium is being sold to:

- repressive, secretive countries (e.g. China, Russia)
- nuclear weapons states that are not fulfilling their disarmament obligations under the Nuclear Non-Proliferation Treaty (US, Russia, China, France, UK)
- countries that have not ratified the Comprehensive Test Ban Treaty (China, USA)
- countries with a history of weapons-related research based on their civil nuclear programs (South Korea and Taiwan).

The Royal Commission seems likely to completely ignore the vital issues of nuclear safeguards and uranium export policy. The Royal Commission's issues paper on Exploration, Extraction and Milling does not list those issues − or any proliferation-related issues whatsoever − in its list of 13 issues to be considered.[29] The Terms of Reference ask the Royal Commission to consider the risks associated with uranium mining yet the greatest risk of all − weapons proliferation − has been excluded.

2.4 ENVIRONMENTAL AND SOCIAL ISSUES

The Royal Commission should investigate the repeated pattern of Aboriginal land rights and heritage protection laws being weakened or circumvented at the

[26] www.aph.gov.au/Parliamentary_Business/Committees/Joint/Treaties/28_October_2014/Submissions
[27] www.aph.gov.au/DocumentStore.ashx?id=35fb7f72-904c-4d44-b387-f34e4afb77f9&subId=301365
[28] www.foe.org.au/anti-nuclear/issues/oz/u/cc#russia
[29] http://nuclearrc.sa.gov.au/our-reports/exploration-extraction-and-milling/

behest of the uranium industry. One example concerns the 1982 South Australian Roxby Downs Indenture Act, which sets the legal framework for the operation of BHP Billiton's Olympic Dam mine. The Act was amended in 2011 but it retains exemptions from the SA Aboriginal Heritage Act. Traditional Owners were not even consulted. The SA government's spokesperson in Parliament said: "BHP were satisfied with the current arrangements and insisted on the continuation of these arrangements, and the government did not consult further than that."[30]

Other examples include:

- Sub-section 40(6) of the Commonwealth's Aboriginal Land Rights Act exempts the Ranger uranium mine in the NT from the Act and thus removed the right of veto that Mirarr Traditional Owners would otherwise have enjoyed.[31]
- NSW legislation exempts uranium mines from provisions of the NSW Aboriginal Land Rights Act.[32]
- The Western Australian government is in the process of gutting the WA Aboriginal Heritage Act 1972 at the behest of the mining industry, including the systematic deregistering of Aboriginal Heritage Sites.[33]

A 2003 report by the federal Senate References and Legislation Committee found "a pattern of under-performance and non-compliance" in the uranium mining industry.[34] It identified many gaps in knowledge and found an absence of reliable data on which to measure the extent of contamination from the uranium mining industry, and it concluded that changes were necessary "in order to protect the environment and its inhabitants from serious or irreversible damage". The committee concluded "that short-term considerations have been given greater weight than the potential for permanent damage to the environment".

Information from Freedom of Information applications and from whistleblowers paint a picture of ongoing lax management at, and inadequate regulation of, the Olympic Dam mine. For example:

- Mining consultants Advanced Geomechanics noted in a 2004 report, obtained by *The Australian* under Freedom of Information laws, that radioactive slurry was deposited "partially off" a lined area of a storage pond, contributing to greater seepage and rising ground water levels; that there is no agreed, accurate

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[30] http://hansard.parliament.sa.gov.au/pages/loaddoc.aspx?e=2&eD=2011_11_24&c=26

[31] 'A History of Duress – A GAC Research Project',
http://web.archive.org/web/20130425181741/www.mirarr.net/duress1.htm

[32] www.parliament.nsw.gov.au/prod/parlment/nswbills.nsf/131a07fa4b8a041cca256e610012de17/f82a7f63ed98b020ca2579a500209b70?OpenDocument

[33] 'Amendments to WA's Aboriginal Heritage Act: a mining 'industry-friendly' high jacking', 27 June 2012,
http://blakandblack.com/2012/06/27/amendments-to-was-aboriginal-heritage-act-a-mining-industry-friendly-high-jacking/
Mia Pepper, 19 April 2015, 'Radioactive racism in the Wild West – WA takes aim at remote communities',
http://thestringer.com.au/radioactive-racism-in-the-wild-west-wa-takes-aim-at-remote-communities-10123

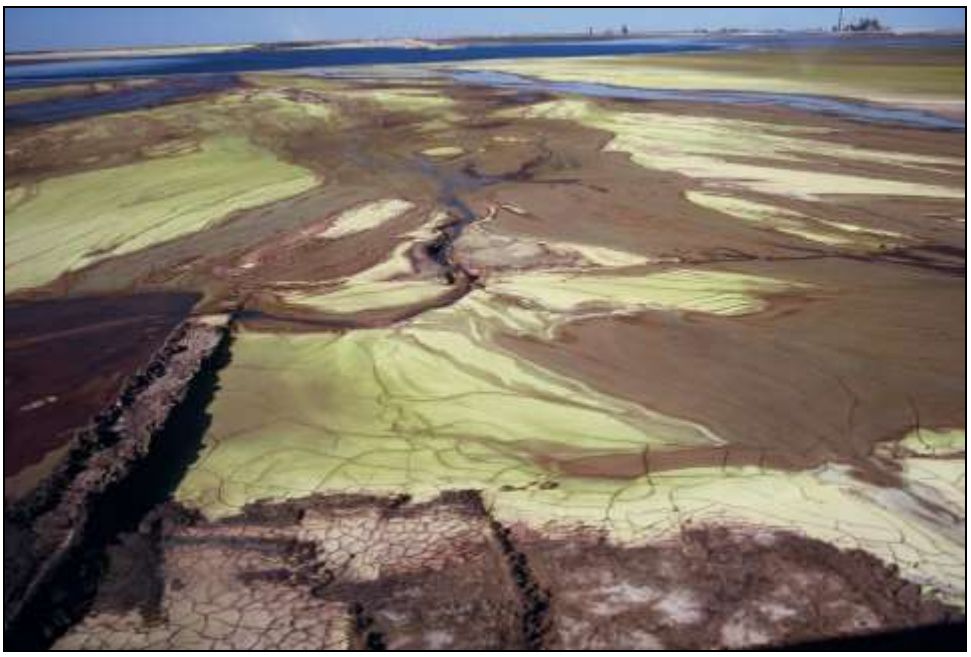
[34] Senate References and Legislation Committee, October 2003, 'Regulating the Ranger, Jabiluka, Beverley and Honeymoon uranium mines',
www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/Completed%20inquiries/2002-04/uranium/index

formula to determine the rate of evaporation of tailings and how much leaks into the ground; that cells within a tailings pond covered an area more than three times greater than a key performance indicator recommended; and that "urgent remedial measures" were required.[35]

- Photos taken by an Olympic Dam mine worker in December 2008 showed multiple leaks of radioactive tailings liquid from the so-called rock armoury of the so-called tailings retention system. BHP Billiton's response was to threaten "disciplinary action" against any worker caught taking photos of the mine site. BHP Billiton claimed that the "allegations" related to a single incident when a small damp patch appeared on the wall of the tailings retention system. In fact, the photos clearly showed multiple leaks, and the leaks were ongoing for months.[36]
- In 2010, a worker was sufficiently concerned about occupational health issues at Olympic Dam that he leaked information to the media. The leaked documents show that BHP Billiton uses manipulated averages and distorted sampling to ensure its official figures of worker radiation exposure slip under the maximum exposure levels set by government.[37]
- In 2013, a Freedom of Information application revealed that the radiation plans for Olympic Dam were more than 15 years out of date. Between 2003 and 2012, BHP Billiton reported 31 radiation leaks at the mine. The Environment Protection Authority could only find plans from 1997 and 1998 and stated: "We acknowledge that an update is overdue and action is being taken to address this situation". The EPA searched its records for 10 months before responding that there was no up-to-date plan and it needed a new one. Greens MLA Mark Parnell said: "All these plans should be available in the public realm and not have to be chased using FOI application."[38]

The environmental and public health problems don't end at the mine sites. Australian uranium is converted into high-level nuclear waste in nuclear power reactors around the world, yet there is still not a single permanent repository anywhere in the world for the disposal of high-level nuclear waste.

[35] Michelle Wiese Bockmann, 10 March 2006, 'Waste fears at uranium mine', *The Australian*.
[36] *The Monitor*, 1 April 2009, 'BHP Billiton opens up on tailings', http://web.archive.org/web/20090912230611/http://themonitor.com.au/editions/2009/APR01-09.pdf
[37] Hendrick Gout, 4 June 2010, 'Roxby's radioactive risk', Independent Weekly, www.archive.indaily.com.au/default.aspx?xml=mob&iid=36944#folio=008
[38] Miles Kemp, 7 July 2013, 'Radiation leak plan 15 years out of date', www.adelaidenow.com.au/business/olympic-dam-mine-radiation-leak-plan-15-years-out-of-date/story-fni6uma6-1226675659296



Radioactive tailings waste at Olympic Dam, with the mine in the background.

3. URANIUM ENRICHMENT

The establishment of a uranium enrichment industry in SA is being promoted as a way to 'value add' to uranium exports. For example Stefaan Simons from the (industry-funded) University College London claims that "an Australian nuclear enrichment industry, depending on the scale, could generate up to $4 billion of investment (from one plant), 600 construction jobs and provide up to 400 new permanent jobs over the next 30 years."[39]

However the 2006 Switkowski Review said:
"The enrichment market is very concentrated, structured around a small number of suppliers in the United States, Europe and Russia. It is characterised by high barriers to entry, including limited and costly access to technology, trade restrictions, uncertainty around the future of secondary supply and proliferation concerns."[40]

The Switkowski Review concluded that "there may be little real opportunity for Australian companies to extend profitably" into enrichment and that "given the new investment and expansion plans under way around the world, the market looks to be reasonably well balanced in the medium term."

BHP Billiton's submission to the Switkowski Review stated:
"Enrichment has massive barriers to entry − including access to technology and approvals under international protocols − and is concentrated with 4 large players:

[39] Andrew Hough, 18 Aug 2013, 'Nuclear enrichment industry could lead to multi-billion-dollar economic bonanza, study says', The Advertiser, www.adelaidenow.com.au/business/nuclear-enrichment-industry-could-lead-to-multibilliondollar-economic-bonanza-study-says/story-fni6uma6-1226699572009
[40] http://pandora.nla.gov.au/tep/66043

USEC, Areva, Urenco and Tenex, located within the nuclear weapon states of the United States, the United Kingdom, France and Russia respectively. ... We do not believe that conversion and enrichment would be commercially viable in Australia. ... The economics of any Australian conversion, enrichment or fabrication do not look positive, either individually or collectively. The global market is currently well supplied by services providers with strong customer relationships, economies of scale and scope, the necessary deep technological expertise and experience, solid reputations for delivery, and expansion plans in place."[41]

Then foreign minister Alexander Downer said in 2007 that uranium enrichment "would have to be commercially viable and I am advised that quite apart from having to work pretty hard to persuade the United States that Australia should enrich uranium … it would take some persuading to convince other countries to feel comfortable with that. I'm not sure that [enrichment] would be commercially viable either. Quite apart from the political obstacles, I think there are a lot of commercial obstacles as well."[42]

Conditions are no more conducive to the establishment of an enrichment industry now than they were in 2006/07.

In March 2015, Dr Switkowski said: "There's a lot of enrichment capacity around the world. It's a tightly controlled technology, it's the area where Iran is creating so much drama globally because if you get involved in enrichment, you are presumed to have the capacity to enrich to military grade."[43]

Former Western Mining Corporation executive Richard Yeeles said in February 2015: "I think there is over-capacity around the world for conversion and enrichment."[44]

Former World Nuclear Association executive Steve Kidd noted in *Nuclear Engineering International* in July 2014 that "the world enrichment market is heavily over-supplied".[45] Kidd wrote:
"The shutdown of reactors in Japan has not helped the supply-demand balance in the market, but it is clear that the producers have been over-optimistic about enrichment demand (in common with the uranium market) in the medium term. The mooted nuclear renaissance has clearly stalled and there are now substantial

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[41] http://web.archive.org/web/20070830182528/www.pmc.gov.au/umpner/submissions/223_sub_umpner.pdf
[42] Katharine Murphy, 6 Sept 2007, 'Australia stakes its claim to uranium enrichment', www.theage.com.au/news/national/australia-stakes-its-claim-to-uranium-enrichment/2007/09/05/1188783321096.html
[43] Cameron England, 6 March 2015, 'Ziggy Switkowski says nuclear power and waste storage to play a big part in South Australia's future', The Advertiser, www.adelaidenow.com.au/news/south-australia/ziggy-switkowski-says-nuclear-power-and-waste-storage-to-play-a-big-part-in-south-australias-future/story-fni6uo1m-1227252018665
[44] ABC, 16 Feb 2015, 'Nuclear waste dump has potential to earn SA billions of dollars: Ziggy Switkowski', www.abc.net.au/news/2015-02-16/nuclear-waste-has-potential-to-earn-sa-billions-ziggy-switkowski/6115694
[45] Steve Kidd, 4 July 2014, 'Uranium enrichment – what's happening today?', www.neimagazine.com/opinion/opinionuranium-enrichment-whats-happening-today-4311115/

doubts about the level of future demand in US and western European markets. The commissioning of new reactors is unlikely to offset the number of closures (for economic or, in the case of Europe, sometimes political reasons) so this over-capacity could remain for some time. Rapidly rising Chinese demand for nuclear fuel could offer a possible market, but it is generally expected that the Chinese will increase their domestic enrichment capacity to meet demand."

Uranium enrichment and weapons proliferation

Enrichment plants can produce both low-enriched uranium to fuel reactors or highly-enriched uranium which can be used in weapons.

A uranium enrichment industry in Australia would undermine long-standing efforts to limit the number of countries with enrichment capabilities. George Perkovich from the Carnegie Endowment for International Peace states:
"Enriching uranium is probably the easiest way for a country to build nuclear weapons secretly. It's not easy ... but it's harder to detect and produces highly enriched uranium which is easier to turn into weapons. And so there is a real concern when enrichment capability spreads around the world or goes to another place."[46]

Andrew Davies from the Australian Strategic Policy Institute notes that:
"[I]t is not always intent that is factored into strategic calculations, but sometimes capability. That is much harder to argue against. Other nations might reasonably conduct their strategic planning based on what we can do rather than what we say. What is true of [enrichment] technology *developed in Iran is also true of technology developed within Australia. Regardless of our motives, our capability to develop nuclear arms would be enhanced."*[47]

Prof. Hugh White noted in a 2007 article:
"No matter what we think, and no matter what we say, a decision to develop uranium enrichment capability in Australia would be seen by our neighbours as a short cut to nuclear weapons. We would need to think very carefully about how they might respond."[48]

Dr Dewi Anwar, a former State Secretary for Foreign Affairs in the Indonesian government, said in 2006:
"I think it's very important that Australia does assure the international community that it will not add another security threat to the already very unstable global situation at the moment. Indonesia and the ASEAN countries would probably be

[46] ABC, 2006, 'Australia and the nuclear renaissance', 'Background Briefing', www.abc.net.au/rn/backgroundbriefing/stories/2006/1726921.htm
[47] Andrew Davies, 1 Sept 2006, 'We should be wary of a nuclear reaction', www.smh.com.au/news/opinion/we-should-be-wary-of-a-nuclear-reaction/2006/08/31/1156817030889.html
[48] Hugh White, 1 March 2007, 'Don't mention the bomb', www.theage.com.au/news/hugh-white/dont-mention-the-bomb/2007/02/28/1172338702694.html

concerned about Australia doing uranium enrichment until we get more details of it."[49]

Depleted uranium

Depleted uranium (DU) is a radioactive by-product of the uranium enrichment process. It gets its name from the fact that much of the uranium-235 has been extracted from it. When natural uranium is enriched, around one-seventh of the original amount becomes enriched uranium fuel and the remainder is DU waste. Thus very large stockpiles of DU waste have been created − the figure is approaching two million tonnes according to a 2014 article in *Nuclear Engineering International*.[50]

Peter Diehl from the World Information Service on Energy summarises storage and disposal issues associated with DU:
"Most of the depleted uranium produced to date is being stored as UF6 in steel cylinders in the open air in so-called cylinder yards located adjacent to the enrichment plants. … Chemically, UF6 is very reactive: with water it forms the extremely corrosive hydrofluoric acid and the highly toxic uranyl fluoride (UO2F2). The hydrofluoric acid causes skin burns, and, after inhalation, damages the lungs. Further health hazards result from the chemical toxicity of the uranium to the kidneys, and from the radiation of the uranium (an alpha emitter). In the storage yards, the cylinders are subject to corrosion. The integrity of the cylinders must therefore be monitored and the painting must be refreshed from time to time. This maintenance work requires moving of the cylinders, causing further hazards from breaching of corroded cylinders, and from handling errors. … For long-term storage or disposal, the depleted UF6 must be converted to a less reactive chemical form: candidates are UF4, U3O8, and UO2."[51]

DU is used in munitions (e.g. missile nose cones) used to pierce armour plating. It has been used in munitions used by the US and NATO in Iraq, the Balkans and Afghanistan. This has generated controversy because of the long-term public health and environmental risks associated with DU.[52]

Because DU is rich in uranium-238, it is ideal for producing fissile plutonium-239 for use in nuclear weapons. This can be done by inserting a 'blanket' or target into a reactor − of particular concern are fast neutron reactors designed to 'breed' fissile material by irradiating blankets/targets comprising fertile isotopes (uranium-238 or thorium-232).

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[49] ABC, 2006, 'Australia and the nuclear renaissance', 'Background Briefing', www.abc.net.au/rn/backgroundbriefing/stories/2006/1726921.htm
[50] Steve Kidd, 6 May 2014, 'The future of uranium – higher prices to come?', www.neimagazine.com/opinion/opinionthe-future-of-uranium-higher-prices-to-come-4259437
[51] www.wise-uranium.org/dhap991.html
[52] www.bandepleteduranium.org/

4. FUEL LEASING

Fuel 'leasing' proposals for South Australia could involve:

- uranium export, and the import and storage or disposal of high-level nuclear waste arising from the use of that uranium in power reactors overseas; or
- comprehensive 'front end' processes (uranium mining, conversion into uranium hexafluoride, enrichment, fuel fabrication) and 'back end' management of spent fuel (reprocessing and re-export, storage and/or disposal).

Among other problems and obstacles, the simpler of those options − uranium export and spent fuel take-back − would likely be unacceptable to at least some of Australia's major uranium customers. BHP Billiton said in its submission to the Switkowski Review said that its major customers "have choices" about where to acquire uranium and "these utilities generally regard their spent fuel as an asset − a resource for future reprocessing to produce more fuel input."[53]

A comprehensive leasing scheme would involve entry into several markets which are already oversupplied, and which are technically challenging with high entry barriers and high entry costs. The improbability of such proposals is clearly spelt out in the 2006 Switkowski Review[54] and BHP Billiton's submission[55] to the Switkowski Review − and they are no less improbable now than they were in 2006.

BHP Billiton's submission stated:
"BHP Billiton believes that there is neither a commercial nor a non-proliferation case for it to become involved in front-end processing or for mandating the development of fuel leasing services in Australia. ... We do not believe that conversion and enrichment would be commercially viable in Australia. Nor do we believe any government imposed requirement to lease fuel, as distinct from acquiring uranium would be acceptable to its major customers, all of whom have alternative choices about where to acquire their U3O8 ... The economics of any Australian conversion, enrichment or fabrication do not look positive, either individually or collectively. ... There is no evidence that a change to current Australian Government policies to facilitate domestic enrichment, fuel leasing and high level waste disposal would lead to significant economic opportunities or reduce proliferation risks in the foreseeable future."[56]

BHP Billiton's submission further stated:
"BHP Billiton has no intention to use the [Olympic Dam] mine as a basis to begin providing fuel leasing, conversion, enrichment, nuclear power or national or international waste disposal/storage services. ... [U]tilities typically acquire U3O8 and then contract directly with established conversion, enrichment and fuel

[53] http://web.archive.org/web/20070830182528/www.pmc.gov.au/umpner/submissions/223_sub_umpner.pdf
[54] http://pandora.nla.gov.au/pan/66043/20070301-0000/www.pmc.gov.au/umpner/docs/nuclear_report.pdf
[55] http://web.archive.org/web/20070830182528/www.pmc.gov.au/umpner/submissions/223_sub_umpner.pdf
[56] http://web.archive.org/web/20070830182528/www.pmc.gov.au/umpner/submissions/223_sub_umpner.pdf

fabrication service suppliers to meet their specific technical specifications for long periods and often spread supply agreements across a number of suppliers. Customers value this flexibility and choice. ... There is little evidence of a preference for purchasing a "bundled" supply of U3O8, conversion, enrichment and fuel fabrication services and no established market for fuel leasing."[57]

BHP Billiton was particularly critical of proposals that would require the company to require uranium customers to enter into fuel leasing arrangements:
"There is no evidence that a change to current Australian Government policies to facilitate domestic enrichment, fuel leasing and high level waste disposal would lead to significant economic opportunities or reduce proliferation risks in the foreseeable future. ... It would also put at risk our reputation with customers of being a reliable supplier of uranium concentrates and our ability to enter into the long term supply arrangements that underpin expansion of uranium mining. Noting that a nuclear fuel leasing industry − if permitted by the regulatory framework − is most unlikely to be commercially viable, BHP Billiton would strongly oppose any policies to artificially support the premature development of such an industry by requiring BHP Billiton's customers to use Australian conversion, enrichment or fabrication services − or to quarantine reserves to underpin such a domestic capacity in the future. It would put customer relations and the investments those underpin at risk."[58]

The Switkowski Review[59] was sceptical about the viability of conversion, enrichment, fuel fabrication and reprocessing:
"The commercial viability and international competitiveness of a new plant in any part of the nuclear fuel cycle will depend on factors such as capital cost, operating costs, the ability to access technology on competitive terms, the state of the international market, access to the required skill base and the regulatory environment. In the case of enrichment, there are also issues associated with the storage of depleted uranium and nuclear non-proliferation."
"Establishment of conversion is only likely to be attractive if it is associated with enrichment"
"The enrichment market is very concentrated, structured around a small number of suppliers in the United States, Europe and Russia. It is characterised by high barriers to entry, including limited and costly access to technology, trade restrictions, uncertainty around the future of secondary supply and proliferation concerns."
"Fuel fabricators are typically associated with reactor vendors, who supply the initial core and in many cases refuel the reactor."
"The WNA [World Nuclear Association] forecasts that fuel fabrication capacity for all types of LWRs significantly exceeds demand..."
"The complexity of reprocessing plants involving remote handling of highly radioactive and corrosive materials requires expensive facilities and many highly

[57] http://web.archive.org/web/20070830182528/www.pmc.gov.au/umpner/submissions/223_sub_umpner.pdf
[58] http://web.archive.org/web/20070830182528/www.pmc.gov.au/umpner/submissions/223_sub_umpner.pdf
[59] http://pandora.nla.gov.au/pan/66043/20070301-0000/www.pmc.gov.au/umpner/docs/nuclear_report.pdf

trained staff. ... The only recently constructed commercial scale reprocessing plant (Rokkasho) is estimated to have cost approximately US$18 billion."
"*Reprocessing in Australia seems unlikely to be commercially attractive, unless the value of the recovered nuclear fuel increases significantly.*"

5. NUCLEAR POWER

5.1 GLOBAL STATUS OF NUCLEAR POWER

Despite the promotion of a nuclear power 'renaissance' over the past decade, the number of 'operable' power reactors fell from 443 to 437 from January 2005 to January 2015.[60] Global nuclear power generating capacity grew by 2.6% over the same period.[61]

In 2014, nuclear capacity increased by 2.4 gigawatts (GW). Approximately 100 GW of solar and wind power capacity were installed in 2014, up from 74 GW in 2013.[62]

Nuclear industry bodies offer implausible growth forecasts. For example the World Nuclear Association in 2014 envisaged the start-up of 266 new reactors by 2030.[63] That would require completion of the 70 reactors now under construction, and start-to-finish construction of another 196 reactors − all in the space of 15 years.

The International Atomic Energy Agency has repeatedly revised its forecasts downwards since the Fukushima accident. The IAEA forecasts nuclear capacity growth of 17−94% by 2030.[64] The upper estimate can be disregarded − historically, the IAEA's upper estimates have been well wide of the mark and even its 'low' estimates tend to be too high (but provide a reasonable guide nonetheless).[65] The IAEA's low estimate − annual growth of about 1% − is a reasonable prediction.

The 2015 edition of BP's annual *Energy Outlook* publication forecasts nuclear capacity growth of 1.8% p.a. between 2015 and 2035, compared to renewables growth of 6.3% p.a.[3]

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[60] Running in reverse: the world's 'nuclear power renaissance', 29 Jan 2015, www.theecologist.org/News/news_analysis/2732640/running_in_reverse_the_worlds_nuclear_power_renaissance.html
[61] IAEA, 'Nuclear Power Capacity Trend', www.iaea.org/PRIS/WorldStatistics/WorldTrendNuclearPowerCapacity.aspx
[62] Tierney Smith, 9 Jan 2015, '5 Countries Leading the Way Toward 100% Renewable Energy', http://ecowatch.com/2015/01/09/countries-leading-way-renewable-energy/
[63] World Nuclear Association, 2014, 'The World Nuclear Supply Chain: Outlook 2030, http://online-shop.world-nuclear.org/bfont-size18pxthe-world-nuclear-supply-chain-broutlook-2030fontb-18-p.asp
[64] IAEA, 24 Sept 2013, 'IAEA Issues Projections for Nuclear Power from 2020 to 2050', www.iaea.org/newscenter/news/2013/np2020.html
World Nuclear News, 25 Sept 2013, 'IAEA foresees continued growth in nuclear capacity', www.world-nuclear-news.org/NP-IAEA_foresees_continued_growth_in_nuclear_capacity-2509134.html
[65] Tables 33 and 34, p.56, www-pub.iaea.org/mtcd/publications/pdf/pub1304_web.pdf

It is by no means certain that there will be any nuclear growth at all.[66] That opinion is increasingly being voiced by nuclear industry 'insiders'. For example former World Nuclear Association executive Steve Kidd states that the "picture of the current reactors gradually shutting down with numbers of new reactors failing to replace them has more than an element of truth given the recent trends."[67] Kidd elaborates:
"[W]e have seen no nuclear renaissance (instead, a notable number of reactor closures in some countries, combined with strong growth in China) ... Countries such as Germany and Switzerland that claim environmental credentials are moving strongly away from nuclear. Even with rapid nuclear growth in China, nuclear's share in world electricity is declining. The industry is doing little more than hoping that politicians and financiers eventually see sense and back huge nuclear building programmes. On current trends, this is looking more and more unlikely."

Writing in *Oilprice.com*, Nick Cunningham argues that the nuclear industry is "failing miserably" to build new plants on time and within budget.[68] He writes:
"Nuclear power plants have often suffered from cost overruns and delays, one factor (among many) that put the industry into a decades-long lull beginning in the early 1980's. The so-called "nuclear renaissance" was thought to put an end to these problems with a new generation of designs and modular construction. So far, it hasn't played out that way. Meanwhile, a tidal wave of nuclear reactors will close down over the next 20 years as their operating licenses expire. ... A massive build out of nuclear power in China is where the nuclear industry's best hopes reside, but it is unclear if even China can make up for the shrinking industry presence in the West ..."

Only in **China** can significant nuclear growth be projected. China has 22 operable reactors, 27 under construction and 64 planned. Significant, rapid growth can be expected unless China's nuclear program is derailed by a major accident or a serious act of sabotage or terrorism. There are numerous concerns about China's nuclear program: inadequate safety standards, inadequate regulation, the lack of transparency, persecution of whistleblowers, inadequate insurance and liability arrangements, the construction of numerous reactors in areas at risk from tsunamis, security risks, and widespread corruption.[69]

Patterns of stagnation or slow decline in **Western Europe** and **North America** can safely be predicted. Steve Kidd wrote in May 2014 that uranium demand (and

[66] 'The nuclear renaissance is stone cold dead', 13 Jan 2014, www.businessspectator.com.au/article/2014/1/13/energy-markets/nuclear-renaissance-stone-cold-dead
[67] Steve Kidd, 21 Jan 2015, 'Is climate change the worst argument for nuclear?', www.neimagazine.com/opinion/opinionis-climate-change-the-worst-argument-for-nuclear-4493537/
[68] Nick Cunningham, 19 Feb 2015, 'Is There Any Hope Left For Nuclear Energy?', http://oilprice.com/Alternative-Energy/Nuclear-Power/Is-There-Any-Hope-Left-For-Nuclear-Energy.html
[69] 'Running in reverse: the world's 'nuclear power renaissance', 29 Jan 2015, *The Ecologist*, www.theecologist.org/News/news_analysis/2732640/running_in_reverse_the_worlds_nuclear_power_renaissance.html

nuclear power capacity) "will almost certainly fall in the key markets in Western Europe and North America" in the period to 2030.[70]

In January 2014, the European Commission forecast that **EU** nuclear generating capacity of 131 GWe in 2010 will decline to 97 GWe in 2025 before rising to 122 GWe in 2050 − still lower than the 2010 figure. The European Commission forecasts that nuclear's share of EU electricity generation will decline from 27% in 2010 to 21% in 2050, while the share held by renewables will increase from 21% to 51.6%, and fossil fuels' share will decline from 52% to 27%.[71]

The US has 99 operable reactors. Five reactors are under construction, "with little prospect for more" according to *Oilprice.com*.[72] Decisions to shut down just as many reactors have been taken in the past few years, in addition to cancelled plans for new reactors and cancelled plans to increase the power of existing reactors.[73] The US Energy Information Administration estimated in April 2014 that 10.8 GW of US nuclear capacity − around 10% of the total − could be shut down by the end of the decade.[74]

The *Financial Times* noted in 2014 that the US nuclear industry has been particularly rattled by two recent decisions − the closures of Dominion Resources' Kewaunee plant in Wisconsin and Entergy's Vermont Yankee. Both were operating and licensed to keep operating into the 2030s, but became uneconomic to keep in operation.[75]

India has 21 operating reactors, six under construction and 22 planned. But India's nuclear program is in a "deep freeze" according to a November 2014 article in the *Hindustan Times*.[76] India's energy minister Piyush Goyal said in November 2014 that the government remains "cautious" about developing nuclear power. He pointed to waning interest in the US and Europe:

[70] Steve Kidd, 6 May 2014, 'The future of uranium – higher prices to come?', www.neimagazine.com/opinion/opinionthe-future-of-uranium-higher-prices-to-come-4259437
[71] World Nuclear News, 9 Jan 2014, 'Policies hold European nuclear steady', www.world-nuclear-news.org/EE-Politics-hold-European-nuclear-steady-0901144.html
[72] Nick Cunningham, 9 Feb 2014, 'Wind and Gas Forcing Out Nuclear in Midwest', http://oilprice.com/Latest-Energy-News/World-News/Wind-and-Gas-Forcing-Out-Nuclear-in-Midwest.html
[73] Peter Bradford, 12 July 2013, 'Nuclear renaissance was just a fairy tale', www.guardian.co.uk/environment/2013/jul/11/nuclear-renaissance-power-myth-us
[74] Reuters, 29 Apr 2014, 'U.S. expects about 10 pct of nuclear capacity to shut by 2020', http://in.reuters.com/article/2014/04/28/utilities-nuclear-eia-idINL2N0NK23D20140428
[75] Ed Crooks, 19 Feb 2014, 'Uneconomic US nuclear plants at risk of being shut down', www.ft.com/intl/cms/s/0/da2a6bc6-98fa-11e3-a32f-00144feab7de.html
[76] Shishir Gupta and Jayanth Jacob, 30 Nov 2014, 'Govt plans N-revival, focuses on investor concerns', www.hindustantimes.com/india-news/govt-plans-n-revival-looks-for-answers-to-investor-concerns/article1-1291627.aspx

"This government would like to be cautious so that we are not saddled with something only under the garb of clean energy or alternate energy; something which the West has discarded and is sought to be brought to India."[77]

A November 2014 article in *The Hindu* newspaper noted that three factors have put a brake on India's reactor-import plans: "the exorbitant price of French- and U.S.-origin reactors, the accident-liability issue, and grass-roots opposition to the planned multi-reactor complexes."[78] In addition, unresolved disagreements regarding safeguards and non-proliferation assurances are delaying US and European investment in India's nuclear program.[79]

Russia has 34 operating reactors, nine under construction and 31 planned. Only three reactors have commenced operation during the past decade, and the pattern of slow growth is likely to continue.

South Korea has 23 operating reactors, five under construction and eight planned. Earlier plans for rapid nuclear expansion have been sharply reduced[80] in the aftermath of the Fukushima accident, a major scandal involving bribery and faked safety certificates for thousands of reactor parts[81], another scandal involving the cover-up of an accident that sent the temperature of a reactor core soaring, and a hacking attack on Korea Hydro's computer network.[82] One hundred people were arrested as a result of the safety scandals, including a former chief executive of Korea Hydro and Nuclear Power, a vice president of Korea Electric Power Corp., and a former deputy minister in charge of energy.[83]

Saudi Arabia last year announced plans to build 16 reactors by 2032. Already, that timeline has been pushed back from 2032 to 2040.[18] As with any country embarking on a nuclear power program for the first time, Saudi Arabia faces daunting logistical and workforce issues.[84] Numerous nuclear supplier are lining up to supply Saudi Arabia's nuclear power program but political obstacles could easily emerge, not least because Saudi officials (and royalty) have repeatedly said

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[77] 6 Nov 2014, 'Govt cautious about tapping nuclear energy for power generation', www.thehindu.com/news/national/govt-cautious-on-westdiscarded-nuclear-technology-says-piyush-goyal-at/article6570575.ece

[78] Brahma Chellaney, 19 Nov 2014, 'False promise of nuclear power', www.thehindu.com/opinion/lead/false-promise-of-nuclear-power/article6612000.ece

[79] Indrani Bagchi, 19 Nov 2014, 'American officials put up hurdles, try to scuttle India-US nuclear deal', http://timesofindia.indiatimes.com/india/American-officials-put-up-hurdles-try-to-scuttle-India-US-nuclear-deal/articleshow/45198136.cms

[80] Jane Chung / Reuters, 14 Jan 2014, 'South Korea cuts future reliance on nuclear power, but new plants likely', http://uk.reuters.com/article/2014/01/14/uk-nuclear-korea-idUKBREA0D05K20140114

[81] http://atomicpowerreview.blogspot.com.au/2013/10/south-korea-cables-fail-tests.html

[82] Heesu Lee, 15 Jan 2015, 'Fukushima Meltdowns Pervade S. Korea Debate on Reactor Life', www.bloomberg.com/news/2015-01-14/fukushima-meltdowns-pervade-korea-debate-on-longer-reactor-life.html

[83] World Nuclear News, 10 Oct 2013, 'Indictments for South Korea forgery scandal', www.world-nuclear-news.org/RS-Indictments_for_South_Korea_forgery_scandal-1010137.html

[84] Dan Yurman, 24 Jan 2015, 'Saudi Arabia delays its nuclear plans', http://neutronbytes.com/2015/01/24/saudi-arabia-delays-its-nuclear-plans/

that the Saudi Kingdom will build nuclear weapons if Iran's nuclear program is not constrained.[85]

South Africa's 'on-again off-again' nuclear power program is on again with plans for 9.6 GW of nuclear capacity in addition to the two operating reactors at Koeberg.[86] In 2007, state energy utility Eskom approved a plan for 20 GW of new nuclear capacity. Areva's EPR and Westinghouse's AP1000 were short-listed and bids were submitted. But in 2008 Eskom announced that it would not proceed with either of the bids due to a lack of finance. Thus the latest plan for 9.6 GW of new capacity is being treated with scepticism.[87]

France's Lower House of Parliament voted in October 2014 to cut nuclear's share of electricity generation from 75% to 50% by 2025, to cap nuclear capacity at 63.2 GW, and to pursue a renewables target of 40% by 2030 with various new measures to promote the growth of renewables.[88] In March 2015, the opposition-controlled Upper House of Parliament passed a watered-down version of the Bill, with a committee of parliamentarians from both Houses tasked with trying to reach a compromise.[89]

Germany's government is systematically pursuing its policy of phasing out nuclear power by 2023.

Japan has 43 operable reactors − down from 55 before the Fukushima accident. All of the 43 reactors are shut down as of May 2015. Before the Fukushima accident, Tokyo planned to add another 15−20 power reactors to the fleet of 55 giving a total of 70−75 reactors. Most of the 43 'operable' reactors will probably be restarted in the coming years but Japan's nuclear power industry will be around half the size it might have been if not for the Fukushima accident.

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[85] 'Saudi Arabia's nuclear power program and its weapons ambitions', Nuclear Monitor #791, 18 Sept 2014, www.wiseinternational.org/node/4195

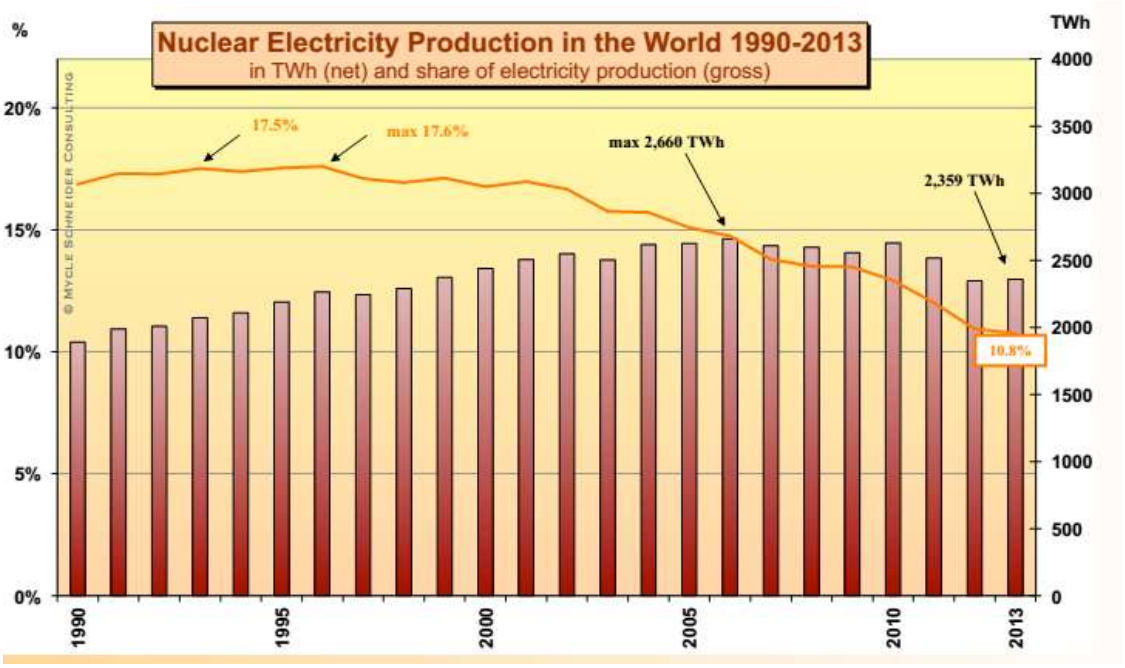
[86] 'South Africa's stop-start nuclear power program', Nuclear Monitor #792, 2 Oct 2014, www.wiseinternational.org/node/4193

[87] Steve Thomas, July 2014, 'Nuclear technology options for South Africa', http://earthlife.org.za/www/wp-content/uploads/2014/09/nuclear-cost_report1.pdf

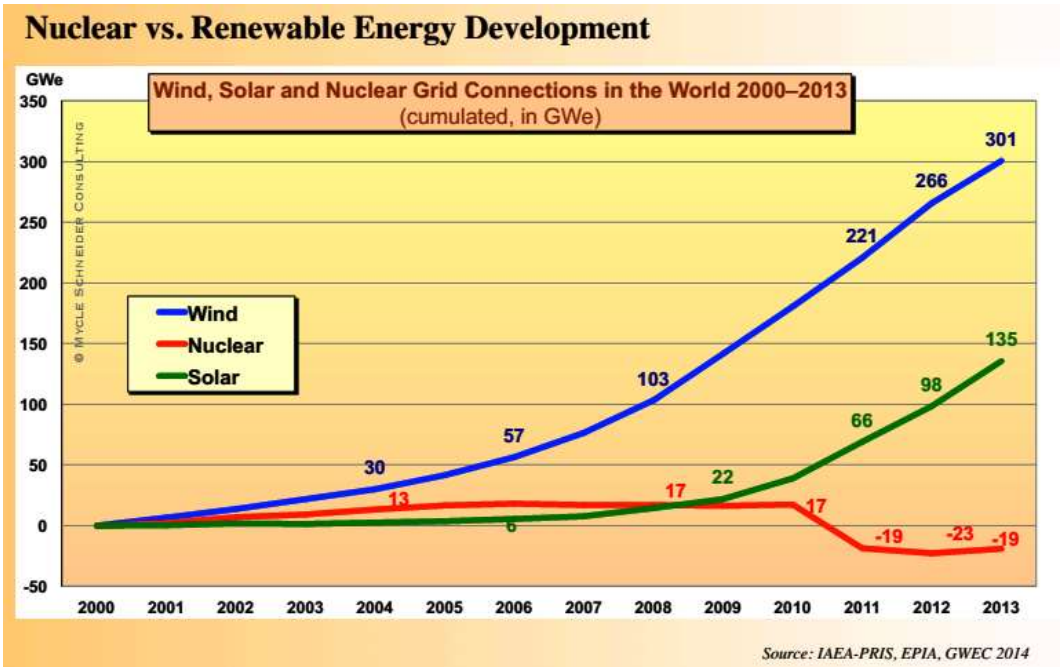
[88] 'France to cut nuclear's share of power market to 50% by 2025', 10 Oct 2014, www.platts.com/latest-news/electric-power/london/france-to-cut-nuclears-share-of-power-market-26900954

Michel Rose, 15 Oct 2014, 'French energy transition law to cut red tape on renewables', http://planetark.org/enviro-news/item/72327

[89] Michel Rose, 4 March 2015, 'Senate waters down French energy bill, committee to seek compromise', http://planetark.org/enviro-news/item/72881



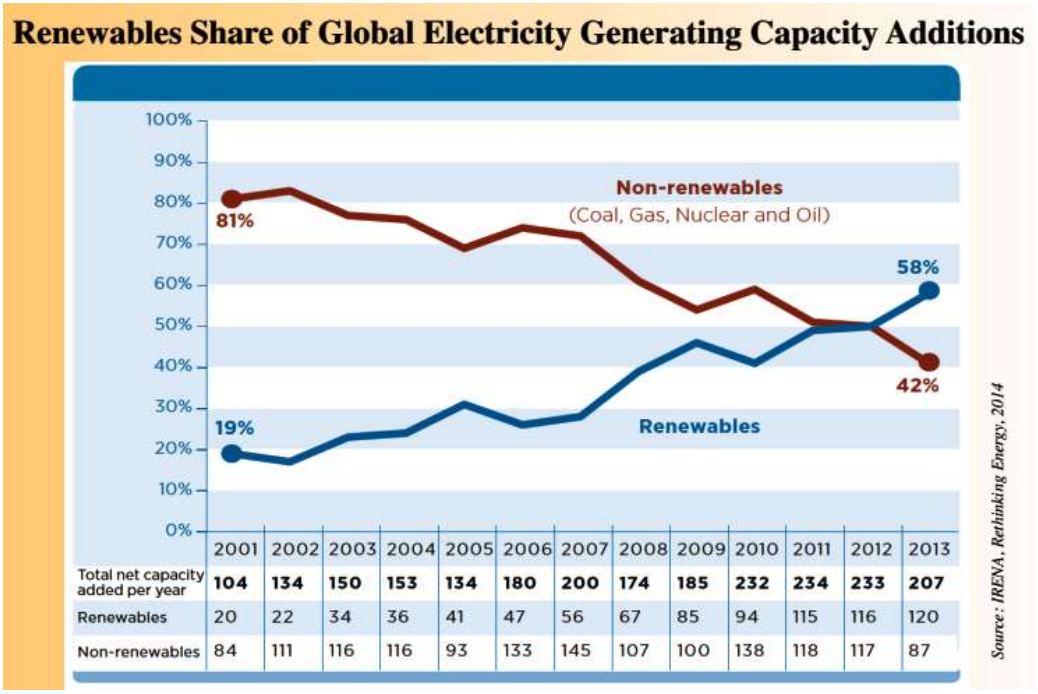
Nuclear electricity generation and nuclear share of total electricity generation, 1990–2013.[90]



Installation of wind, solar and nuclear power, 2000–2013.[91]

[90] Mycle Scheider, April 2015, World Nuclear Industry Status Report update, http://static1.1.sqspcdn.com/static/f/356082/26159765/1429631468703/20150415MSC-WNISR2014-WUS-Quebec.pdf

[91] Mycle Scheider, April 2015, World Nuclear Industry Status Report update, http://static1.1.sqspcdn.com/static/f/356082/26159765/1429631468703/20150415MSC-WNISR2014-WUS-Quebec.pdf



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total net capacity added per year	**104**	**134**	**150**	**153**	**134**	**180**	**200**	**174**	**185**	**232**	**234**	**233**	**207**
Renewables	20	22	34	36	41	47	56	67	85	94	115	116	120
Non-renewables	84	111	116	116	93	133	145	107	100	138	118	117	87

Renewable vs non-renewable capacity additions, 2001−2013.[92]

5.2 AGEING REACTORS

The problem of ageing reactors came into focus in 2014 and will remain in focus for decades to come.[93] The average age of the world's power reactors now stands at 29 years and is steadily increasing.[94]

Problems with ageing reactors include:

- the increased risk of accidents (and associated problems such as generally inadequate accident liability arrangements);
- debates over appropriate safety standards for reactors designed decades ago;
- an increased rate of unplanned reactors outages (at one point in 2014, less than half of the UK's nuclear capacity was available due to multiple outages[95]);
- costly refurbishments; and
- the costs associated with reactor decommissioning and long-term nuclear waste management.

The International Energy Agency (IEA) said in its *World Energy Outlook 2014* report:

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[92] Mycle Scheider, April 2015, World Nuclear Industry Status Report update, http://static1.1.sqspcdn.com/static/f/356082/26159765/1429631468703/20150415MSC-WNISR2014-WUS-Quebec.pdf

[93] Nina Chestney and Geert De Clercq, 19 Jan 2015, 'Global nuclear decommissioning cost seen underestimated, may spiral', www.reuters.com/article/2015/01/19/nuclear-decommissioning-idUSL6N0UV2BI20150119
Greenpeace International, 2014, 'Lifetime extension of ageing nuclear power plants: Entering a new era of risk', www.greenpeace.nl/Global/nederland/2014/Documenten/Rapport%20Lifetime%20extension%20of%20ageing%20nuclear%20power%20plants.pdf

[94] World Nuclear Industry Status Report 2014, www.worldnuclearreport.org

[95] Nuclear Free Local Authorities, 9 Dec 2014, 'NFLA concerns over the reliability of aging nuclear reactors in the UK', www.nuclearpolicy.info/docs/briefings/A241_%28NB127%29_Aging_nuclear_reactor_concerns.pdf

"A wave of retirements of ageing nuclear reactors is approaching: almost 200 of the 434 reactors operating at the end of 2013 are retired in the period to 2040, with the vast majority in the European Union, the United States, Russia and Japan."[96]

IEA chief economist Fatih Birol said:
"Worldwide, we do not have much experience and I am afraid we are not well-prepared in terms of policies and funds which are devoted to decommissioning. A major concern for all of us is how we are going to deal with this massive surge in retirements in nuclear power plants."[97]

The *World Energy Outlook 2014* report estimates the cost of decommissioning reactors to be more than US$100 billion up to 2040, adding that "considerable uncertainties remain about these costs, reflecting the relatively limited experience to date in dismantling and decontaminating reactors and restoring sites for other uses."

The IEA's head of power generation analysis, Marco Baroni, said that even excluding waste disposal costs, the final cost could be as much as twice as high as the $100 billion estimate, and that decommissioning costs per reactor can vary by a factor of four.[98]

Evidence of inadequate decommissioning funds is mounting. To give just one example, Entergy estimates a cost of US$1.24 billion to decommission the Vermont Yankee plant in the US, but the company's decommissioning trust fund for the plant − US$0.67 billion − is barely half that amount.[99]

5.3 ECONOMICS

It is a standard characteristic of technological development that unit costs decrease over time, as the industry gains experience. Yet nuclear power is subject to a 'negative learning curve' − it has become increasingly expensive over time.[100]
Citigroup states:
"The capital cost of nuclear build has actually risen in recent decades in some developed markets, partly due to increased safety expenditure, and due to smaller construction programmes (i.e. lower economies of scale). Moreover the 'fixed cost' nature of nuclear generation in combination with its relatively high price (when back end liabilities are taken into account) also places the technology at a significant disadvantage; utilities are reluctant to enter into a very long term (20+

[96] International Energy Agency, 2014, 'World Economic Outlook 2014', www.worldenergyoutlook.org
[97] World Nuclear News, 12 Nov 2014, 'Nuclear industry shares IEA concern', www.world-nuclear-news.org/NP-Nuclear-industry-shares-IEA-concern-12111401.html
[98] Nina Chestney and Geert De Clercq, 19 Jan 2015, 'Global nuclear decommissioning cost seen underestimated, may spiral', www.reuters.com/article/2015/01/19/nuclear-decommissioning-idUSL6N0UV2BI20150119
[99] Robert Audette, 19 Dec 2014, 'Vermont Yankee decommissioning plan submitted to NRC', www.reformer.com/localnews/ci_27171602/vermont-yankee-decommissioning-plan-submitted-nrc
[100] Joe Romm, 6 April 2011, 'Does nuclear power have a negative learning curve?', http://thinkprogress.org/romm/2011/04/06/207833/does-nuclear-power-have-a-negative-learning-curve/

years of operation, and decades of aftercare provisioning) investment with almost no control over costs post commissioning, with the uncertainty and rates of change currently occurring in the energy mix."[101]

Even the large-scale, standardised French nuclear power program has been subject to a negative learning curve[102], and the problem appears to be worsening with the massive cost blowouts associated with the afore-mentioned EPR projects in France and Finland.

In 2009, an updated version of a 2003 MIT Interdisciplinary Study on the Future of Nuclear Power was published, stating:
"The estimated cost of constructing a nuclear power plant has increased at a rate of 15% per year heading into the current economic downturn. This is based both on the cost of actual builds in Japan and Korea and on the projected cost of new plants planned for in the United States."[103]

The high capital costs of nuclear power make it vulnerable to interest rate rises, credit squeezes and construction delays. As the World Nuclear Association notes, "long construction periods will push up financing costs, and in the past they have done so spectacularly."[104]

High capital costs make it difficult or impossible for all but the wealthiest countries and the wealthiest corporations to pursue nuclear power. Countries with annual GDP of less than US$50 billion, and electricity grid capacity of 5 GW or less, are poorly placed to be introducing nuclear power − and most countries that have expressed recent interest in introducing nuclear power do not meet both criteria.[105]

Citigroup commented on three 'Corporate Killers' in a 2009 report:
"Three of the risks faced by developers − Construction, Power Price, and Operational − are so large and variable that individually they could each bring even the largest utility company to its knees financially. This makes new nuclear a unique investment proposition for utility companies."[106]

In September 2011, German industrial conglomerate Siemens announced its intention to withdraw entirely from the nuclear industry.[107] A more recent example is the French state-owned giant Areva, which has posted losses in each of the past

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[101] www.businessinsider.com.au/5-charts-that-show-nuclear-is-declining-2013-10
[102] Arnulf Grubler, September 2010, 'The costs of the French nuclear scale-up: A case of negative learning by doing', *Energy Policy*, Vol.38, Issue 9, pp.5174–5188, www.sciencedirect.com/science/article/pii/S0301421510003526
[103] http://web.mit.edu/nuclearpower/
[104] World Nuclear Association, 16 February 2015, 'The Economics of Nuclear Power', www.world-nuclear.org/info/Economic-Aspects/Economics-of-Nuclear-Power/
[105] Frank von Hippel et al., 2012, 'Nuclear Energy', www.iiasa.ac.at/web/home/research/researchPrograms/Energy/GEA_Chapter14_nuclear_hires.pdf
[106] www.citigroupgeo.com/pdf/SEU27102.pdf
[107] 'Siemens to quit nuclear industry', 18 Sept 2011, www.bbc.co.uk/news/business-14963575

four years including a €4.83 billion (A$6.67b) loss in 2014. Areva chairman Philippe Varin said: "Areva's paradox is that it is a world leader in its sector and a company in crisis." Varin said the crisis was due to deficient management of big reactor projects and Areva's failure to adapt to a weaker global market following the 2011 Fukushima accident.[108]

The International Energy Agency's *World Economic Outlook 2014* report noted that nuclear growth will be "concentrated in markets where electricity is supplied at regulated prices, utilities have state backing or governments act to facilitate private investment." Conversely, "nuclear power faces major challenges in competitive markets where there are significant market and regulatory risks, and public acceptance remains a critical issue worldwide."[109]

Edward Kee from the Nuclear Economics Consulting Group noted in a February 2015 article in *World Nuclear News* that of the 69 reactors under construction around the world, only one is in a liberalised electricity market.[110]

Nuclear power is heavily subsidised.[111] Earlier promises not to subsidise new reactors in the UK have been abandoned. Construction cost estimates for two planned large EPR reactors (totalling 3.2 GW) at Hinkley Point in Somerset range from £16 billion (A$30.6b) to the European Commission's estimate (which includes financing costs) of £24.5 billion (A$46.8b), or A$9.6−14.6 billion / GW.[112] EU Competition Commissioner Joaquin Almunia said the total cost could be as high as £34 billion (A$65.9b, A$20.6/GW), a figure that EDF Energy chief executive Vincent de Rivaz said included the maximum EDF could have to put into the project in a worst-case scenario if there were "huge problems".[113]

The UK government is offering loan guarantees of £10 billion (A$19.3b) for the Hinkley Point project. The UK government is also guaranteeing French utility EDF £89.50 (A$173.30) for every megawatt-hour generated by the Hinkley Point reactors, fully indexed for inflation, for 35 years. For comparison, the guaranteed payment of A$173.30/MWh is 2.7 times greater than typical wholesale electricity purchase costs in Australia of around A$65/MWh.[114] The legality of the subsidies is likely to be challenged by Austria (and others) under EU regulations.

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[108] Geert De Clercq, 4 March 2015, 'Loss-making Areva bets on cost cuts, EDF cooperation, China', www.reuters.com/article/2015/03/04/areva-results-idUSL5N0W60I420150304

[109] International Energy Agency, 2014, 'World Economic Outlook 2014', www.worldenergyoutlook.org

[110] World Nuclear News, 4 Feb 2015, 'Can nuclear succeed in liberalized power markets?', www.world-nuclear-news.org/V-Can-nuclear-succeed-in-liberalized-power-markets-0420152.html

[111] World Information Service on Energy, 24 June 2005, 'UNFAIR AID: The subsidies keeping nuclear energy afloat', www.wiseinternational.org/node/3163

[112] European Commission, 8 Oct 2014, http://europa.eu/rapid/press-release_IP-14-1093_en.htm

[113] Emily Gosden, 8 Oct 2014, 'Hinkley Point nuclear plant to cost £24.5bn', www.telegraph.co.uk/finance/newsbysector/energy/11148193/Hinkley-Point-nuclear-plant-to-cost-34bn-EU-says.html

[114] NERA Economic Consulting, 19 Aug 2013, 'Wholesale Electricity Costs in the NEM', p.15, www.aemc.gov.au/getattachment/83698230-ac57-43b2-a8e0-e4bae4acce3f/NERA-Wholesale-Electricity-Costs-in-the-NEM.aspx

Other costs are also spiralling in the UK. The UK National Audit Office estimates the total future costs for decommissioning the (dual civil-military) Sellafield nuclear site in Cumbria will be £67 billion (A$130b) − well up from the 2009 estimate of £47 billion (A$91b).[115] Estimates of the clean-up costs for a range of (civil and military) UK nuclear sites including Sellafield have jumped from a 2005 estimate of £56 billion (A$108b) to over £100 billion (A$193b).[116] Moreover there is a great deal of uncertainty and a great deal of upside risk with the clean-up cost estimates − the estimates for Sellafield alone range from £88−218 billion (A$170−421 billion).[117]

The estimated cost of the Flamanville EPR in France has increased from €3.3 billion (A$4.7b) to at least €9 billion (A$12.8b).[118] The first concrete was poured at Flamanville in 2007 and commercial operation was expected in 2012. That timeframe has been pushed back five years to 2017 (with further delays likely).[119] The British *Daily Mail* characterised the Flamanville EPR project as one "beset by financial mismanagement with rocketing costs, the deaths of workers, an appalling inability to meet construction deadlines, industrial chaos, and huge environmental concerns", and notes that "it continues to be plagued by delays, soaring costs, and litigation in both the criminal and civil courts."[120]

On April 7, the French Nuclear Safety Authority (ASN) announced that fabrication defects had been found in the reactor pressure vessel of the EPR under construction at Flamanville. Tests revealed areas with high carbon concentration resulting in "lower than expected mechanical toughness values".[121] Pierre-Franck Chevet, head of ASN, said: "It is a serious fault, even a very serious fault, because it involves a crucial part of the nuclear reactor."[122] Questions are being asked as to why the problem was not discovered before the vessel was installed.

Since the contract was signed in 2003 for a new EPR in Finland, the estimated cost has risen from €3.2 billion (A$4.6b) to €8.5 billion (A$12.1b). Areva has already

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[115] Emily Gosden, 20 June 2013, 'Sellafield clean-up could be taken into state hands as £22bn contract up for review', *The Telegraph*, www.telegraph.co.uk/finance/newsbysector/energy/10133528/Sellafield-clean-up-could-be-taken-into-state-hands-as-22bn-contract-up-for-review.html

[116] Jonathan Leake, 9 Dec 2012, 'Nuclear cleanup to take 120 years and cost £100bn', www.thesundaytimes.co.uk/sto/news/uk_news/National/article1173042.ece

[117] *The Independent*, 12 March 2015, www.independent.co.uk/news/business/news/ultimate-cost-of-sellafield-cleanup-cannot-be-forecast-10102380.html

[118] 21 Apr 2015, France's nuclear calamity has UK worried, www.thelocal.fr/20150421/flamanville-frances-own-nuclear-nightmare

Carol Matlack, 16 April 2015, 'Areva Is Costing France Plenty', www.bloomberg.com/news/articles/2015-04-16/france-s-areva-falters-in-reactor-business-leaks-cash

[119] World Nuclear Association, March 2015, 'Nuclear Power in France', www.world-nuclear.org/info/Country-Profiles/Countries-A-F/France/

[120] Steve Bird, 26 Oct 2013, 'Deaths, chilling safety lapses, lawsuits, huge cost over-runs and delays: Why we can't trust the French with Britain's nuclear future', www.dailymail.co.uk/news/article-2477202/Deaths-chilling-safety-lapses-lawsuits-huge-cost-runs-delays-Why-trust-French-Britains-nuclear-future.html

[121] Yves Marignac, WISE-Paris, April 2015, 'Fabrication Flaws in the Pressure Vessel of the EPR Flamanville-3', http://bit.ly/EPR_WISE-Paris

[122] John Lichfield, 18 April 2015, 'UK nuclear strategy faces meltdown as faults are found in identical French project', www.independent.co.uk/news/uk/home-news/uk-nuclear-strategy-faces-meltdown-as-faults-are-found-in-identical-french-project-10186163.html

made provision for a €2.7 billion (A$3.8b) writedown on the project, with further losses expected.[123] French and Finnish utilities have been locked in legal battles for several years over the cost overruns.[124] The project is nine years behind schedule − the start-up date has been pushed back from 2009 to 2018.[125]

A similar pattern is evident with new reactor projects in the US: lengthy delays and large cost escalations. Mark Cooper, senior fellow for economic analysis at Vermont Law School's Institute for Energy and the Environment, states: *"In contrast to the success of the alternatives, the projected cost of nuclear power has increased five-fold since technology vendors and academic boosters declared the "Nuclear Renaissance" in the mid-2000s. If the industry had been able to deliver on the hype of a decade ago, it would not be in such dire straits. Having failed miserably a second time, the industry is demanding another round of massive subsidies, relaxed oversight, and pampered treatment for a third bite at the apple."*[126]

The introduction of nuclear power in Australia would incur additional, very large start-up costs such as those associated with the acquisition of greenfield sites and the recruitment and training of a large workforce.

Claims that 'Generation IV' reactors will produce cheap electricity are baseless. Fast neutron reactors are neither new nor cheap. For example, the French Superphenix fast neutron reactor was promoted as the first commercial-scale fast breeder reactor in the world but the electricity it produced is estimated to have cost US$1.33 per kilowatt-hour.[127] That is over 20 times greater than typical wholesale electricity purchase costs in Australia of around A$65/MWh.[128]

5.4 NUCLEAR POWER AND WEAPONS PROLIFERATION

Nuclear power is the only energy source with a repeatedly-demonstrated connection to the proliferation of Weapons of Mass Destruction. There is a long history of peaceful nuclear programs providing political cover and technical

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[123] World Nuclear Association, April 2015, 'Nuclear Power in Finland', www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Finland/

[124] World Nuclear News, 6 July 2012, 'Partial ruling on Olkiluoto 3', www.world-nuclear-news.org/-Arbitration_court_rules_on_Olkiluoto_3-0607124.html
World Nuclear Association, April 2015, 'Nuclear Power in Finland', www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Finland/

[125] Reuters, 1 Sept 2014, 'Finland's nuclear plant start delayed again; Areva, TVO trade blame', www.reuters.com/article/2014/09/01/finland-nuclear-olkiluoto-idUSL5N0R20CV20140901

[126] Mark Cooper, 20 Feb 2014, 'Why The Economics Don't Favor Nuclear Power In America', www.forbes.com/sites/energysource/2014/02/20/why-the-economics-dont-favor-nuclear-power-in-america/

[127] Salahodeen Abdul-Kafi, 30 March 2011, 'The Superphénix Fast-Breeder Reactor', http://large.stanford.edu/courses/2011/ph241/abdul-kafi1/

[128] NERA Economic Consulting, 19 Aug 2013, 'Wholesale Electricity Costs in the NEM', p.15, www.aemc.gov.au/getattachment/83698230-ac57-43b2-a8e0-e4bae4acce3f/NERA-Wholesale-Electricity-Costs-in-the-NEM.aspx

support for nuclear weapons programs.[129] Of the 10 countries to have produced nuclear weapons, six did so with political cover and/or technical support from their supposedly peaceful nuclear programs – France, India, Pakistan, Israel, South Africa and North Korea. There are also links between peaceful and military nuclear programs in the other four nuclear weapons states (US, Russia, China, UK), such as the transfer of personnel between peaceful and military programs.

Examples of the direct use of nuclear power reactors in weapons programs include the following:

- Some of North Korea's nuclear weapons tests used plutonium produced in an 'Experimental Power Reactor'.
- Power reactors are used in India's nuclear weapons program.
- In recent years the US has used a power reactor to produce tritium, which is used to increase the explosive power of nuclear weapons.
- France and the UK have used power reactors to produce plutonium for weapons.

The 'reactor grade' plutonium produced during routine operation of a power reactor is not ideal for weapons, but can be used nonetheless. Moreover it is possible to operate power reactors on a short cycle to produce weapon grade plutonium. A typical reactor (1,000 Mwe) could produce around 200 kg of weapon grade plutonium annually[130] − enough for 50 weapons.

Nuclear power programs have facilitated weapons programs even without direct use of power reactors to produce materials for weapons. Nuclear power programs provide a rationale for the acquisition and use of:

- Uranium enrichment technology, which can produce low enriched uranium for power reactors or highly enriched uranium for weapons.
- Reprocessing technology, which divides spent nuclear fuel into three streams − uranium, high-level waste, and weapons-useable plutonium.
- Research and training reactors, which can produce plutonium and other materials for weapons and can also be used for weapons-related research. India and Israel have used research reactors to produce plutonium. Research reactors have been used for weapons-related experiments and research in numerous other countries including Iraq, Iran, South Korea, North Korea, Taiwan, Yugoslavia, and possibly Romania.

All existing and proposed reactor types and nuclear fuel cycles pose proliferation risks. The UK Royal Society notes:

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[129] www.foe.org.au/anti-nuclear/issues/nfc/power-weapons

[130] Gilinsky, Victor with Marvin Miller and Harmon Hubbard, 22 Oct 2004, 'A Fresh Examination of the Proliferation Dangers of Light Water Reactors', www.npolicy.org/article.php?aid=172
Mian, Zia and M. V. Ramana, Jan/Feb 2006, 'Wrong Ends, Means, and Needs: Behind the U.S. Nuclear Deal With India', Arms Control Today, www.armscontrol.org/act/2006_01-02/JANFEB-IndiaFeature

"There is no proliferation proof nuclear fuel cycle. The dual use risk of nuclear materials and technology and in civil and military applications cannot be eliminated."[131]

Likewise, John Carlson, former Director-General of the Australian Safeguards and Non-Proliferation Office, notes that "no presently known nuclear fuel cycle is completely proliferation proof".[132]

Thorium is sometimes promoted as a nuclear fuel that would reduce or negate proliferation risks. However irradiation of thorium produces uranium-233, which can be used as the fissile material in nuclear weapons. Uranium-233 weapons have been tested by the US, the Soviet Union, and India. There are several other proliferation risks associated with thorium, such as the need for fissile material as a 'driver' fuel, and the potential to use thorium reactors for plutonium production through irradiation of uranium targets. John Carlson summarises:
"Arguments that the thorium fuel cycle is inherently proliferation resistant are overstated. In some circumstances the thorium cycle could involve significant proliferation risks."[133]

Former Australian Prime Minister John Gorton had military ambitions for a nuclear power reactor he wanted to have constructed in the late 1960s at Jervis Bay. He later said: "We were interested in this thing because it could provide electricity to everybody and it could, if you decided later on, it could make an atomic bomb."[134] The reactor plan was deferred by the McMahon Government in 1971 and later cancelled by the Whitlam Government.

Proposals to expand South Australia's role in the nuclear fuel cycle would inevitably have proliferation implications, *regardless of intent*:

- an enrichment plant could produce highly enriched uranium;
- conventional uranium-fuelled power reactors routinely produce weapons-useable reactor grade plutonium (enough for about 30 weapons each year) and could be operated on a short operating cycle to produce weapon grade plutonium;
- a reprocessing plant could be used to separate plutonium from irradiated materials for weapons;
- importing spent fuel would necessarily mean acquiring plutonium (which accounts for 1% of spent fuel).

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[131] UK Royal Society, 13 Oct 2011, 'Fuel cycle stewardship in a nuclear renaissance', http://royalsociety.org/policy/projects/nuclear-non-proliferation/report
[132] John Carlson, 2009, 'Introduction to the Concept of Proliferation Resistance', www.foe.org.au/sites/default/files/Carlson%20ASNO%20ICNND%20Prolif%20Resistance.doc
[133] John Carlson, 2009, 'Introduction to the Concept of Proliferation Resistance', www.foe.org.au/sites/default/files/Carlson%20ASNO%20ICNND%20Prolif%20Resistance.doc
[134] Pilita Clark, 1 Jan 1999, 'PM's Story: Very much alive... and unfazed', *Sydney Morning Herald*.

5.5 NUCLEAR POWER AND CLIMATE CHANGE

Nuclear power could at most make a modest contribution to climate change abatement. The main limitation is that it is used almost exclusively for electricity generation, which accounts for less than 25% of global greenhouse emissions.[135]

The Switkowski Review stated that the construction of 12 power reactors from 2025−2050 would reduce Australia's greenhouse emissions by 8% relative to business as usual, assuming that nuclear power displaces coal.[136] Emissions savings would be lower if the assumption is that nuclear power displaces gas.

Greenhouse emissions from renewable energy sources vary but are typically similar to nuclear power.[137] If nuclear power displaces those renewable energy sources that are less greenhouse intensive than nuclear power and/or the many energy efficiency measures which are less greenhouse intensive than nuclear power, nuclear power will result in increased greenhouse emissions. Global renewable energy capacity – mostly hydroelectricity – already exceeds nuclear capacity. Renewable energy sources can also be deployed more rapidly than nuclear power.

Energy efficiency measures are capable of generating large reductions in greenhouse emissions and can do so more cheaply and quickly than installing nuclear power – therefore, investing in nuclear power instead of energy efficiency measures exacerbates and accelerates climate change.

Expanding nuclear power is impractical as a short-term response to the need to urgently reduce greenhouse emissions. The industry does not have the capacity to rapidly expand production as a result of over 20 years of stagnation. Limitations include bottlenecks in the reactor manufacturing sector, the ageing workforce (a 'silver tsunami'), and the considerable time it takes to build a reactor and to pay back the energy debt from construction.

Prof. Ian Lowe notes:
"The Switkowski report says at least 10 and possibly 15 years would be a realistic time scale for building one nuclear power station in Australia. It would take more time still to "pay back" the energy used in construction and fuelling, so it would take 15 to 20 years for any such station to make any contribution to cutting greenhouse pollution. Fifteen to 20 months is a more realistic time scale for large-

[135] Electricity plus heat account for 25% of emissions. See IPCC, 2014: Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the IPCC, p.9, www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_summary-for-policymakers.pdf
[136] Switkowski Review, 2006, 'Uranium Mining, Processing and Nuclear Energy Review', http://pandora.nla.gov.au/tep/66043
[137] Switkowski Review, 2006, 'Uranium Mining, Processing and Nuclear Energy Review', p.93, http://pandora.nla.gov.au/tep/66043

scale renewables. Global warming is an urgent problem that demands a concerted response now, not a half-baked response after 2020."[138]

As well as being a limited response to climate change, nuclear power is a highly problematic response, not least because of the links between the 'peaceful atom' and weapons proliferation. An expansion of nuclear power is likely to exacerbate the problem. Doubling nuclear output by the middle of the century would require the construction of approximately 800 reactors to replace most of the existing cohort of reactors and to build as many again. Those reactors would produce enough plutonium to build over one million nuclear weapons. Since most power reactors use enriched uranium fuel, further proliferation risks would arise from enrichment plants.

A much larger expansion of nuclear power would have a greater impact on greenhouse emissions to the extent that it displaced fossil fuels. But the weapons proliferation risks would also grow. The Intergovernmental Panel on Climate Change maps out a scenario whereby nuclear capacity would grow to about 3,300 gigawatts in 2100 (approximately nine times greater than current capacity), and the accumulated plutonium inventory would rise to 50−100 thousand tonnes.[139] That amount of plutonium would suffice to build 5−10 million nuclear weapons.

Dr Mark Diesendorf from the University of NSW states:
"On top of the perennial challenges of global poverty and injustice, the two biggest threats facing human civilisation in the 21st century are climate change and nuclear war. It would be absurd to respond to one by increasing the risks of the other. Yet that is what nuclear power does."[140]

Likewise, former US Vice President Al Gore said:
"For eight years in the White House, every weapons-proliferation problem we dealt with was connected to a civilian reactor program. And if we ever got to the point where we wanted to use nuclear reactors to back out a lot of coal ... then we'd have to put them in so many places we'd run that proliferation risk right off the reasonability scale."[141]

Running the proliferation risk off the reasonability scale brings the debate back to climate change − a connection explained by Alan Robock in *The Bulletin of the Atomic Scientists*:

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[138] Ian Lowe, 7 Sept 7, 2007, 'Heeding the warning signs', *Sydney Morning Herald*, www.smh.com.au/news/national/heeding-the-warning-signs/2007/09/06/1188783415604.html
[139] Intergovernmental Panel on Climate Change, 1995, 'Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses', Contribution of Working Group II to the Second Assessment of the IPCC, R.Watson, M.Zinyowera, R.Moss (eds), Cambridge University Press: UK.
[140] Mark Diesendorf, 14 Oct 2009, 'Need energy? Forget nuclear and go natural', www.theage.com.au/opinion/society-and-culture/need-energy-forget-nuclear-and-go-natural-20091014-gvzo.html)
[141] Quoted in David Roberts, 9 May 2006, 'An interview with accidental movie star Al Gore', http://grist.org/article/roberts2/

"As recent work ... has shown, we now understand that the atmospheric effects of a nuclear war would last for at least a decade − more than proving the nuclear winter theory of the 1980s correct. By our calculations, a regional nuclear war between India and Pakistan using less than 0.3% of the current global arsenal would produce climate change unprecedented in recorded human history and global ozone depletion equal in size to the current hole in the ozone, only spread out globally."[142]

5.6 GENERATION IV REACTORS

So-called 'next generation' or 'Generation IV' reactor concepts are diverse. The six concepts being investigated by the Generation IV International Forum are: the gas-cooled fast reactor, the sodium-cooled fast reactor, the lead-cooled fast reactor, the molten salt reactor, the supercritical water-cooled reactor, and the very high temperature reactor.[143] The Generation IV International Forum brings together 12 countries with an interest in new reactor types, plus Euratom.[144]

The Generation IV International Forum states: "Depending on their respective degree of technical maturity, the first Generation IV systems are expected to be deployed commercially around 2030-2040."[145]

The Generation IV International Forum also states: "It will take at least two or three decades before the deployment of commercial Gen IV systems. In the meantime, a number of prototypes will need to be built and operated. The Gen IV concepts currently under investigation are not all on the same timeline and some might not even reach the stage of commercial exploitation."[146]

The International Atomic Energy Agency states: "Experts expect that the first Generation IV fast reactor demonstration plants and prototypes will be in operation by 2030 to 2040."[147]

A 2015 report by the French government's Institute for Radiological Protection and Nuclear Safety (IRSN) states: "There is still much R&D to be done to develop the Generation IV nuclear reactors, as well as for the fuel cycle and the associated waste management which depends on the system chosen."[148]

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[142] Alan Robock, 14 Aug 2008, 'We should really worry about nuclear winter', *The Bulletin of the Atomic Scientists*, http://thebulletin.org/has-time-come-geoengineering/we-should-really-worry-about-nuclear-winter
[143] www.gen-4.org/gif/jcms/c_40465/generation-iv-systems
[144] www.gen-4.org/gif/jcms/c_9335/charter
[145] www.gen-4.org/gif/jcms/c_9260/public
[146] www.gen-4.org/gif/jcms/c_41890/faq-2
[147] Peter Rickwood and Peter Kaiser, 1 March 2013, 'Fast Reactors Provide Sustainable Nuclear Power for "Thousands of Years"', www.iaea.org/newscenter/news/2013/fastreactors.html
[148] Institute for Radiological Protection and Nuclear Safety, 2015, 'Review of Generation IV Nuclear Energy Systems', www.irsn.fr/EN/newsroom/News/Pages/20150427_Generation-IV-nuclear-energy-systems-safety-potential-overview.aspx
Direct download: www.irsn.fr/EN/newsroom/News/Documents/IRSN_Report-GenIV_04-2015.pdf

The World Nuclear Association noted in 2009 that "progress is seen as slow, and several potential designs have been undergoing evaluation on paper for many years."[149]

Specifically regarding thorium, a 2012 report by the UK National Nuclear Laboratory states: "NNL has assessed the Technology Readiness Levels (TRLs) of the thorium fuel cycle. For all of the system options more work is needed at the fundamental level to establish the basic knowledge and understanding. Thorium reprocessing and waste management are poorly understood. The thorium fuel cycle cannot be considered to be mature in any area."[150]

Clearly the commercial deployment of Generation IV reactors is some way off.

Moreover it is doubtful whether the purported benefits of Generation IV reactors will be realised.

The French government's Institute for Radiological Protection and Nuclear Safety reviewed the six concepts prioritised by the Generation IV International Forum and concludes:
"*At the present stage of development, IRSN does not notice evidence that leads to conclude that the systems under review are likely to offer a significantly improved level of safety compared with Generation III reactors, except perhaps for the VHTR [Very High Temperature Reactor] ...*"[151]

Moreover the VHTR system could bring about significant safety improvements, the Institute for Radiological Protection and Nuclear Safety states, "but only by significantly limiting unit power".[152]

Regarding Generation IV concepts, Hirsch et al. state:
"*A closer look at the technical concepts shows that many safety problems are still completely unresolved. Safety improvements in one respect sometimes create new safety problems. And even the Generation IV strategists themselves do not expect significant improvements regarding proliferation resistance. But even real technical improvements that might be feasible in principle are only implemented if their costs are not too high. There is an enormous discrepancy between the catch-words used to describe Generation IV for the media, politicians and the public,*

[149] World Nuclear Association, 15 Dec 2009, 'Fast moves? Not exactly...', www.world-nuclear-news.org/NN_France_puts_into_future_nuclear_1512091.html
[150] UK National Nuclear Laboratory Ltd., 5 March 2012, 'Comparison of thorium and uranium fuel cycles', www.decc.gov.uk/assets/decc/11/meeting-energy-demand/nuclear/6300-comparison-fuel-cycles.pdf
[151] Institute for Radiological Protection and Nuclear Safety, 2015, 'Review of Generation IV Nuclear Energy Systems', www.irsn.fr/EN/newsroom/News/Pages/20150427_Generation-IV-nuclear-energy-systems-safety-potential-overview.aspx
Direct download: www.irsn.fr/EN/newsroom/News/Documents/IRSN_Report-GenIV_04-2015.pdf
[152] Institute for Radiological Protection and Nuclear Safety, 2015, 'Review of Generation IV Nuclear Energy Systems', www.irsn.fr/EN/newsroom/News/Pages/20150427_Generation-IV-nuclear-energy-systems-safety-potential-overview.aspx
Direct download: www.irsn.fr/EN/newsroom/News/Documents/IRSN_Report-GenIV_04-2015.pdf

and the actual basic driving force behind the initiative, which is economic competitiveness."[153]

The 2012 report by the UK National Nuclear Laboratory argues that thorium has "theoretical advantages regarding sustainability, reducing radiotoxicity and reducing proliferation risk" but that "while there is some justification for these benefits, they are often over stated." The report further states that the purported benefits "have yet to be demonstrated or substantiated, particularly in a commercial or regulatory environment." It is sceptical about safety claims: "Thorium fuelled reactors have already been advocated as being inherently safer than LWRs [light water reactors], but the basis of these claims is not sufficiently substantiated and will not be for many years, if at all."[154]

Some Generation IV concepts promise major advantages, such as the potential to use long-lived nuclear waste and weapons-usable material (esp. plutonium) as reactor fuel. However, fast neutron reactor technology might more accurately be described as failed Generation I technology. The history of fast reactors has largely been one of extremely expensive, underperforming and accident-prone reactors which have contributed more to WMD proliferation problems than to the resolution of those problems.[155] Most of the countries that invested in fast reactor technology have since abandoned those efforts. The latest setback was the indefinite postponement of the planned BN-1200 fast reactor in Russia, amid speculation about the cost-effectiveness of the project.[156]

Most importantly, whether Generation IV concepts deliver on their potential depends on a myriad of factors − not just the resolution of technical challenges. India's fast reactor / thorium program illustrates how badly things can go wrong, and it illustrates problems that can not be solved with technical innovation. John Carlson writes:
"India has a plan to produce [weapons-grade] plutonium in fast breeder reactors for use as driver fuel in thorium reactors. This is problematic on non-proliferation and nuclear security grounds. Pakistan believes the real purpose of the fast breeder program is to produce plutonium for weapons (so this plan raises tensions between the two countries); and transport and use of weapons-grade plutonium

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[153] Helmut Hirsch, Oda Becker, Mycle Schneider and Antony Froggatt, April 2005, 'Nuclear Reactor Hazards: Ongoing Dangers of Operating Nuclear Technology in the 21st Century', report prepared for Greenpeace International, www.greenpeace.org/international/press/reports/nuclearreactorhazards

[154] UK National Nuclear Laboratory Ltd., 5 March 2012, 'Comparison of thorium and uranium fuel cycles', www.decc.gov.uk/assets/decc/11/meeting-energy-demand/nuclear/6300-comparison-fuel-cycles.pdf

[155] International Panel on Fissile Materials, Feb 2010, 'Fast Breeder Reactor Programs: History and Status', www.ipfmlibrary.org/rr08.pdf
On the use of fast reactors in support of weapons production, see also Mycle Schneider, 2009, 'Fast Breeder Reactors in France', *Science and Global Security*, 17:36–53, www.princeton.edu/sgs/publications/sgs/archive/17-1-Schneider-FBR-France.pdf

[156] World Nuclear News, 16 April 2015, 'Russia postpones BN-1200 in order to improve fuel design', www.world-nuclear-news.org/NN-Russia-postpones-BN-1200-in-order-to-improve-fuel-design-16041502.html

in civil reactors presents a serious terrorism risk (weapons-grade material would be a priority target for seizure by terrorists)."[157]

Small modular reactors

Small modular reactors (SMR) are being promoted on the grounds that they could potentially be deployed in circumstances unsuitable for large reactors, they might be safer than large reactors, they might use less water for cooling, etc.

However interest in SMRs is on the wane. Thomas W. Overton, associate editor of POWER magazine, wrote in a September 2014 article:
"At the graveyard wherein resides the "nuclear renaissance" of the 2000s, a new occupant appears to be moving in: the small modular reactor (SMR). ... Over the past year, the SMR industry has been bumping up against an uncomfortable and not-entirely-unpredictable problem: It appears that no one actually wants to buy one."[158]

Overton notes that a central premise of SMR rhetoric is large-scale standardised manufacturing producing many identical plants:
"It's an attractive idea. But it's also one that depends on someone building that massive supply chain, since none of it currently exists. ... That money would presumably come from customer orders − if there were any."

Likewise, Glenn George from KPMG states:
"I think that investors are in a wait-and-see mode regarding development of the SMR market. ... Investors will want to see SMR learning-curve effects, but a chicken-and-egg situation is at work: Decreased cost comes from production of multiple units over time, yet such production requires investment in the first place."[159]

Integral fast reactors

A number of Australian nuclear advocates are promoting a plan to import spent nuclear fuel (and possibly other forms of nuclear waste) and to process it for use as fuel in 'integral fast reactors' (IFRs). IFRs don't exist but they were the subject of an R&D program in the US for several decades.

That R&D program was not without controversy. Dr James Smith, a scientist who worked on an IFR R&D project in the US, was improperly pressured to resign from the project for raising concerns about defective work including fundamental errors

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[157] John Carlson, 2014, first submission to Joint Standing Committee on Treaties, inquiry into Australia−India Nuclear Cooperation Agreement, Parliament of Australia, www.aph.gov.au/DocumentStore.ashx?id=79a1a29e-5691-4299-8923-06e633780d4b&subId=301365
[158] Thomas W. Overton, 1 Sept 2014, 'What Went Wrong with SMRs?', www.powermag.com/what-went-wrong-with-smrs/
[159] Peter Taberner, 3 March 2015, 'SMRs: private investors call for track record and big government orders', http://analysis.nuclearenergyinsider.com/small-modular-reactors/smrs-private-investors-call-track-record-and-big-government-orders

in metallurgy and related sciences, at least some of which had safety implications. He further claimed that Argonne National Laboratory published false and misleading accounts of its work. The Office of Nuclear Safety concurred with Dr Smith's claims that ANL failed to act on his proposals for improving how errors are detected.[160]

On the basis of the R&D program in the US, GE Hitachi says it is willing to build an IFR if it can find a customer. The US and UK governments have shown some interest, and both governments published reports last year on the topic.

The US report notes that pursuit of IFR technology would be associated with "major technical challenges"; that it would take 18 years to construct an IFR and associated facilities; and that the IFR option is by far the most expensive option for dealing with the US stockpile of surplus plutonium.[161]

The UK report notes that IFR facilities have not been industrially demonstrated; that waste disposal issues remain unresolved; and that GE Hitachi's timeframe of 14 to 18 years for development, licensing and construction is "ambitious".[162]

If IFRs *are* built, might they live up to expectations? Claims that IFRs would be proliferation-resistant do not stand up to scrutiny.[163]

IFR proponents claim that there is essentially no risk of a serious accident. Such claims are often made about reactor concepts that exist only on paper and they should be treated with scepticism. As a nuclear industry insider puts it: "We know that the paper-moderated, ink-cooled reactor is the safest of all." He went on to warn that: "All kinds of unexpected problems may occur after a project has been launched."[164] Likewise, nuclear engineer David Lochbaum says that: "The IFR looks good on paper. So good, in fact, that we should leave it on paper. For it only gets ugly in moving from blueprint to backyard."[165]

5.7 POSSIBLE SITES FOR NUCLEAR POWER REACTORS

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[160] www.faqs.org/abstracts/Zoology-and-wildlife-conservation/Fusion-programme-could-aid-terrorists-California-to-keep-energy-labs-contracts.html
www.osti.gov/energycitations/product.biblio.jsp?osti_id=6030509
www.nature.com/nature/journal/v356/n6369/pdf/356469a0.pdf
https://inis.iaea.org/search/search.aspx?orig_q=RN:23040624

[161] US Department of Energy, April 2014, 'Report of the Plutonium Disposition Working Group: Analysis of Surplus Weapon- Grade Plutonium Disposition Options', www.nnsa.energy.gov/sites/default/files/nnsa/04-14-inlinefiles/SurplusPuDispositionOptions.pdf

[162] UK Nuclear Decommissioning Authority, Jan 2014, 'Progress on approaches to the management of separated plutonium – Position Paper', www.nda.gov.uk/publication/progress-on-approaches-to-the-management-of-separated-plutonium-position-paper

[163] http://foe.org.au/anti-nuclear/issues/nfc/power-weapons/g4nw

[164] Quoted in Helmut Hirsch, Oda Becker, Mycle Schneider and Antony Froggatt, April 2005, 'Nuclear Reactor Hazards: Ongoing Dangers of Operating Nuclear Technology in the 21st Century', report prepared for Greenpeace International, www.greenpeace.org/international/press/reports/nuclearreactorhazards

[165] http://skirsch.com/politics/globalwarming/ifrUCSresponse.pdf

The Australia Institute identified possible sites for nuclear power plants in a 2007 report.[166]

The study used four primary criteria:
1. Proximity to appropriate existing electricity infrastructure; sites close to the National Electricity Market, preferably near existing large generators.
2. Proximity to major centres of electricity demand.
3. Proximity to transport infrastructure to facilitate the movement of nuclear fuel, waste and other relevant materials.
4. Access to large quantities of water for reactor cooling.

Secondary criteria included the following:
1. Population density − sites with adequate buffers to populated areas.
2. Geological and seismological issues.
3. Atmospheric conditions − sites with low risk of extreme weather events and suitable pollution dispersion conditions.
4. Security risk − sites with low security risks (e.g. sufficient buffers to potentially hazardous areas).
5. Sensitive ecological areas − sites that pose minimal risk to important ecological areas.
6. Heritage and aesthetics − sites that pose minimal risk to important heritage areas.
7. Economic factors − sites that accommodate local economic and social factors.

Based on the above criteria, the report identifies the following sites:

South Australia:
- Mt Gambier / Millicent
- Port Adelaide
- Port Augusta and Port Pirie

Queensland:
- Townsville
- Mackay
- Rockhampton (e.g. around Yeppoon, Emu Park or Keppel Sands)
- Gladstone
- Bundaberg
- Sunshine Coast (e.g. near Maroochydore, Coolum or Noosa)
- Bribie Island area

New South Wales and the Australian Capital Territory:
- Port Stephens (e.g. Nelson Bay)

[166] Andrew Macintosh (The Australia Institute), 2007, 'Siting Nuclear Power Plants in Australia Where would they go?', www.tai.org.au/documents/downloads/WP96.pdf

- Central Coast (e.g. near Tuggerah Lakes)
- Port Kembla
- Botany Bay
- Jervis Bay and Sussex Inlet

Victoria:
- South Gippsland (e.g. Yarram, Woodside, Seaspray)
- Western Port (e.g. French Island, Hastings, Kooweerup, Coronet Bay)
- Port Phillip (e.g. Newport, Werribee, Avalon)
- Portland

Western Australia and the Northern Territory were excluded from the siting study because they are not on the National Electricity Market grid. The report did not consider Tasmania in any detail and considered it unlikely that a nuclear power plant would be constructed there in the short to medium term.

6. NUCLEAR ACCIDENTS AND ATTACKS

6.1 SAFETY CHALLENGES

In a 2010 paper, academic Benjamin Sovacool documented 99 accidents at nuclear power plants from 1952 to 2009 that resulted in the loss of human life and/or more than US$50,000 of property damage. Of the 99 accidents, 57 occurred since the Chernobyl disaster in 1986, and 56 were in the USA, refuting the notion that severe accidents are relegated to the past or to countries without modern US technology and oversight."[167]

A 2015 study using the same criteria (loss of human life and/or more than US$50,000 of property damage) documents 174 accidents between 1946 and 2014 at nuclear power plants and associated facilities (uranium mines, enrichment plants, etc) and during transportation.[168] The authors note that statistical/empirical analyses of nuclear accidents have "almost universally" found that probabilistic risk assessment "dramatically underestimates the risk of accidents".

The Los Alamos National Laboratory lists 60 criticality accidents − accidental nuclear chain reactions in fissile material such as enriched uranium or plutonium.[169] Of the 60 accidents, 38 occurred at research or experimental facilities such as

[167] Benjamin Sovacool, August 2010, 'A Critical Evaluation of Nuclear Power and Renewable Electricity in Asia', *Journal of Contemporary Asia*, Vol. 40, No. 3, pp.393–400.
See also Benjamin Sovacool, 2008, 'The costs of failure: A preliminary assessment of major energy accidents', *Energy Policy*, Vol. 36, pp.1802-1820.
[168] Spencer Wheatley, Benjamin Sovacool and Didier Sornette, April 2015, 'Of Disasters and Dragon Kings: A Statistical Analysis of Nuclear Power Incidents & Accidents', *Physics and Society*, http://arxiv.org/abs/1504.02380
[169] Monahan S, T McLaughlin, N Pruvost et al., 2000, 'A review of criticality accidents', Los Alamos National Laboratory, www.lanl.gov/news/index.php/fuseaction/home.story/story_id/1054. Direct download: www.orau.org/ptp/Library/accidents/la-13638.pdf

research reactors, while 22 occurred in commercial nuclear facilities.

Claims that the safety of nuclear power is comparable to that of renewable energy sources do not stand up to scrutiny, for the following reasons (among others).

Firstly, and most importantly, nuclear power is the only energy source with multifaceted and repeatedly-demonstrated connections to the proliferation of Weapons of Mass Destruction. Moreover, there are serious proliferation-related security risks such as military attacks on nuclear plants to prevent their use in support of a weapons program (discussed below).

Secondly, claims that the safety of nuclear power is comparable to that of renewable energy sources ignore the long-term cancer death toll from major accidents, in particular Chernobyl and Fukushima. For Chernobyl, the World Health Organization estimates up to 9,000 excess cancer deaths in Belarus, the Russian Federation and Ukraine. Credible estimates of the Chernobyl cancer death toll across Europe range from 16,000[170] to 93,000[171]. For Fukushima, the long-term cancer death toll will be in the thousands. Based on UN data on human radiation exposure, UK radiation biologist Dr Ian Fairlie estimates around 5,000 fatal cancers from Fukushima fallout.[172]

Thirdly, claims that the safety of nuclear power is comparable to that of renewable energy sources ignore or downplay human radiation exposure from routine emissions from the nuclear fuel cycle. The United Nations Scientific Committee on the Effects of Atomic Radiation's estimated collective effective dose to the world population over a 50-year period of operation of nuclear power reactors and associated nuclear fuel cycle facilities is two million person-Sieverts.[173] Applying a risk estimate of 0.05−0.1 fatal cancers per person-Sievert gives a total of 100,000−200,000 fatal cancers.

Fourthly, non-fatal impacts must be considered. For example, the relocation of 350,000 people[174] in the aftermath of the Chernobyl disaster was associated with a great deal of trauma. Four years after the Fukushima disaster, around 80,000 people remain displaced specifically as a result of the nuclear accident. Using those figures, and the global experience of around 14,500 reactor-years of power

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[170] E. Cardis, D. Krewski, et al, 2006, 'Estimates of the Cancer Burden in Europe from Radioactive Fallout from the Chernobyl', *International Journal of Cancer*, Volume 119, Issue 6, pp.1224-1235, www.ncbi.nlm.nih.gov/pubmed/16628547

[171] Greenpeace, 2006, 'The Chernobyl Catastrophe − Consequences on Human Health'. www.greenpeace.org/international/en/publications/reports/chernobylhealthreport/

[172] Ian Fairlie, 2 April 2014, 'New UNSCEAR Report on Fukushima: Collective Doses', www.ianfairlie.org/news/new-unscear-report-on-fukushima-collective-doses/

[173] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1994, 'Ionising Radiation: Sources and Biological Effects', New York: UNSCEAR, www.unscear.org/unscear/en/publications/1994.html

[174] WHO, 26 April 2006, 'World Health Organization report explains the health impacts of the world's worst-ever civil nuclear accident', www.who.int/mediacentre/news/releases/2006/pr20/en/

reactor operations[175], gives a figure of approximately 30 'nuclear refugees' per reactor-year.

Physicist M.V. Ramana challenges "misleading" probabilistic risk assessments (PRA) such as Areva's estimate for its EPR of one core-damage incident per reactor in 1.6 million years, and Westinghouse's claims PDF that for its AP1000 reactors the core melt frequency is roughly one incident per reactor in two million years.[176]

Ramana writes:
"There are both empirical and theoretical reasons to doubt these numbers. A 2003 study on the future of nuclear power carried out by the Massachusetts Institute of Technology points out that "uncertainties in PRA methods and data bases make it prudent to keep actual historical risk experience in mind when making judgments about safety." What does history tell us? Globally, there have been close to 15,000 reactor-years of experience, with well-known severe accidents at five commercial power reactors -- three of them in Fukushima. However, as Thomas Cochran of the Natural Resources Defense Council explained in his recent testimony to the US Senate, depending on how core damage is defined, there are other accidents that should be included. The actuarial frequency of severe accidents may be as high as 1 in 1,400 reactor-years. At that rate, we can expect an accident involving core damage every 1.4 years if nuclear power expands from today's 440 commercial power reactors to the 1,000-reactor scenario laid out in the MIT study. In either case, though, our experience is too limited to make any reliable predictions."

Ramana notes that probabilistic risk assessment suffers from a number of problems and "any conclusions about overall accident probabilities derived from its use are far from dependable". He notes that before the Chernobyl accident, B.A. Semenov, the head of the International Atomic Energy Agency's safety division, said that "a serious loss-of-coolant accident is practically impossible" with Chernobyl-type reactors.

Numerous safety challenges confront the industry, including the following:
- The ageing of the global nuclear workforce and the consequent loss of skills both for the operation of nuclear facilities and for regulatory bodies.
- Safety challenges will be greater in countries developing nuclear power for the first time, especially countries with limited technical and industrial bases, inadequate regulation, and/or widespread corruption.
- The 'bathtub effect' − a likely scenario in the coming 20 years is that an increasing majority of the global fleet of power reactors will be very young or very old, the two phases of a reactor's lifespan when they are most accident-

[175] World Nuclear Association, updated Feb 2015, 'Safety of Nuclear Power Reactors', www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Safety-of-Nuclear-Power-Reactors/
[176] M. V. Ramana, 19 April 2011, 'Beyond our imagination: Fukushima and the problem of assessing risk', *Bulletin of the Atomic Scientists*, http://thebulletin.org/web-edition/features/beyond-our-imagination-fukushima-and-the-problem-of-assessing-risk

prone.[177]
- Inadequate regulation in a number of countries, including advanced nuclear countries such as the US and Japan.
- The potential for commercial imperatives to reduce safety margins.
- Attacks on nuclear plants, whether by nation-states or sub-national groups (terrorists).

An MIT Interdisciplinary Study on the Future of Nuclear Power states:
"We do not believe there is a nuclear plant design that is totally risk free. In part, this is due to technical possibilities; in part due to workforce issues. Safe operation requires effective regulation, a management committed to safety, and a skilled work force."[178]

Serious, unresolved problems remain on all three fronts – regulation, management, and workforce skills. The safety culture varies considerably within and between nations operating nuclear power plants. As the MIT Study notes:
"It is still an open question whether the average performers in the industry have yet incorporated an effective safety culture into their conduct of business."

Regulatory problems include 'captured bureaucracies', the revolving door between regulatory bodies and regulated organisations, and shortages of skilled personnel to adequately carry out regulatory functions.

6.2 AUSTRALIA'S TRACK RECORD

The 2006 Switkowski Review stated:
"There is every reason to be confident that Australia's health and safety systems will continue to provide a sound framework for the management of the uranium mining industry and would enable any other parts of the nuclear fuel cycle envisaged for Australia to be equally well regulated, ensuring the highest levels of health and safety."[179]

However there is a wealth of contrary evidence concerning the record of organisations involved in the nuclear sector in Australia.

In the late 1990s, the federal government undermined the independence of the newly-created regulatory agency, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), by allowing the chief executive of the Australian Nuclear Science and Technology Organisation (ASNTO) to sit on the panel which interviewed applicants for the position of CEO of ARPANSA.

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[177] David Lochbaum, 2004, 'U.S. Nuclear Plants in the 21st Century', Union of Concerned Scientists, www.ucsusa.org/assets/documents/nuclear_power/nuclear04fnl.pdf
[178] Stephen Ansolabehere et al., 2003, 'The Future of Nuclear Power: An Interdisciplinary MIT Study', http://web.mit.edu/nuclearpower/pdf/nuclearpower-full.pdf
[179] Switkowski Review, 2006, 'Uranium Mining, Processing and Nuclear Energy Review', http://pandora.nla.gov.au/tep/66043

The Australian National Audit Office wrote a 2005 report critical of many aspects of ARPANSA's operations.[180] The Audit Office report stated that "deficiencies in planning, risk management and performance management limit ARPANSA's ability to align its regulatory operations with risks, and to assess its regulatory effectiveness." It further stated that "procedures for licensing and monitoring of compliance have not been sufficient" and that arrangements "do not adequately support ... ARPANSA's responsibilities for transparently managing the potential for conflict of interest."

The Australian Nuclear Science and Technology Organisation (ANSTO) also has a poor track record. Tony Wood, former head of the Divisions of Reactors and Engineering at ANSTO's reactor plant in Sydney, has criticised ANSTO for its "misleading public statements" and for "sugar-coating" its information. Mr. Wood said:
"I believe that it is very important that the public be told the truth even if the truth is unpalatable. I have cringed at some of ANSTO's public statements. Surely there is someone at ANSTO with a practical reactor background and the courage to flag when ANSTO is yet again, about to mislead the public."[181]

Mr. Wood also said:
"Another document called the Sutherland Shire Local Disaster Plan is needed to cater for the public. This plan is a most remarkable document. In this case the vulnerable community represents the people in the Sutherland Shire who would be exposed in the event of a reactor accident and it lists a number of hazards to which they might be exposed, such as bushfires, earthquakes, oil spills and aircraft crashes, but there is no mention of radioactivity, among the hazards. In the whole document there is no mention of the words "iodine" or "nuclear" or " reactor" and only one mention of "ANSTO". No one would guess from reading this plan that there was a nuclear reactor in the area."[182]

A culture of secrecy undermines community confidence in ANSTO and has been the subject of frequent criticism. For example a Senate Select Committee noted in 2001:
"The Committee is highly critical of ANSTO's approach to providing documents. Its attitude seems to stem from a culture of secrecy so embedded that it has lost sight of its responsibility to be accountable to the Parliament."[183]

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[180] Australian National Audit Office, 2 March 2005, 'Regulation of Commonwealth Radiation and Nuclear Activities: Australian Radiation Protection and Nuclear Safety Agency', Audit Report No.30 2004–05, www.anao.gov.au/uploads/documents/2004-05_Audit_Report_30.pdf
[181] Tony Wood, 17 Dec 2001, presentation to ARPANSA Public Forum on Replacement Research Reactor Project, www.arpansa.gov.au/pubs/regulatory/opal/forum2.pdf
[182] Tony Wood, 17 Dec 2001, presentation to ARPANSA Public Forum on Replacement Research Reactor Project, www.arpansa.gov.au/pubs/regulatory/opal/forum2.pdf
[183] Senate Select Committee Inquiry into the Contract for a New Reactor at Lucas Heights, Final Report, May 2001, www.aph.gov.au/Parliamentary_Business/Committees/Senate/Former_Committees/lucasheights/index

6.3 ATTACKS ON NUCLEAR PLANTS

Historical examples of military strikes on nuclear plants include the following:

- Israel's destruction of a research reactor in Iraq in 1981.
- the United States' destruction of two smaller research reactors in Iraq in 1991.
- attempted military strikes by Iraq and Iran on each other's nuclear facilities during the 1980-88 war.
- Iraq's attempted missile strikes on Israel's nuclear facilities in 1991.
- Israel's bombing of a suspected nuclear plant in Syria in 2007.

Most of the above examples have been motivated by attempts to prevent weapons proliferation. Nuclear plants might also be targeted with the aim of widely dispersing radioactive material or, in the case of power reactors, disrupting electricity supply.

If and when nuclear-powered nations go to war, they will have to choose between shutting down their power reactors, or taking the risk of attacks potentially leading to widespread, large-scale dispersal of radioactive materials.

Nuclear physicist Richard Garwin poses these questions:
"What happens with a failed state with a nuclear power system? Can the reactors be maintained safely? Will the world (under the IAEA and U.N. Security Council) move to guard nuclear installations against theft of weapon-usable material or sabotage, in the midst of chaos? Not likely."[184]

Incidents at ANSTO's Lucas Heights site in southern Sydney include the following[185]:

- 1983: nine sticks of gelignite, 25 kg of ammonium nitrate (usable in explosives), three detonators and an igniter were found in an electrical substation inside the boundary fence. A detonator was set off but did not detonate the main explosives. Two people were charged.
- 1984: a threat was made to fly an aircraft packed with explosives into the HIFAR reactor; one person was found guilty of public mischief.
- 1985: after vandalism of a pipe, radioactive liquid drained into Woronora river, and this incident was not reported for 10 days. In 1986 an act of vandalism resulted in damage to the sampling pit on the effluent pipeline.
- 2000: in the lead-up to the Sydney Olympics, New Zealand detectives foiled a plot to attack the Lucas Heights reactor by Afghan sympathisers of Osama bin Laden.
- 9 October 2001: NSW and Federal police conducted a search following a bomb threat directed at ANSTO.

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[184] Richard L. Garwin, 2001, 'Can the World Do Without Nuclear Power?', www.solarpeace.ch/solarpeace/Download/20010409_Garwin_NuclearPowerArticle.pdf
[185] Tilman Ruff, 2006, 'Nuclear Terrorism', EnergyScience Coalition Briefing Paper #10, www.energyscience.org.au/FS10%20Nuclear%20Terrorism.pdf

- December 2001: Greenpeace activists easily breach security at the front gate and the back fence of Lucas Heights, some activists scale the reactor while another breaches the 'secure air space' in a paraglider.
- October 2003: French terror suspect Willy Brigitte deported from Australia, held on suspicion of terrorism in France; alleged to have been planning to attack the reactor and to have passed on bomb-making skills to two Australians.
- November 2005: multiple coordinated arrests of terrorist suspects in Sydney and Melbourne. Court documents reveal the Lucas Heights reactor was a potential target. Three of the eight alleged members of the Sydney terror cell had previously been caught near the reactor facility by police in December 2004, each alleged to have given different versions of what they had been doing.
- November 2005: a reporter and photographer were able to park a one-tonne van for more than half an hour outside the Lucas Heights back gate, protected by a simple padlock able to be cut with bolt-cutters, 800 m from the reactor. *The Australian* reported: "The back door to one of the nation's prime terrorist targets is protected by a cheap padlock and a stern warning against trespassing or blocking the driveway."[186]
- A man facing terrorism charges in 2007 had purchased five rocket launchers allegedly stolen from the army. According to a witness statement, the accused purchaser said "I am going to blow up the nuclear place", an apparent reference to Lucas Heights.[187]

6.4 RADIATION AND HEALTH

A number of nuclear lobbyists claim that low-level radiation exposure is harmless.

However, informed scientific opinion holds otherwise. For example, the 2006 report of the US National Academy of Sciences' Committee on the Biological Effects of Ionising Radiation (BEIR) states that "the risk of cancer proceeds in a linear fashion at lower doses without a threshold and … the smallest dose has the potential to cause a small increase in risk to humans."[188]

Likewise, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) states in a 2010 report that "the current balance of available evidence tends to favour a non-threshold response for the mutational component of radiation-associated cancer induction at low doses and low dose rates."[189]

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[186] Jonathan Porter, 19 Nov 2005, 'Nuclear site left exposed at the back door', *The Australian*.
[187] Sally Neighbour, 2 July 2007, 'Nations linked by blood and Islam', *The Australian*.
Charles Ferguson, 9 Jan 2007, 'Nuclear risk could be an inside job', www.smh.com.au/news/opinion/nuclear-risk-could-be-an-inside-job/2007/01/08/1168104921045.html
[188] US Committee on the Biological Effects of Ionising Radiation, US National Academy of Sciences, 2006, 'Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2', www.nap.edu/books/030909156X/html
[189] UNSCEAR, 2010, Report of the United Nations Scientific Committee on the Effects of Atomic Radiation on the Effects of Atomic Radiation 2010', www.unscear.org/docs/reports/2010/UNSCEAR_2010_Report_M.pdf

Likewise, a report in the Proceedings of the National Academy of Sciences states: "Given that it is supported by experimentally grounded, quantifiable, biophysical arguments, a linear extrapolation of cancer risks from intermediate to very low doses currently appears to be the most appropriate methodology."[190]

One topical debate concerns the incidence of childhood leukemias in the vicinity of nuclear power plants (NPP). UK radiation biologist Dr Ian Fairlie notes that data from four European countries reveal "a highly statistically significant 37% increase in childhood leukemias within 5 km of almost all NPPs in the UK, Germany, France and Switzerland. ... So the matter is now beyond question, i.e. there's a very clear association between increased child leukemias and proximity to NPPs. The remaining question is its cause(s)."[191]

Dr Fairlie states:
"The core issue is that, world-wide, over 60 epidemiological studies have examined cancer incidences in children near nuclear power plants (NPPs): most (>70%) indicate leukemia increases. I can think of no other area of toxicology (e.g. asbestos, lead, smoking) with so many studies, and with such clear associations as those between NPPs and child leukemias. Yet many nuclear Governments and the nuclear industry refute these findings and continue to resist their implications. It's similar to the situations with cigarette smoking in the 1960s and with man-made global warming nowadays."[192]

While the overwhelming weight of scientific opinion holds that there is no threshold below which radiation exposure is harmless, there is less scientific confidence about how to quantify the risks. Estimates of the death toll from low-level radiation exposure are sometimes based on the linear no-threshold (LNT) model, a linear extrapolation of better-understood risks from higher levels of exposure − 0.1 cancer deaths per person-Sievert of exposure. Sometimes a lower figure is used, e.g. 0.05 or 0.08 cancer deaths per person-Sievert of exposure.

UNSCEAR and the International Commission on Radiological Protection recommend against using collective dose figures and risk estimates to estimate total deaths, due to the uncertainties that inevitably attend consideration of exposure to low-level radiation. Many nuclear industry representatives and lobbyists take that one step further by falsely conflating uncertain risks with zero risk. Hence the claims that Fukushima (or Chernobyl, or other accidents, or routine emissions) have not resulted in cancer deaths. There is no scientific basis for conflating uncertain risk with zero risk.

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[190] David Brenner et al., 2003, 'Cancer risks attributable to low doses of ionizing radiation: Assessing what we really know', Proceedings of the National Academy of Sciences, November 25, 2003, vol.100, no.24, pp.13761–13766, www.ncbi.nlm.nih.gov/pubmed/14610281
[191] Ian Fairlie, 25 July 2014, 'Childhood Leukemias Near Nuclear Power Stations', www.ianfairlie.org/news/childhood-leukemias-near-nuclear-power-stations-new-article/
[192] Ian Fairlie, 25 July 2014, 'Childhood Leukemias Near Nuclear Power Stations', www.ianfairlie.org/news/childhood-leukemias-near-nuclear-power-stations-new-article/

The LNT model may indeed result in inflated estimates of cancer deaths − but it may also result is underestimates. The above-mentioned BEIR report states that "combined analyses are compatible with a range of possibilities, from a reduction of risk at low doses to risks twice those upon which current radiation protection recommendations are based." Likewise the BEIR report states:
"The committee recognizes that its risk estimates become more uncertain when applied to very low doses. Departures from a linear model at low doses, however, could either increase or decrease the risk per unit dose."

For Fukushima (discussed below), an LNT-based estimate is 5,000 long-term cancer deaths. The true figure may be higher or lower. There is no scientific basis for the frequent claims that radiation exposure from Fukushima will not result in cancer deaths. Likewise, an LNT-based estimate of the Chernobyl cancer death toll is around 60,000 deaths, but the true figure may be higher or lower.[193]

6.5 FUKUSHIMA

The Fukushima nuclear disaster in Japan in 2011 involved nuclear reactor fuel meltdowns, explosions and fires. The 2012 report of Japan's Nuclear Accident Independent Investigation Commission (NAIIC) concluded that the Fukushima disaster was "a profoundly man-made disaster that could and should have been foreseen and prevented" if not for "a multitude of errors and wilful negligence that left the Fukushima plant unprepared for the events of March 11".[194]

Consequences of the Fukushima disaster include:

- The World Health Organisation predicts an increase in the number of all solid cancers, breast cancer, leukaemia and thyroid cancer as a result of radioactive Fukushima fallout.[195] As mentioned, based on UN data on human radiation exposure, UK radiation biologist Dr Ian Fairlie estimates around 5,000 fatal cancers from Fukushima fallout.[196]
- A September 2012 editorial in *Japan Times* noted that 1632 deaths occurred during or after evacuation from the triple-disaster; and nearly half (160,000) of the 343,000 evacuees were dislocated specifically because of the nuclear disaster.[197] A January 2013 article in *The Lancet* notes that "the fact that 47 per cent of disaster-related deaths were recognised in Fukushima prefecture alone

[193] 'Chernobyl − how many died?', 26 April 2014, *The Ecologist*, www.theecologist.org/News/news_analysis/2370256/chernobyl_how_many_died.html
[194] Nuclear Accident Independent Investigation Commission, 2012, http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/
[195] www.who.int/mediacentre/news/releases/2013/fukushima_report_20130228/en/
[196] Ian Fairlie, 2 April 2014, 'New UNSCEAR Report on Fukushima: Collective Doses', www.ianfairlie.org/news/new-unscear-report-on-fukushima-collective-doses/
[197] 'Slow road to reconstruction', 19 Sept 2012, *The Japan Times*, www.japantimes.co.jp/?post_type=opinion&p=8338

indicates that the earthquake-triggered nuclear crisis at the Fukushima power plant caused extreme hardship for local residents."[198]

- Around 160,000 people were evacuated specifically because of the Fukushima accident. Around 80,000 people remain evacuated as of January 2015.[199] The 2012 NAIIC report noted that evacuees "continue to face grave concerns, including the health effects of radiation exposure, displacement, the dissolution of families, disruption of their lives and lifestyles ..."[200] Two years later, the situation has worsened for many evacuees. Around 60% of the remaining evacuees are still living in small temporary housing units.[201]
- The total cost of the disaster will be around US$500 billion according to a study by the American Society of Mechanical Engineers.[202]

The internationally accepted dose limit for members of the public from anthropogenic sources of 1 millisievert per year has been increased to 20 mSv p.a. in areas affected by Fukushima fallout. Assoc. Prof. Tilman Ruff gives some indication of the risks:
"To provide a perspective on these risks, for a child born in Fukushima in 2011 who was exposed to a total of 100 mSv of additional radiation in its first five years of life, a level tolerated by current Japanese policy, the additional lifetime risk of cancer would be on the order of one in thirty, probably with a similar additional risk of premature cardiovascular death."[203]

Prime Minister Shinzo Abe is stridently pro-nuclear but in January 2015 he retracted his early claim that the situation at Fukushima is 'under control'. In January Mr Abe said:
"There [are] a mountain of issues, including contaminated water, decommissioning, compensation and contamination ... When I think of the victims still living in difficult evacuation conditions, I don't think we can use the word 'settled' to describe the Fukushima plant".[204]

Australian uranium was used in the Fukushima reactors. In 2011, Mirarr Senior Traditional Owner Yvonne Margarula wrote to UN Secretary General Ban Ki Moon expressing her sadness at the devastation that uranium from the Ranger uranium mine was causing in Japan: "This is an industry we never supported in the past and

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[198] Ichiseki, Hajime, 19 Jan 2013, 'Features of disaster-related deaths after the Great East Japan Earthquake', The Lancet, Vol.381, Issue 9862, www.thelancet.com/journals/lancet/article/PIIS0140-6736%2813%2960091-4/fulltext
[199] Hiriko Ito, 30 Jan 2015, 'Officials resume lives in radiation-hit town in hope of paving way for mass return', http://ajw.asahi.com/article/0311disaster/fukushima/AJ201501300010
[200] Nuclear Accident Independent Investigation Commission, 2012, http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/
[201] SimplyInfo.org Fukushima Disaster Four Year Report, 10 March 2015, www.fukuleaks.org/web/?p=14550
[202] American Society of Mechanical Engineers, June 2012, 'Forging a New Nuclear Safety Construct: The ASME Presidential Task Force on Response to Japan Nuclear Power Plant Events', www.asme.org/getmedia/73081de8-e963-4557-9498-f856b56dabd1/Forging_a_new_nuclear_safety_construct.aspx
[203] Tilman Ruff, 2013, 'A Public Health Perspective on the Fukushima Nuclear Disaster', *Asian Perspective*, 37, pp.523–549, www.mapw.org.au/files/downloads/AP37-4_Tilman%20Ruff%20%281%29.pdf
[204] Osamu Tsukimori and Mari Saito, Jan 2015, 'Japan looks at 2030 energy targets in shadow of Fukushima cleanup', https://uk.news.yahoo.com/japan-looks-2030-energy-targets-shadow-fukushima-cleanup-111550113.html

want no part of in the future. We are all diminished by the events unfolding at Fukushima," Ms Margarula said.[205]

Uranium mining companies in Australia, and successive federal governments, turned a blind eye to serious problems in Japan's nuclear industry over a long period of time. Those problems included[206]:

- revelations in 2002 that TEPCO had systematically and routinely falsified safety data and breached safety regulations for 25 years or more;
- revelations in 2007 of over 300 incidents of 'malpractice' at Japan's nuclear plants;
- evidence that Japan's nuclear plants were poorly equipped to withstand earthquakes and tsunamis; and
- evidence of manifestly inadequate regulation.

The collusive and sub-standard practices of Japan's nuclear industry led to numerous accidents before the Fukushima accident, and they were a root cause of the Fukushima accident itself. As the NAIIC report said: "The accident was the result of collusion between the government, the regulators and TEPCO, and the lack of governance by said parties."[207]

The patterns that led to the Fukushima disaster are re-emerging in Japan.[208] In other words the 'nuclear village' is back in control. Junko Edahiro, chief executive of Japan for Sustainability and one of the people removed from an energy policy advisory committee by the Abe government, noted in November 2014:
"Now what we have is a situation where government officials and committees are back to doing their jobs as if the March 2011 disasters had never occurred. They have resumed what they had been doing for 30 or 40 years, focusing on nuclear power ... In Japan we have what some people refer to as a 'nuclear village': a group of government officials, industries, and academia notorious for being strongly pro-nuclear. There has been little change in this group, and the regulatory committee to oversee nuclear policies and operations is currently headed by a well-known nuclear proponent."[209]

Japan has steadily slipped down Reporters Without Borders global ranking for press freedom since the Fukushima disaster, from 11th in 2010 to 61st in the latest ranking.[210] Journalists have been threatened with 'criminal contempt' and

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[205] 11 March 2015, 'Four years on: Kakadu Traditional Owners remain saddened by ongoing Fukushima disaster', www.mirarr.net/media_releases/four-years-on-kakadu-traditional-owners-remain-saddened-by-ongoing-fukushima-disaster
[206] March 2012, 'Japan's nuclear scandals and the Fukushima disaster', www.foe.org.au/anti-nuclear/issues/nfc/power/japan
[207] Nuclear Accident Independent Investigation Commission, 2012, http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/
[208] 31 March 2015, 'Atomic zombies: Japan's 'nuclear village' is back in control', Climate Spectator, www.businessspectator.com.au/article/2015/3/31/policy-politics/atomic-zombies-japans-nuclear-village-back-control
[209] Junko Edahiro, Nov 2014, 'Toward a Sustainable Japan: Fukushima Accidents Show Japan's Challenges', JFS Newsletter No.147, www.japanfs.org/en/news/archives/news_id035110.html
[210] Reporters Without Borders: http://index.rsf.org/#!/index-details/JPN

defamation suits, and Japan's 'state secrets' law makes investigative journalism about Japan's nuclear industry a perilous undertaking.[211] Under the law, which took effect in December 2014, the government can sentence those who divulge government secrets − which are broadly defined − to a decade in jail.

One of the ruined Fukushima reactors.

7. RADIOACTIVE WASTE

7.1 GLOBAL EXPERIENCE WITH RADIOACTIVE WASTE.

"The greatest minds in the nuclear establishment have been searching for an answer to the radioactive waste problem for fifty years, and they've finally got one: haul it down a dirt road and dump it on an Indian reservation".
-- Winona LaDuke, Indigenous World Uranium Summit, 2006

Radioactive wastes can be solid, liquid or gaseous and are produced at every stage of the nuclear fuel cycle:

- Underground and open pit uranium mines generate large volumes of long lived, low level waste which is kept on site.
- In-situ leach uranium mines pollute groundwater with radioactive particles, heavy metals and acid.
- Enrichment plants generate large volumes of depleted uranium waste.
- Reactors produce high level radioactive waste in the form of spent nuclear fuel.
- Reactors and other nuclear fuel cycle facilities discharge radioactive emissions to air and water.

Toko Sekiguchi, 13 Feb 2015, 'Japan Slips in Press Freedom Ranking', http://blogs.wsj.com/japanrealtime/2015/02/13/japan-slips-in-press-freedom-rankings/

[211] 12 March 2014, 'Japan – Nuclear lobby still gagging independent coverage three years after disaster', http://foreignaffairs.co.nz/2014/03/12/japan-nuclear-lobby-still-gagging-independent-coverage-three-years-after-disaster/

- Reprocessing plants generate a high level radioactive waste stream.

By far the greatest quantity of nuclear fuel cycle waste is low level waste from the mining and milling of uranium ores (for example the Olympic Dam mine generates 10 million tonnes of low-level tailings waste annually). This includes tailings (finely crushed, solid residues from ore processing), liquid waste from ore processing, and radon gas. There are numerous recorded examples of problems with tailings dams including leaks, spills and dam collapses.[212]

The waste produced in nuclear reactors − called spent nuclear fuel − is orders of magnitude more radioactive than fresh uranium fuel. This is because irradiation of uranium produces many types of radioactive particles. It takes about 200,000 years for the radioactivity of spent fuel to decline to that of the original uranium ore body.

A typical power reactor produces about 30 tonnes of spent nuclear fuel annually.[213] Annually, nuclear power plants around the world produce about 12,000 tonnes of spent fuel, and about 200,000 m3 of low and intermediate level waste.

About 350,000 tonnes of spent fuel have been produced in power reactors around the world. About one third of that amount has been reprocessed and the remainder is stored.

The mass/volume of spent fuel is small compared to that of wastes generated by coal-fired electricity plants. However, there are very large waste streams generated across the nuclear fuel cycle. Moreover, it is not the mass or volume of spent fuel that is of concern but its extreme toxicity, longevity, heat generation, and the fact that it contains plutonium which can be extracted for use in nuclear weapons.

Not a single repository exists anywhere in the world for the disposal of high level waste from nuclear power reactors. Only a few countries have identified a repository site. Sweden and Finland are the most advanced, with repositories under construction.

Plans for a high level waste repository at Yucca Mountain in Nevada, USA, were abandoned in 2009 (although attempts are being made to revive the project). Over 20 years of work was put into the repository plan, and over A$10 billion spent. The repository plan was controversial and subject to occasional scandals. These included a scandal involving the falsification of safety data in relation to groundwater modeling. Studies found that Yucca Mountain could not meet the

[212] World Information Service on Energy, Uranium Project, 2010, Chronology of uranium tailings dam failures, www.wise-uranium.org/mdafu.html
[213] Switkowski Review, 2006, Uranium Mining, Processing and Nuclear Energy Review, http://pandora.nla.gov.au/tep/66043

existing radiation protection standards in the long term and subsequent moves by the US Environmental Protection Agency to weaken radiation protection standards generated controversy.[214]

Shallow repositories for low and short-lived intermediate level waste have been established in over 30 countries. Three repositories in the USA have been closed because of environmental problems. Farmers in the Champagne region of France have taken legal action in relation to a leaking radioactive waste dump. In Asse, Germany, all 126,000 barrels of waste already placed in a repository are being removed because of large-scale water infiltration over a period of two decades.

The MIT *Interdisciplinary Study into the Future of Nuclear Power* notes that if global nuclear output was increased almost three-fold to 1000 GWe, and assuming direct disposal rather than reprocessing, new repository storage capacity equal to the legal limit established for Yucca Mountain (70,000 tonnes) would have to be created somewhere in the world "roughly every three or four years". With a ten-fold increase in nuclear power, new repository storage capacity equal to the legal limit for Yucca Mountain would have to be created somewhere in the world every year. The MIT Interdisciplinary Study notes that "the organizational and political challenges of siting will surely be formidable."[215]

Spent fuel reprocessing

Reprocessing involves dissolving spent nuclear fuel in acid and separating the unused uranium (about 96% of the mass), plutonium (1%) and high level wastes (3%). Most commercial reprocessing takes place in the UK (Sellafield) and France (La Hague). There are smaller plants in India, Russia and Japan. Japan plans to begin large-scale reprocessing at the Rokkasho plant. (In addition, a number of countries have military reprocessing plants.)

Proponents of reprocessing give the following four justifications:

1. Reducing the volume and facilitating the management of high level radioactive waste. However reprocessing does nothing to reduce radioactivity or toxicity, and the overall waste volume, including low and intermediate level waste, is increased.

2. 'Recycling' uranium to reduce reliance on natural reserves. However, only an improbably large expansion of nuclear power would result in any problems with uranium supply this century. Most uranium separated from spent fuel at reprocessing plants is not reused; it is "mostly stockpiled" according to the World Nuclear Association.[216] It contains isotopes such as uranium-232 which complicate

[214] Nuclear Information & Resource Service, www.nirs.org/radwaste/yucca/yuccahome.htm
[215] Stephen Ansolabehere, et al., 2003, 'The Future of Nuclear Power: An Interdisciplinary MIT Study', http://web.mit.edu/nuclearpower/pdf/nuclearpower-full.pdf
[216] World Nuclear Association, 8 Oct 2014, 'Supply of Uranium', www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Uranium-Resources/Supply-of-Uranium/

its use as a reactor fuel. Uranium from reprocessing is used only in France and Russia and accounts for only 1% of global uranium usage.[217]

3. Separating plutonium for use as nuclear fuel. However there is very little demand for plutonium as a nuclear fuel. It is used in 'MOX' reactor fuel (mixed uranium-plutonium oxide), which accounts for about 5% of worldwide nuclear fuel[218], and possibly in a small number of fast neutron reactors.

4. Using plutonium as a fuel so that it can no longer be used in nuclear weapons. However, reactors which can use plutonium as fuel also *produce* plutonium. Moreover, since there is so little demand for plutonium as a reactor fuel, stockpiles of separated plutonium have steadily increased and now amount to about 260 tonnes[219] (enough for 26,000 nuclear weapons). Reprocessing has clearly worsened rather than reduced proliferation risks. Addressing the problem of growing stockpiles of separated plutonium could hardly be simpler – it only requires that reprocessing be slowed, suspended, or stopped altogether.

The main reason reprocessing proceeds is that reprocessing plants act as long-term, de facto storage facilities for spent nuclear fuel. Unfortunately this sets up a series of events which has been likened to the old woman who swallowed a fly – every solution is worse than the problem it was supposed to solve:
1. The perceived need to do something about growing spent fuel stockpiles at reactor sites (not least to maintain or obtain reactor operating licences), coupled with the lack of repositories for permanent disposal, encourages nuclear utilities to send spent fuel to commercial reprocessing plants, which act as long-term, de facto storage sites.
2. Eventually the spent fuel must be reprocessed, which brings with it proliferation, public health and environmental risks.
3. Reprocessing has led to a large and growing stockpile of separated plutonium, which is an unacceptable and unnecessary proliferation risk.
4. Reprocessing creates the 'need' to develop mixed uranium-plutonium fuel (MOX) or fast neutron reactors to make use of the plutonium separated by reprocessing.
5. All of the above necessitates a global pattern of transportation of spent fuel, high level waste, separated plutonium and MOX, with the attendant risks of accidents, terrorist strikes and theft leading to the production of nuclear weapons.

The Switkowski Review[220] stated:

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[217] International Atomic Energy Agency, 2006, 'Nuclear Technology Review 2006', www.iaea.org/OurWork/ST/NE/Pess/assets/ntr2006.pdf
[218] World Nuclear Association, Dec 2014, 'Mixed Oxide (MOX) Fuel', www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Fuel-Recycling/Mixed-Oxide-Fuel-MOX/
[219] International Panel on Fissile Materials, www.fissilematerials.org
[220] Switkowski Review, 2006, Uranium Mining, Processing and Nuclear Energy Review, http://pandora.nla.gov.au/pan/66043/20070301-0000/www.pmc.gov.au/umpner/docs/nuclear_report.pdf

"The complexity of reprocessing plants involving remote handling of highly radioactive and corrosive materials requires expensive facilities and many highly trained staff. ... The only recently constructed commercial scale reprocessing plant (Rokkasho) is estimated to have cost approximately US$18 billion."
"Reprocessing in Australia seems unlikely to be commercially attractive, unless the value of the recovered nuclear fuel increases significantly."

7.2 US DEEP GEOLOGICAL REPOSITORY ACCIDENT

No deep underground repositories for high level nuclear waste exist, however there is one deep underground repository for long lived intermediate-level nuclear waste − the Waste Isolation Pilot Plant (WIPP) in the US state of New Mexico.

On 5 February 2014, a truck hauling salt caught fire at WIPP. Six workers were treated at the Carlsbad hospital for smoke inhalation, another seven were treated at the site, and 86 workers were evacuated. A March 2014 report by the US Department of Energy identified the root cause of the fire as the "failure to adequately recognize and mitigate the hazard regarding a fire in the underground." In 2011, the Defense Nuclear Facilities Safety Board, an independent advisory board, reported that WIPP "does not adequately address the fire hazards and risks associated with underground operations."[221]

In a separate incident on 14 February 2014, a heat-generating chemical reaction ruptured one of the barrels stored underground at WIPP, and this was followed by a failure of the filtration system which was meant to ensure that radiation did not reach the outside environment. Twenty-two workers were exposed to low-level radiation, the total cost to fix up the problems will exceed $500 million, and WIPP will be shut for at least four years.[222]

A US government report blamed the barrel rupture and radiation release on the operator and regulator of WIPP, noting their "failure to fully understand, characterize, and control the radiological hazard ... compounded by degradation of key safety management programs and safety culture."[223]

A safety analysis conducted before WIPP opened predicted that one radiation release accident might occur every 200,000 years.[224] On the basis of real-world

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[221] 6 June 2014, 'Fire and leaks at the world's only deep geological waste repository', Nuclear Monitor #787, www.wiseinternational.org/node/4245
[222] 27 Nov 2014, 'New Mexico nuclear waste accident a 'horrific comedy of errors' that exposes deeper problems', *The Ecologist*, www.theecologist.org/News/news_analysis/2642182/new_mexico_nuclear_waste_accident_a_horrific_comedy_of_errors_that_exposes_deeper_problems.html
[223] US Dept of Energy, Office of Environmental Management, April 2014, 'Accident Investigation Report: Phase 1: Radiological Release Event at the Waste Isolation Pilot Plant on February 14, 2014', http://energy.gov/em/downloads/radiological-release-accident-investigation-report
[224] Matthew Wald, 29 Oct 2014, 'In U.S. Cleanup Efforts, Accident at Nuclear Site Points to Cost of Lapses', www.nytimes.com/2014/10/30/us/in-us-cleanup-efforts-accident-at-nuclear-site-points-to-cost-of-lapses.html

experience, that estimate needs to be revised upwards to over 13,000 accidents over a 200,000 year period.

A troubling aspect of the WIPP problems is that complacency and cost-cutting set in just 10−15 years after the repository opened. Earl Potter, a lawyer who represented Westinghouse, WIPP's first operating contractor, said:
"At the beginning, there was an almost fanatical attention to safety. I'm afraid the emphasis shifted to looking at how quickly and how inexpensively they could dispose of this waste." Likewise, Rick Fuentes, president of the Carlsbad chapter of the United Steelworkers union, said: "In the early days, we had to prove to the stakeholders that we could operate this place safely for both people and the environment. After time, complacency set in. Money didn't get invested into the equipment and the things it should have."[225]

Complacency and cost-cutting set in just 10−15 years after WIPP opened. The half-life of plutonium-239, one of the components in the WIPP waste, is 24,100 years.

7.3 AUSTRALIAN EXPERIENCES WITH RADIOACTIVE WASTE

"The disposal of radioactive waste in Australia is ill-considered and irresponsible. Whether it is short-lived waste from Commonwealth facilities, long-lived plutonium waste from an atomic bomb test site on Aboriginal land, or reactor waste from Lucas Heights. The government applies double standards to suit its own agenda; there is no consistency, and little evidence of logic."
− Nuclear engineer Alan Parkinson[226]

Maralinga 'clean up'

The British government conducted 12 nuclear bomb tests in Australia in the 1950s, most of them at Maralinga. The 1985 Royal Commission found that regard for Aboriginal safety was characterised by "ignorance, incompetence and cynicism".[227]

In the late-1990s, the Australian government carried out a clean-up of the Maralinga nuclear test site.[228] It was done on the cheap and many tonnes of plutonium-contaminated debris remain buried in shallow, unlined pits in totally unsuitable geology. The government said the Maralinga clean-up was 'world's best

[225] Patrick Malone, 14 Feb 2015, 'Repository's future uncertain, but New Mexico town still believes', www.santafenewmexican.com/special_reports/from_lanl_to_leak/repository-s-future-uncertain-but-new-mexico-town-still-believes/article_38b0e57b-2d4e-5476-b3f5-0cfe81ce94cc.html
[226] Alan Parkinson, 2002, 'Double standards with radioactive waste', *Australasian Science*, www.foe.org.au/anti-nuclear/issues/oz/britbombs/clean-up
[227] www.foe.org.au/anti-nuclear/issues/oz/britbombs/
[228] www.foe.org.au/anti-nuclear/issues/oz/britbombs/clean-up

practice' even though it breached Australian standards for the management of long-lived nuclear waste.[229]

Nuclear engineer and whistleblower Alan Parkinson said of the 'clean-up': "What was done at Maralinga was a cheap and nasty solution that wouldn't be adopted on white-fellas land."

Scientist and whistleblower Dale Timmons said the government's technical report was littered with "gross misinformation".[230]

An officer with the Commonwealth nuclear regulator ARPANSA said that the 'clean-up' was beset by a "host of indiscretions, short-cuts and cover-ups".

Nuclear physicist Prof. Peter Johnston (now with ARPANSA) noted that "there were ... very large expenditures and significant hazards resulting from the deficient management of the project by DEST [the Department of Education, Science and Training]."[231]

Prof. Johnston also commented on plans for a national repository in SA (from 1998−2004):
"DEST is responsible for the Former Nuclear Test site at Maralinga, as well as the Repository project. DEST was an ineffective manager of the Maralinga Cleanup in a number of key ways. The pattern of contracting ... services for the Repository project is similar to the Maralinga cleanup. ... The applicant has inadequate technical competence to manage its contractors."[232]

In 2011, barely a decade after the Maralinga 'clean-up', a survey revealed that 19 of the 85 contaminated debris pits have been subject to erosion or subsidence.[233] The half-life of plutonium-239, one of the components in the WIPP waste, is 24,100 years.

Abandoned plan for a national radioactive waste facility in SA

In 1998, the Howard government announced its intention to build a radioactive waste dump near Woomera in South Australia for Australia's stockpile of about 4000 m3 of low and intermediate level waste.

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[229] Alan Parkinson, 'DEST National Radioactive Waste Repository, A Second Round Submission to ARPANSA', www.foe.org.au/sites/default/files/ParkinsonARPANSA2004.doc
[230] http://pandora.nla.gov.au/pan/30410/20090218-0153/www.geocities.com/jimgreen3/martac.html
[231] 2004, Submission to ARPANSA inquiry into proposed repository in SA, www.foe.org.au/anti-nuclear/issues/oz/britbombs/clean-up
[232] 2004, Submission to ARPANSA inquiry into proposed repository in SA, www.foe.org.au/anti-nuclear/issues/oz/britbombs/clean-up
[233] Philip Dorling, 12 Nov 2011, 'Maralinga sites need more repair work, files show', www.theage.com.au/national/maralinga-sites-need-more-repair-work-files-show-20111111-1nbpp.html

Leading the battle against the dump were the Kupa Piti Kungka Tjuta[234], a council of senior Aboriginal women from northern SA. Many of the Kungkas personally suffered the impacts of the British nuclear bomb tests at Maralinga and Emu in the 1950s.

The proposed dump generated such controversy in SA that the federal government hired a public relations company.[235] Correspondence between the company and the government was released under Freedom of Information laws. In one exchange, a government official asks the PR company to remove sand-dunes from a photo to be used in a brochure.[236] The explanation provided by the government official was that: "Dunes are a sensitive area with respect to Aboriginal Heritage". The sand-dunes were removed from the photo, only for the government official to ask if the horizon could be straightened up as well.

In 2003, the federal government used the Lands Acquisition Act 1989 to seize land for the dump. Native Title rights and interests were extinguished with the stroke of a pen. This took place with no forewarning and no consultation with affected Aboriginal people.

The Kungkas continued to implore the federal government to 'get their ears out of their pockets', and after six long years the government did just that. In the lead-up to the 2004 federal election, with the dump issue deeply unpopular, and the Federal Court having rejected the government's use of urgency provisions in the Lands Acquisition Act, the Howard government decided to abandon the repository plan.

Abandoned plan for a national radioactive waste facility in the NT

The Howard government announced in July 2005 that the Northern Territory would host a national radioactive waste dump, like it or not. The nomination of the Muckaty site in the NT was made with the promise of $12 million compensation package comprising roads, houses and scholarships. Traditional Owner Kylie Sambo said: "I think that is a very, very stupid idea for us to sell our land to get better education and scholarships. As an Australian we should be already entitled to that."

The Howard government passed legislation − the Commonwealth Radioactive Waste Management Act − overriding the Aboriginal Heritage Act and the Aboriginal Land Rights Act, and allowing the imposition of a nuclear dump with no Aboriginal consultation or consent.

The Labor Party voted against the Commonwealth Radioactive Waste Management Act, with Labor parliamentarians describing it as "extreme",

[234] http://web.archive.org/web/20080718193150/http:/www.iratiwanti.org/home.php3
[235] http://pandora.nla.gov.au/pan/30410/20090218-0153/www.geocities.com/jimgreen3/wasteleak.html
[236] www.foe.org.au/anti-nuclear/issues/oz/nontdump/mw

"arrogant", "draconian", "sorry", "sordid", and "profoundly shameful". At its 2007 national conference, Labor voted unanimously to repeal the legislation. Yet after the 2007 election, the Labor government passed legislation − the National Radioactive Waste Management Act (NRWMA) [237] − which was almost as draconian and still permitted the imposition of a nuclear dump with no Aboriginal consultation or consent.

Both Labor and the Liberal/National Coalition voted in support of the NRWMA.

A small group of Traditional Owners supported the dump but a much larger group were opposed[238] and some initiated legal action[239] in the Federal Court challenging the nomination of the Muckaty site by the federal government and the Northern Land Council (NLC).

The Federal Court trial finally began in June 2014. After two weeks of evidence, the NLC gave up and the federal government acceded to the NLC's request not to proceed with the Muckaty nomination.[240] The announcement came just days before the NLC and government officials were due to take the stand to face cross-examination. Kylie Sambo said: "I believe [the NLC] didn't want to go through that humiliation of what they really done. But it's better now that they actually backed off. It's good for us."

Marlene Nungarrayi Bennett said:
"*Today will go down in the history books of Indigenous Australia on par with the Wave Hill Walk-off, Mabo and Blue Mud Bay. We have shown the Commonwealth and the NLC that we will stand strong for this country. The NLC tried to divide and conquer us but they did not succeed.*"[241]

Federal Industry Minister Ian Macfarlane characterised the Muckaty process as a "disaster".[242]

As of April 2015, attempts are underway to secure a site for a national radioactive waste facility. Nominations are being sought from interested landholders.

7.4 NUCLEAR POWER IN AUSTRALIA − HOW MUCH WASTE?

[237] www.foe.org.au/anti-nuclear/issues/oz/nontdump/feb2010
[238] www.beyondnuclearinitiative.com/
[239] ABC Lateline, 13 March 2012, 'NT step closer to nuclear waste dump', www.abc.net.au/lateline/content/2012/s3452671.htm
[240] Elizabeth O'Shea, 19 June 2014, 'Muckaty nuclear dump defeat is a huge victory for Aboriginal Australia', www.theguardian.com/commentisfree/2014/jun/19/muckaty-nuclear-dump-defeat-is-a-huge-victory-for-aboriginal-australia
[241] www.foe.org.au/muckaty-winnerz
[242] ABC, 16 Aug 2014, 'Failed Muckaty nuclear dump process 'a disaster', Federal Industry Minister Ian MacFarlane says', www.abc.net.au/news/2014-08-14/muckaty-nuke-dump-process-a-disaster-minister/5669980

Former Chair of the Board of the Australian Nuclear Science and Technology Organisation, Ziggy Switkowski, has been promoting the construction of 50 nuclear power reactors in Australia.[243]

Over a 50-year lifespan, 50 (1 GW) reactors would:

- be responsible for 1.8 billion tonnes of low-level radioactive tailings waste (assuming the uranium came from Olympic Dam).
- be responsible for 430,000 tonnes of depleted uranium waste.
- produce 75,000 tonnes of high-level nuclear waste (approx. 25,000 cubic metres).
- produce 750,000 cubic metres of low-level waste and intermediate level waste.
- produce 750 tonnes of plutonium, enough for 75,000 nuclear weapons.

As the Switkowski Review noted:
"Establishing a nuclear power industry would substantially increase the volume of radioactive waste to be managed in Australia and require management of significant quantities of HLW [high level waste]."[244]

The Switkowski Review stated that with a nuclear power industry in Australia, a repository would be required for the more voluminous low level wastes soon after start-up. The smaller volumes of long-lived intermediate and high level waste could be managed initially through interim storage, followed by deep geological disposal.

Former Liberal Party Senator Nick Minchin has commented on the difficulty of managing wastes from a nuclear power program:
"My experience with dealing with just low level radioactive waste from our research reactor tells me it would be impossible to get any sort of consensus in this country around the management of the high level waste a nuclear reactor would produce."[245]

7.5 SHOULD SOUTH AUSTRALIA ACCEPT HIGH LEVEL NUCLEAR WASTE FROM OVERSEAS?

History

No country has ever imported spent nuclear fuel or high-level nuclear waste as a commercial venture (other than the import of spent fuel for reprocessing).

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[243] Ziggy Switkowski, 3 Dec 2009, 'Australia must add a dash of nuclear ambition to its energy agenda', www.smh.com.au/opinion/politics/australia-must-add-a-dash-of-nuclear-ambition-to-its-energy-agenda-20091201-k3pq.html
[244] Switkowski Review, 2006, Uranium Mining, Processing and Nuclear Energy Review, http://pandora.nla.gov.au/tep/66043
[245] Brad Crouch, 21 May 2006, 'No nuke plant in 100 years', *The Advertiser*.

There is a precedent to current discussions about establishing an international high-level nuclear waste repository in Australia. Pangea Resources was an international consortium that was planning such a repository in Australia.[246] Pangea set up an office in Australia in the late 1990s but gave up in 2002 in the face of overwhelming public opposition. The existence of Pangea Resources was a closely-guarded secret until a corporate video was leaked to the media. Pangea chief Jim Voss denied meeting with federal government ministers when he had in fact met at least one minister. A Pangea spokesperson said: "We would not like to be lying ... we very much regret getting off on the wrong foot."

Economics

How much money might be made by taking nuclear waste from other countries? There is no precedent to base an estimate on.

It is doubtful whether it would generate any more than a fraction of the revenue that Liberal Senator Sean Edwards thinks it might. He thinks the income would cover the cost of building nuclear power reactors, it would enable the supply of free electricity to South Australians, and it would supplant the $4.4 billion in state taxes paid by South Australians each year.[247]

There are many constraints, such as the fact that some of the major nuclear countries − such as Russia, France, and India − reprocess their spent nuclear fuel so would be unlikely to want to send it to Australia. BHP Billiton's submission to the Switkowski Review states that the utilities to which it sells uranium "generally regard their spent fuel as an asset".[248]

Some nuclear proponents believe that spent nuclear fuel is a "multi-trillion dollar asset"[249] − because it can be processed for reuse as reactor fuel − and they also believe that countries will pay "tens of billions of dollars"[250] to relieve themselves of this multi-trillion dollar asset.

Former Prime Minister Bob Hawke said Australia could end the disadvantage endured by indigenous people by opening up traditional lands as dumping sites for nuclear waste from around the world.[251] But there are simpler and safer

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[246] www.foe.org.au/anti-nuclear/issues/oz/import-waste
[247] Sean Edwards, 18 Mar 2015, 'Greenies are holding up a clean energy future by opposing nuclear', www.abc.net.au/environment/articles/2015/03/18/4199992.htm
Sean Edwards, 20 March 2015, 'Greens exposed on nuclear storage', www.senatoredwards.com.au/Media/MediaReleases/tabid/89/articleType/ArticleView/articleId/145/Greens-exposed-on-nuclear-storage.aspx
[248] http://web.archive.org/web/20070830182528/www.pmc.gov.au/umpner/submissions/223_sub_umpner.pdf
[249] http://decarbonisesa.com/2012/02/22/a-matter-of-waste-latest-in-the-sacome-series/
[250] http://theconversation.com/royal-commission-into-nuclear-will-open-a-world-of-possibilities-37363
[251] Oliver Milman, 3 Aug 2014, 'Bob Hawke: nuclear waste storage could end Indigenous disadvantage', www.theguardian.com/world/2014/aug/03/bob-hawke-nuclear-waste-storage-could-end-indigenous-disadvantage?CMP=twt_gu

methods to close the gap. For example, the federal government could reverse planned cuts of $500 million from indigenous spending over the next five years.

Public health and environmental considerations

Professor John Veevers from Macquarie University wrote in *Australian Geologist* about the serious public health and environmental risks associated with a high-level nuclear waste repository:
"Tonnes of enormously dangerous radioactive waste in the northern hemisphere, 20,000 kms from its destined dump in Australia where it must remain intact for at least 10,000 years. These magnitudes − of tonnage, lethality, distance of transport, and time − entail great inherent risk."[252]

Dr Mike Sandiford from the School of Earth Sciences at University of Melbourne writes:
"Australia is relatively stable but not tectonically inert, and appears to be less stable than a number of other continental regions. Some places in Australia are surprisingly geologically active. We occasionally get big earthquakes in Australia (up to about magnitude 7) and the big ones have tended to occur in somewhat unexpected places like Tennant Creek. The occurrences of such earthquakes imply that we still have much to learn about our earthquake activity. From the point of view of long-term waste disposal this is very important, since prior to the 1988 (M 6.8) quake, Tennant Creek might have been viewed as one of the most appropriate parts of the continent for a storage facility. Australia is not the most stable of continental regions, although the levels of earthquake risk are low by global standards. To the extent that past earthquake activity provides a guide to future tectonic activity, Australia would not appear to provide the most tectonically stable environments for long-term waste facilities. However, earthquake risk is just one of the 'geologic' factors relevant to evaluating long-term integrity of waste storage facilities, and other factors such as the groundwater conditions, need to be evaluated in any comprehensive assessment of risk."[253]

There are social as well as technical dimensions to risk assessments. For example, the 'clean-up' of Maralinga was badly mishandled because the government officials had little or no project management experience and little or no understanding of the technical risks, and because the federal government wasn't prepared to spend the money to carry out the clean-up properly.[254]

Moral arguments

Some argue that Australia has a moral responsibility to accept the high-level nuclear waste arising from the use of Australian uranium in power reactors

[252] J.J. Veevers, 'Disposal of British RADwaste at home and in antipodean Australia', http://web.archive.org/web/20120410062832/http:/eps.mq.edu.au/media/veevers1.htm
[253] ABC, 'Ask an Expert', www.abc.net.au/science/expert/realexpert/nuclearpower/08.htm
[254] www.foe.org.au/anti-nuclear/issues/oz/britbombs/clean-up

overseas. In fact and in practice, the responsibility for managing nuclear waste lies with the countries that make use of Australian uranium. There are no precedents for Australia or any other country being morally or legally responsible for managing wastes arising from the use of exported fuels, or from the export of any other products.

If any moral responsibility lies with Australia, that responsibility arguably rests with the uranium mining companies (which are foreign-owned or majority foreign-owned) rather than with Australian citizens or federal or state governments. Such responsibility could be framed in 'cradle-to-grave' or life-cycle stewardship arguments of corporate social responsibility.

One plausible scenario is uranium being mined on Aboriginal land regardless of Aboriginal opposition, and high level nuclear waste being dumped on Aboriginal land, again without consent. That scenario is immoral twice over.

It is also argued that Australia has a moral responsibility to accept high-level nuclear waste because Australia has more suitable geology than other countries, and/or or a more stable political system. Those arguments rest on questionable assumptions. Australia is less tectonically stable than a number of other continental regions according to Dr Mike Sandiford.[255] On the basis of the flawed Maralinga clean-up, there is no reason to believe that a high-level nuclear repository (or a waste-to-fuel recycling project) would be carefully and responsibly managed in Australia, or that regulation would be rigorous and independent.

The Northern Territory Minerals Council has questioned whether Australia has an obligation to accept nuclear waste:
"In terms of the proposition of taking back nuclear waste, that should be viewed as an economic rather than a moral decision. I do not think that it follows, as some have said, that because we produce uranium we have a moral obligation to take back spent fuel rods and the like. The vast quantity of economic benefit is derived by those producing power and selling it down the track. The percentage we derive from selling the product is minuscule. If it makes economic sense, by all means look at it on that economic and scientific basis, but I do not think there is a moral obligation to do it."[256]

Likewise, Alan Layton from the Association of Mining and Exploration Companies said:
"The only observation I would make is that there is probably an argument that there is some safety in burying the wastes close to where the product is used,

[255] ABC, 'Ask an Expert', www.abc.net.au/science/expert/realexpert/nuclearpower/08.htm
[256] House of Representatives – Federal Standing Committee on Industry and Resources, Dec 2006, 'Australia's uranium: Greenhouse friendly fuel for an energy hungry world', ch.12, www.aph.gov.au/Parliamentary_Business/Committees/House_of_Representatives_Committees?url=isr/uranium/report.htm

rather than transporting them. I am not certain about this notion that when we sell uranium we necessarily have to take back its wastes."[257]

Proliferation arguments

It is argued that Australia would be making a contribution to global non-proliferation efforts by accepting nuclear waste from overseas. However it is not clear that non-proliferation efforts would be advanced − it would depend on many factors. Australia's acceptance of high-level nuclear waste would add to the number of countries with significant stockpiles of fissile material − in that sense it would contribute to proliferation risks, not to the resolution of those risks.

BHP Billiton's submission to the Switkowski Review stated:
"BHP Billiton believes that there is neither a commercial nor a non-proliferation case for it to become involved in front-end processing or for mandating the development of fuel leasing services in Australia. ... There is no evidence that a change to current Australian Government policies to facilitate domestic enrichment, fuel leasing and high level waste disposal would lead to significant economic opportunities or reduce proliferation risks in the foreseeable future."[258]

[257] House of Representatives – Federal Standing Committee on Industry and Resources, Dec 2006, 'Australia's uranium: Greenhouse friendly fuel for an energy hungry world', transcript of hearings, 23 Sept 2005, http://parlinfo.aph.gov.au/parlInfo/download/committees/commrep/8750/toc_pdf/4256-2.pdf;fileType=application%2Fpdf#search=%22committees/commrep/8750/0000%22

[258] http://web.archive.org/web/20070830182528/www.pmc.gov.au/umpner/submissions/223_sub_umpner.pdf