Analyse, inform and activate

LAKA

Analyseren, informeren, en activeren

Stichting Laka: Documentatie- en onderzoekscentrum kernenergie

De Laka-bibliotheek

Dit is een pdf van één van de publicaties in de bibliotheek van Stichting Laka, het in Amsterdam gevestigde documentatie- en onderzoekscentrum kernenergie.

Laka heeft een bibliotheek met ongeveer 8000 boeken (waarvan een gedeelte dus ook als pdf), duizenden kranten- en tijdschriftenartikelen, honderden tijdschriftentitels, posters, video's en ander beeldmateriaal. Laka digitaliseert (oude) tijdschriften en boeken uit de internationale antikernenergiebeweging.

De catalogus van de Laka-bibliotheek staat op onze site. De collectie bevat een grote verzameling gedigitaliseerde tijdschriften uit de Nederlandse antikernenergie-beweging en een verzameling video's.

Laka speelt met oa. haar informatievoorziening een belangrijke rol in de Nederlandse anti-kernenergiebeweging.

The Laka-library

This is a PDF from one of the publications from the library of the Laka Foundation; the Amsterdam-based documentation and research centre on nuclear energy.

The Laka library consists of about 8,000 books (of which a part is available as PDF), thousands of newspaper clippings, hundreds of magazines, posters, video's and other material.
Laka digitizes books and magazines from the international movement against nuclear power.

The catalogue of the Laka-library can be found at our website. The collection also contains a large number of digitized magazines from the Dutch anti-nuclear power movement and a video-section.

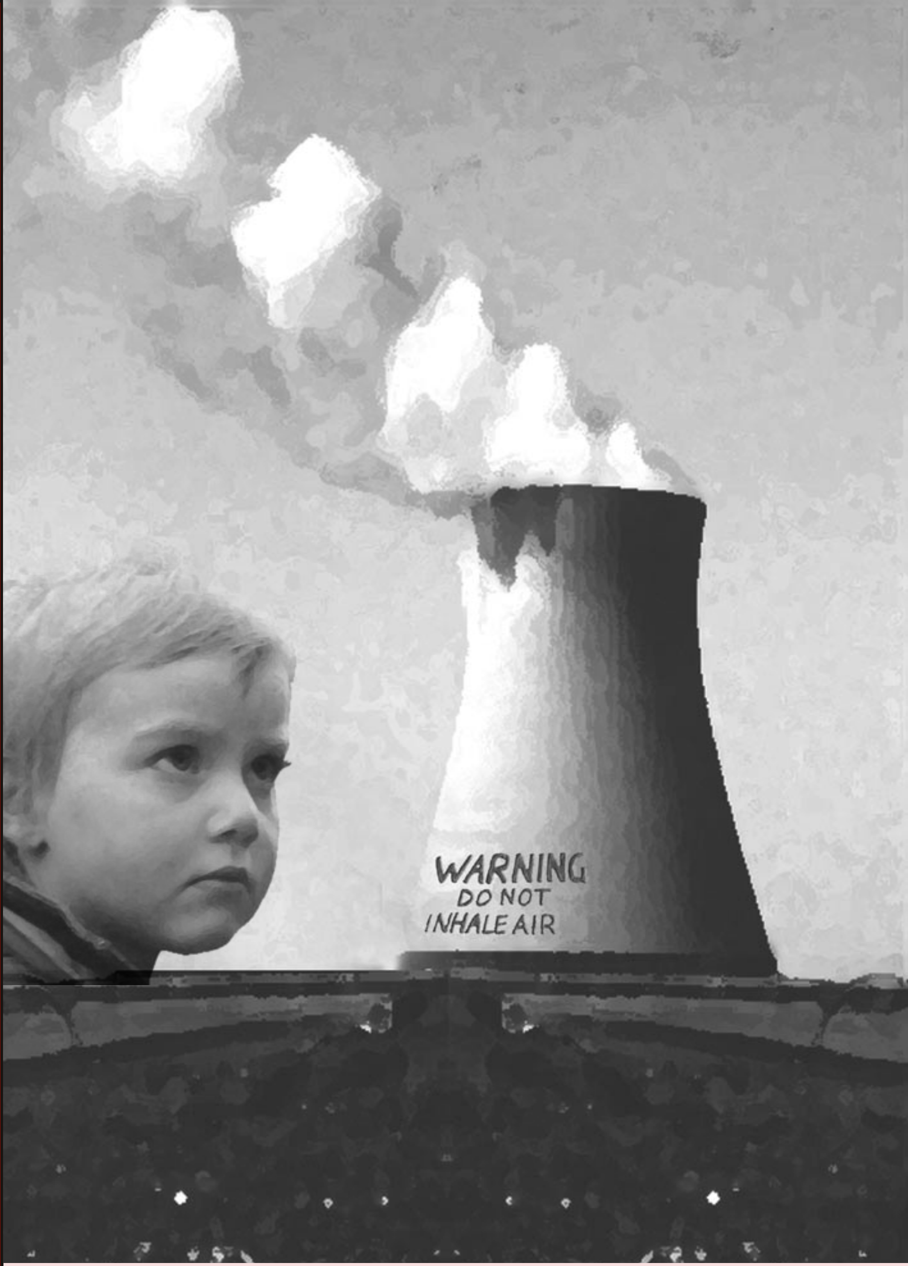
Laka plays with, amongst others things, its information services, an important role in the Dutch anti-nuclear movement.

Appreciate our work? Feel free to make a small donation. Thank you.

www.laka.org | info@laka.org | Ketelhuisplein 43, 1054 RD Amsterdam | 020-6168294

nuclear power
no solution to climate change

September, 2005



scroll down

nuclear power

no solution to climate change

September, 2005

A paper prepared for Friends of the Earth (Australia), the Australian Conservation Foundation, Greenpeace Australia Pacific, the Medical Association for the Prevention of War, the Public Health Association of Australia and the Climate Action Network of Australia.

Written by Dr. Jim Green (national nuclear campaigner, Friends of the Earth). Friends of the Earth would like to acknowledge financial support provided for this project by Australian Ethical Investment, the Australian Conservation Foundation and Greenpeace Australia Pacific.

Friends of the Earth

Australian Conservation Foundation

GREENPEACE

PUBLIC HEALTH ASSOCIATION of Australia Inc

CANA
CLIMATE ACTION NETWORK AUSTRALIA

back to table of contents

table of contents

back to table of contents

foreword

By Professor Ian Lowe

The debate about nuclear energy is a welcome recognition of the urgent need to respond to climate change. I welcome that awareness and the resulting debate, but the nuclear option is not a wise response. It is too costly, too dangerous, too slow and makes too little impact on greenhouse pollution. That is why most of the developed world is rejecting the nuclear option in favour of renewable energy and improved efficiency.

There is no serious doubt that climate change is real; it is happening now and its effects are accelerating. It is already causing serious economic impact such as reduced agricultural production, increased costs of severe events such as fires and storms, and the need to consider radical water-supply measures such as desalination plants. So we should set a serious target for reducing our rate of releasing carbon dioxide, like Britain's goal of 60 per cent by 2050. The Australian policy vacuum is a failure of moral leadership and also an uncertain investment framework.

The economics of nuclear power just don't stack up. The real cost of nuclear electricity is certainly more than for wind power, energy from bio-wastes and some forms of solar energy. Geothermal energy from hot dry rocks also promises to be less costly than nuclear. That is without including the huge costs of decommissioning power reactors and storing the radioactive waste. So there is no economic case for nuclear power. As energy markets have liberalised around the world, investors have turned their backs on nuclear energy. The number of reactors in western Europe and the United States peaked 15 years ago and has been declining since. By contrast, the amount of wind power and solar energy is rising at rates of 20 to 30 per cent a year.

Reducing energy waste is the cheapest way to reduce greenhouse pollution. For instance, more than 10 per cent of household electricity is used by keeping appliances such as TVs and videos on standby.

Nuclear power is too dangerous – not just the risk of accidents such as Chernobyl, but the increased risk of nuclear weapons or nuclear terrorism. The recent United Nations conference on the Nuclear Non-Proliferation Treaty ended in disarray. Most countries

back to table of contents

holding weapons and some others aspiring to join the nuclear "club" are in breach of the treaty.

It's possible this debate will do little more than provide a smokescreen for proponents of increased uranium mining in Australia. Uranium mining should not be expanded. It remains the case, as the Ranger Inquiry found nearly 30 years ago, that increased export of Australian uranium would contribute to the proliferation of nuclear weapons.

Nuclear power also inevitably produces radioactive waste that will have to be stored safely for hundreds of thousands of years. After nearly 50 years of the nuclear power experiment, nobody has yet demonstrated a solution to this problem. In the absence of a viable solution, expanding the rate of waste production is just irresponsible.

Nuclear power is too slow and too limited in its capacity to make a difference. Even if all government approvals were granted, it would still take about 10 more years and several billion dollars to construct a power station and deliver the first electricity.
Nuclear power won't stop climate change. The argument that it would reduce greenhouse pollution presumes high-grade uranium ores are available. Even with such high-grade ores, there is a massive increase in greenhouse pollution from mining, processing and reactor construction before any electricity is generated. The known resources of high-grade uranium ores only amount to a few decades' use at the present rate, so an expansion of nuclear power would see those resources rapidly depleted.

To avoid dangerous further changes to our climate, we need to act now. We should make a commitment to the sensible alternatives that produce sustainable cost-effective reductions in greenhouse pollution: wind power, solar water-heating, energy efficiency, gas and energy from organic matter such as sewage and waste.

Nuclear power is expensive, slow and dangerous, and it won't stop climate change. If nuclear power is the answer, it must have been a pretty stupid question.

Ian Lowe is Emeritus Professor of Science, Technology and Society at Griffith University, Brisbane. One of Australia's best-known environmental scientists, he is president of the Australian Conservation Foundation.

back to table of contents

1. executive summary

Over the past year the nuclear power industry has once again tried to exploit concern about climate change to reverse its ongoing decline.

One positive aspect of this debate is that it has highlighted the need for action to avert the adverse social and environmental impacts associated with climate change. The debate has shifted – the science has been accepted and we are now debating solutions.

It is widely accepted that global greenhouse gas emissions must be reduced by at least 60% by the middle of the century to stabilise atmospheric concentrations of greenhouse gases. We urgently need to change the way we produce and consume energy, and it is now clear that Australia and other countries cannot continue to rely on coal for electricity generation without major climate impacts.

Key environmental and medical groups reject nuclear power as a method of reducing greenhouse gas emissions. Nuclear power poses unacceptable proliferation and security risks, it is not clean, it is not cheap, and there is no solution to the intractible problem of nuclear waste.

The true climate-friendly solutions to Australia's energy and greenhouse problems lie in the fields of renewable energy – such as wind and solar power – and stopping energy wastage. This report shows that nuclear power is a dangerous and inefficient way to address climate change. It also shows why policy-makers should focus on the practical benefits provided by renewable energy and energy efficiency – safe, proven technologies available now.

the false nuclear 'debate' – a front for expanding uranium mining

The nuclear industry, long in decline in Europe and the US, has seized on climate change to promote nuclear power as a 'climate friendly' energy source. However, there is little political support for the introduction of nuclear power in Australia.

Nuclear power is currently unlawful under the 1998 Australian Radiation Protection and Nuclear Safety Act, while Victoria and New South Wales also have legislation

back to table of contents

banning nuclear power and nuclear waste storage and disposal. Three other states – South Australia, Western Australia and the Northern Territory – have legal prohibitions against various forms of radioactive waste transportation and dumping.

In Australia, nuclear interests are far more concerned to expand uranium mining rather than to promote the introduction of nuclear power reactors.

The adverse environmental impacts of uranium mining in Australia have been significant. This year's prosecution of ERA over its operations at the Ranger uranium mine in the Northern Territory highlights the risks. The Olympic Dam uranium/copper mine in South Australia illustrates the scale of the environmental impacts associated with uranium mining. The Olympic Dam mine has produced a radioactive tailings dump of 60 million tonnes, growing at 10 million tonnes annually with no plans for its long-term management. The mine's daily extraction of over 30 million litres of water from the Great Artesian Basin has adversely impacted on the fragile Mound Springs, and the mine is a large consumer of electricity and a major contributor to South Australia's greenhouse gas emissions. (ACF, 2005C.)

A further concern is that the current regulatory environment for uranium mining is inadequate. For example, the Olympic Dam mine enjoys a range of exemptions from the South Australian Environmental Protection Act, the Water Resources Act, the Aboriginal Heritage Act and the Freedom of Information Act. (ACF, 2005C.)

A 2003 Senate inquiry into the regulation of uranium mining in Australia reported "a pattern of under-performance and non-compliance", it identified "many gaps in knowledge and found an absence of reliable data on which to measure the extent of contamination or its impact on the environment", and it concluded that changes were necessary "in order to protect the environment and its inhabitants from serious or irreversible damage". (Senate References and Legislation Committee, 2003.)

Attempts to establish new uranium mines would likely result in further examples of mining companies exerting unwanted pressure on Indigenous communities, as with the attempt to override the Mirarr traditional owners' unanimous opposition to the Jabiluka mine.

Australia's uranium mining industry may expand with proposed exports to China and India. Both China and India have nuclear weapons programs. India is not even a signatory to the Non Proliferation Treaty (NPT). China is not an open society and faces

back to table of contents

serious, unresolved human rights issues. It is difficult to imagine a nuclear industry worker in China publicly raising safety, security or proliferation concerns without reprisal.

Australia's uranium exports are already a cause for concern. Why do we allow uranium sales to Japan given the grossly inadequate safety culture in the nuclear industry there, as demonstrated by a number of serious and fatal accidents over the past decade and by revelations of systematic falsification of safety data? Why do we turn a blind eye to the regional tensions arising from Japan's plutonium program and its status as a 'threshold' or 'breakout' state capable of producing nuclear weapons in a short space of time? (Burnie and Smith, 2001; Burnie, 2005.)

Why do we allow uranium sales to South Korea when only last year it was revealed that numerous nuclear weapons research projects were secretly carried out there from the 1980s until 2000, in violation of the country's NPT obligations? (Kang et al., 2005; Burnie, 2005.)

Why do we allow uranium sales to the US, the UK and France – nuclear weapons states which are failing to fulfil their NPT disarmament obligations? As retired Australian diplomat Richard Butler (2005) notes: "[The NPT] is a two-way – not one-way – street. It provides that states which do not have nuclear weapons must never acquire them and that those which do have them must progressively get rid of them."

Nuclear power: a limited and problematic response to climate change

There are significant constraints on the growth of nuclear power, such as its high capital cost and, in many countries, lack of public acceptability. As a method of reducing greenhouse gas emissions, nuclear power is further limited because it is used almost exclusively for electricity generation, which is responsible for less than one third of global greenhouse gas emissions.

Because of these problems, the potential for nuclear power to help reduce greenhouse gas emissions by replacing fossil fuels is limited. Few predict a doubling of nuclear power output by 2050, but even if it did eventuate it would still only reduce greenhouse gas emissions by about 5% – less than one tenth of the reductions required to stabilise atmospheric concentrations of greenhouse gases.

Nuclear power is being promoted as the solution to climate change, as a technical fix or magic bullet. Clearly it is no such thing. As

back to table of contents

a senior analyst from the International Atomic Energy Agency, Alan McDonald (2004), said: "Saying that nuclear power can solve global warming by itself is way over the top".

Nuclear power is not a 'renewable' energy source. High-grade, low-cost uranium ores are limited and will be exhausted in about 50 years at the current rate of consumption. The estimated total of all conventional uranium reserves is estimated to be sufficient for about 200 years at the current rate of consumption. (Nuclear Energy Agency and International Atomic Energy Agency, 2004.) But in a scenario of nuclear expansion, these reserves will be depleted more rapidly.

Claims that nuclear power is 'greenhouse free' are incorrect as substantial greenhouse gas emissions are generated across the nuclear fuel cycle. Fossil-fuel generated electricity is more greenhouse intensive than nuclear power, but this comparative benefit will be eroded as higher-grade uranium ores are depleted. Most of the earth's uranium is found in very poor grade ores, and recovery of uranium from these ores is likely to be considerably more greenhouse intensive. (van Leeuwen and Smith, 2004.) Nuclear power emits more greenhouse gases per unit energy than most renewable energy sources, and that comparative deficit will widen as uranium ore grades decline.

the hazards of nuclear power

The hazards associated with nuclear power include the risk of potentially catastrophic accidents, routine releases of radioactive gases and liquids from nuclear plants, the intractible problem of nuclear waste, and the risks of terrorism and sabotage.

But there is another hazard which is unique to nuclear power and which is of such concern that alone it must lead to a clear rejection of a nuclear 'solution' to climate change ... even if such a solution were possible. This is the repeated pattern of 'peaceful' nuclear facilities being used for nuclear weapons research and production.

nuclear proliferation – the myth of the peaceful atom

Global expansion of nuclear power could contribute to an increase in the number of nuclear weapons states – as it has in the past. It would probably lead to an increase in the number of 'threshold' or 'breakout' nuclear states which could quickly produce weapons drawing on expertise, facilities and materials from their 'civil' nuclear program. Nuclear expansion would also increase the availability of nuclear materials for use in nuclear weapons or radioactive 'dirty bombs' by terrorist groups.

back to table of contents

Supposedly ‘peaceful’ nuclear facilities and materials have been used in various ways in secret weapons programs, including the production of highly enriched uranium (used in the Hiroshima bomb) and plutonium (used in the Nagasaki bomb).

Of the 60 countries which have built nuclear power or research reactors, over 20 are known to have used their ‘peaceful’ nuclear facilities for covert weapons research and/or production. (Nuclear Weapon Archive, n.d.; Green, 2002; Institute for Science and International Security, n.d.) In some cases the military R&D was small-scale and short-lived, but in other cases nation states have succeeded in producing nuclear weapons under cover of a peaceful nuclear program – India, Pakistan, Israel, South Africa and possibly North Korea.

In other cases, substantial progress had been made towards a weapons capability before the weapons program was terminated, with Iraq’s nuclear program from the 1970s until 1991 being the most striking of several examples. The current tensions around the nuclear programs in Iran and North Korea further highlight the potential use of ‘peaceful’ nuclear facilities for nuclear weapons production.

The International Atomic Energy Agency’s (IAEA) safeguards system still suffers from flaws and limitations despite improvements over the past decade. At least eight Nuclear Non-Proliferation Treaty (NPT) member states have carried out weapons-related projects in violation of their NPT agreements, or have carried out permissible (weapons-related) activities but failed to meet their reporting requirements to the IAEA – Egypt, Iraq, Libya, North Korea, Romania, South Korea, Taiwan, and Yugoslavia.

Recent statements from the IAEA and US President George W. Bush about the need to limit the spread of enrichment and reprocessing technology, and to establish multinational control over sensitive nuclear facilities, are an effective acknowledgement of the fundamental flaws and limitations of the international non-proliferation system. The NPT enshrines an ‘inalienable right’ of member states to all ‘civil’ nuclear technologies, including dual-use technologies with both peaceful and military capabilities. In other words, the NPT enshrines the ‘right’ to develop a nuclear weapons threshold or breakout capability.

Another serious deficiency is that the NPT places no stronger obligation on the five ‘declared’ nuclear weapons states – the US, Russia, the UK, France and China – than to engage in negotiations on nuclear disarmament. The intransigence of the nuclear weapons states provides incentives

back to table of contents

and excuses for other states to pursue nuclear weapons – and civil programs can provide the expertise, the facilities and the materials to pursue military programs. IAEA Director-General Mohamed El Baradei noted in a 2004 speech to the Council on Foreign Relations in New York: '"There are some who have continued to dangle a cigarette from their mouth and tell everybody else not to smoke." (Quoted in Traub, 2004.)

plutonium & proliferation

A nuclear weapon powerful enough to destroy a city requires a mere 10 kg of plutonium. The 'peaceful' nuclear power industry has produced 1,600 tonnes of plutonium (Institute for Science and International Security, 2004) – enough to build about 160,000 nuclear weapons. If 99% of this plutonium is indefinitely protected from military use, the remaining 1% would suffice for 1,600 nuclear weapons.

Australia's uranium exports, once irradiated in nuclear power reactors, have produced about 80 tonnes of plutonium (ASNO, 2003-04) – enough for about 8,000 nuclear weapons.

The UN's Intergovernmental Panel on Climate Change (IPCC) has considered a scenario involving a ten-fold increase in nuclear power over this century, and calculated that this could produce 50-100 thousand tonnes of plutonium – enough to build millions of nuclear weapons. The IPCC concluded that the security threat "would be colossal." (IPCC, 1995; see also Greenpeace n.d.)

loose nukes & terrorism

Nuclear smuggling – much of it from civil nuclear programs – presents a significant challenge. The IAEA's Illicit Trafficking Database records over 650 confirmed incidents of trafficking in nuclear or other radioactive materials since 1993. In 2004 alone, almost 100 such incidents occurred. (El Baradei, 2005C; IAEA, n.d.) Smuggling can potentially provide fissile material for nuclear weapons and a wider range of radioactive materials for use in 'dirty bombs'.

Civil nuclear plants are potentially "attractive" targets for terrorist attacks because of the importance of the electricity supply system in many societies, because of the large radioactive inventories in many facilities, and because of the potential or actual use of 'civil' nuclear facilities for weapons research or production.

A 2004 study by the Union of Concerned Scientists concluded that a major terrorist attack on the Indian Point reactor in the US could result in as many as 44,000 near-term

back to table of contents

deaths from acute radiation syndrome and as many as 518,000 long-term deaths from cancer among individuals within fifty miles of the plant. The attack would pose a severe threat to the entire New York metropolitan area. Economic damages could be as great as US$2.1 trillion. (Lyman, 2004.)

Proliferation concerns have led a number of nation states to use conventional weapons to attack nuclear facilities. Iraq's nuclear facilities have been bombed by Iran, Israel and the US, and Iraq itself targeted a nuclear plant in Iran in the 1980s and claimed to have targeted Scud missiles at Israel's Dimona nuclear plant in 1991.

The IAEA Director-General Mohamed El Baradei (2005) addressed a range of serious nuclear security problems in his address to the 2005 Non-Proliferation Treaty Review Conference: "In five years, the world has changed. Our fears of a deadly nuclear detonation – whatever the cause – have been reawakened. In part, these fears are driven by new realities. The rise in terrorism. The discovery of clandestine nuclear programmes. The emergence of a nuclear black market. But these realities have also heightened our awareness of vulnerabilities in the NPT regime. The acquisition by more and more countries of sensitive nuclear know-how and capabilities. The uneven degree of physical protection of nuclear materials from country to country. The limitations in the IAEA's verification authority – particularly in countries without additional protocols in force. The continuing reliance on nuclear deterrence. The ongoing perception of imbalance between the nuclear haves and have-nots. And the sense of insecurity that persists, unaddressed, in a number of regions, most worryingly in the Middle East and the Korean Peninsula."

radioactive waste

Radioactive wastes arise across the nuclear fuel cycle. High-level waste – which includes spent nuclear fuel and the waste stream from reprocessing plants – is by far the most hazardous of the waste types. A typical power reactor produces 25-30 tonnes of spent fuel annually. Annually, about 12,000 to 14,000 tonnes of spent fuel are produced by power reactors worldwide.

About 80,000 tonnes of spent fuel have been reprocessed, representing about one third of the global output of spent fuel. Reprocessing poses a major proliferation risk because it involves the separation of plutonium from spent fuel. It also poses major public health and environmental hazards as reprocessing plants release significant quantities of radioactive wastes into the sea and gaseous radioactive discharges into the air. Cogema's

back to table of contents

reprocessing plant at La Hague in France, and British Nuclear Fuel's plant at Sellafield in the UK, are the largest source of radioactive pollution in the European environment. (WISE-Paris, 2001.)

Not a single repository exists anywhere in the world for the disposal of high-level waste from nuclear power. Only a few countries – such as Finland, Sweden, and the US – have identified potential sites for a high-level waste repository.

The legal limit for the proposed repository at Yucca Mountain in the US is less then the projected output of high-level waste from currently operating reactors in the US. If global nuclear output was increased three-fold, new repository storage capacity equal to the legal limit for Yucca Mountain would have to be created somewhere in the world every 3-4 years. (Ansolabehere et al., 2003.) 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 single year.

Attempts to establish international repositories are likely to be as unpopular and unsuccessful as was the attempt by Pangea Resources to win support for such a repository in Australia.

Synroc – the ceramic waste immobilisation technology developed in Australia – seems destined to be a permanently 'promising' technology. As nuclear advocate Leslie Kemeny (2005) notes, Synroc "showed great early promise but so far its international marketing and commercialisation agendas have failed".

The nuclear industry transfers risks and costs to future generations. As AMP Capital Investors (2004) notes in its Nuclear Fuel Cycle Position Paper: "The waste problems of the uranium mining and power generation are numerous and long lasting. Due to the long half lives and inability ... to find an acceptable final disposal method for radioactive materials, the problem will continue for a long time without a solution. Therefore there are significant concerns about whether an acceptable waste disposal option currently exists. From a sustainability perspective, while the nuclear waste issues remain unresolved, the uranium/nuclear power industry is transferring the risks, costs and responsibility to future generations."

nuclear accidents

The "safe and clean" image being pushed by nuclear proponents seriously misrepresents the true performance of the industry. In fact, nuclear accidents and near misses are

back to table of contents

common, and radioactive emissions are routine.

Chernobyl and Three Mile Island are only the best-known of hundreds of nuclear accidents:

- There have been at least eight accidents involving damage to or malfunction of the core of nuclear power or research reactors.

- At least five nuclear research reactor accidents have resulted in fatalities.

- There have been other serious reactor accidents which did not involve core damage or malfunction, and a number of 'near misses' with power reactors found to be in a serious state of disrepair – one such incident was discovered in 2002 at the Davis-Besse reactor in the United States.

- There have been many accidents involving reprocessing plants, waste stores and other nuclear facilities.

In addition to the hazards posed by accidents, radioactive emissions are routinely generated across the nuclear fuel cycle. The United Nations Scientific Committee on the Effects of Atomic Radiation (1994) has estimated the collective effective dose to the world population over a 50-year period of operation of nuclear power reactors and associated nuclear facilities to be two million person-Sieverts. Applying the standard risk estimate to that level of radiation exposure gives an alarming total of 80,000 fatal cancers.

Applying the standard risk estimate to the IAEA's (1996) estimate of human exposure to radiation from the Chernobyl disaster gives a figure of 24,000 fatal cancers. While the death toll is subject to uncertainty, the broader social impacts are all too clear, including those resulting from the permanent relocation of about 220,000 people from Belarus, the Russian Federation, and the Ukraine. As the OECD's Nuclear Energy Agency (2002) notes, Chernobyl "had serious radiological, health and socio-economic consequences for the populations of Belarus, Ukraine and Russia, which still suffer from these consequences."

Safety concerns are not limited to the ex-Soviet states. For example, the Japanese nuclear power industry has been in turmoil since the August 2002 revelations of 29 cases of false reporting on the inspections of cracks in numerous reactors. There have also been a number of serious accidents, including fatal accidents, at nuclear reactors and other nuclear facilities in Japan in the past decade. (WISE/NIRS, 2002; Anon., 2002; Anon., 2002B.)

Commercial pressures and inadequate regulation have clearly played some part in

back to table of contents

the flawed safety standards in Japan. Such pressures are by no means unique to Japan, and they will intensify if privatisation and liberalisation of electricity markets proceeds.

Calculations indicate that the probability of an accident involving damage to the reactor core is about one in 10,000 per reactor per year for current nuclear power reactors. In a world with 1,000 such reactors, accidents resulting in core damage would occur once per decade on average. (Fetter, 1999. Ansolabehere et al., 2003.) With a ten-fold nuclear expansion, a reactor core damage accident would occur every 2-3 years on average.

The hype about future reactor designs with supposedly ‘passive’ safety systems has attracted scepticism and cynicism even from within the nuclear industry, with one industry representative quipping that “the paper-moderated, ink-cooled reactor is the safest of all.” (Hirsch et al., 2005.)

	Spent Fuel from Power Reactors (tonnes p.a.)	Plutonium Production from Power Reactors (tonnes p.a.)	Potential Additional Plutonium Weapons (annual)*	Reactor Core Damage Accident	Longevity of high-grade uranium ores	Longevity of all conventional uranium ores
Current nuclear output	**13,000**	**70**	**7,000**	**1 / 30 yrs**	**50 yrs**	**200 yrs**
Three-fold nuclear expansion	**39,000**	**210**	**21,000**	**1 / 10 yrs**	**15-20 yrs**	**60-70 yrs**
Ten fold nuclear expansion	**130,000**	**700**	**70,000**	**1 / 3 yrs**	**5 yrs**	**20 yrs**

** Assuming 10 kg of plutonium for one nuclear weapon.*

*** Assuming a risk of one in ten thousand per reactor per year.*

back to table of contents

The real solutions to climate change: energy efficiency and renewables

Renewable energy and energy efficiency can deliver the power we need – without the problems. Renewable energy, mostly hydroelectricity, already supplies 19% of world electricity, compared to nuclear's 16%. The share of renewables is increasing, while nuclear's share is decreasing.
Worldwide, there were only 26 nuclear reactors under construction at the end of 2004, with only one in Western Europe and none in the USA. Nuclear power capacity in Europe is falling and is expected to drop 25% over the next 15 years. The projected growth of nuclear power in a small number of countries, such as China and India, will not substantially change the global picture of stagnation and decline. (Schneider and Froggatt, 2004.)

By contrast, wind power and solar power are growing by 20-30% every year. (Sawin, 2004.) In 2004, renewable energy added nearly three times as much net generating capacity as nuclear power. (ACF, 2005.)

Europe is planning to get 22% of its electricity from renewable sources by 2010, creating nearly a million additional jobs (MITRE, 2004):

- Germany is on track to supply 13% of its electricity from renewables by 2010, while nuclear power is being phased out.

- Spain expects to get 26% of electricity from renewable energy by 2010.

- Sweden already supplies 48% of its electricity from renewable sources (mostly hydroelectricity) and expects renewables to provide 60% by 2010 with increased use of wind and bioenergy sources. Sweden plans to phase out nuclear power and has shut two reactors since 1999.

- Denmark already supplies 13% of its electricity from wind, and will supply 29% of electricity from renewables by 2010.

Many other countries are setting ambitious renewable energy targets. However, in Australia, only 8% of electricity is from renewable energy – down from 10% in 1999. (ACF, 2005.) With the political commitment, we could achieve much greater usage of renewable energy, and also go a long way to solving energy and greenhouse problems through energy efficiency measures.

A clean energy future will include a range of technologies including wind, wave and tidal power, small scale hydro schemes, biomass and solar technologies (ACF, 2005):

back to table of contents

- **Wind power:** Australia could get 10% of its electricity from wind without major modifications to the electricity grid. This would create about 37,000 job years in construction and manufacturing and up to 1,000 fulltime jobs in operation and maintenance.

- **Bioenergy:** Bioenergy (energy from organic matter, including non native forest wood, energy crops, sewage, or wastes) could provide 30% of our electricity in the long term – but only if we plan for it. This would need about 14,000 MW of bioenergy and would create up to 46,000 permanent rural jobs in operation and maintenance, and a further 140,000 short term construction jobs.

- **Solar electricity (Photovoltaics):** Solar electricity has a huge potential to provide electricity for Australia. According to the PV Industry Roadmap we could supply 6,700 MW capacity by 2020. This would be equivalent to building two 600 MW nuclear power stations. The solar electricity option would create 31,000 jobs.

The biggest gains are to be made in the field of energy efficiency. Government reports have shown that reductions in energy consumption of up to 70% are cost effective in some sectors of the economy. Energy experts have projected that adopting a national energy efficiency target could reduce the need for investment in new power stations by 2,500 – 5,000 MW by 2017 (equal to about 2-5 large nuclear power stations). The energy efficiency investments would pay for themselves in reduced bills before a nuclear power station could generate a single unit of electricity. (ACF, 2005.)

The Australian Ministerial Council on Energy (2003) has identified that energy consumption in the manufacturing, commercial and residential sectors could be reduced by 20-30% with the adoption of current commercially available technologies with an average payback of four years.

Many studies have detailed how major greenhouse gas emissions reductions can be achieved without reliance on nuclear power (see Appendix 1.) A number of studies have considered the relative cost of various means of reducing greenhouse gas emissions. Replacing fossil fuels with nuclear power does not fare well in these studies. Energy efficiency measures are shown in an American study to deliver almost seven times the greenhouse gas emissions reductions as nuclear power per dollar invested. (Keepin and Kats, 1988.)

The argument that nuclear power could be a “bridging” energy source while renewables are further developed is erroneous. Nuclear expansion would require such vast

back to table of contents

expenditure that renewables would fall by the wayside. Of the funds spent by 26 OECD member states between 1991 and 2001 on energy R&D, 50% was spent on nuclear power and only 8% on renewable energy. (Schneider and Froggatt, 2004.)

We need to make a clear choice for a clean energy future based on renewables and energy efficiency. As former US and UN environment advisor Professor Frank Muller (2005) notes: "Nuclear power and sustainable energy involve future paths for electricity systems that diverge. Nuclear power reinforces conventional grids dominated by central power stations and powerful supply-side institutions – a pattern that we have inherited from an era of more centralised economic decision making. The sustainable energy vision is for these grids to evolve into more decentralised consumer-oriented networks. Investment would be directed to the lowest cost options for meeting customer needs, on either the supply or demand sides, rather than into an inexorable expansion of supply."

The nuclear industry is not financially or environmentally sustainable. AMP Capital Investors (2004) notes in its Nuclear Fuel Cycle Position Paper: "Nuclear power and the uranium industry are neither financially or environmentally sustainable. ... The positive greenhouse impacts could be equally, and arguably better, obtained from investment in, or support of, the renewable energy sector. It is critical that the nuclear industry does not manipulate the climate change threat to divert government policy and finance away from the intrinsically safe renewable sources of electricity."

back to table of contents

2. nuclear power:

a limited and problematic response

2.1. a limited response

Nuclear power is used almost exclusively for electricity generation. A small number of reactors are used for heat co-generation, but this application is unlikely to become widespread because of the distance between most nuclear reactors and population centres and the associated inefficiencies. Proposals have been advanced to use nuclear power for hydrogen production, but future demand for hydrogen is uncertain and nuclear power would need to be shown to be attractive compared to alternative production methods. Several nuclear desalinisations plants are in operation, but it is far from certain that nuclear desalinisation will prove to be an attractive option. These applications raise the same set of issues as with nuclear electricity generation, not least weapons proliferations concerns – for example, proposals for Russia to sell a nuclear desalinisation plant to Syria have generated controversy.

Electricity is responsible for less than a third of global greenhouse gas emissions. The contribution of the electricity sector to total greenhouse gas emissions varies considerably:

- In Australia, the figure is 37% (Australian Greenhouse Office, 2000).

- Of the total emissions from the fifteen European Union Countries in 1999, electricity accounted for under 21% of the total. (Roberts, 2005.)

- Figures from the World Resources Institute (n.d.), drawing on data from the International Energy Agency, show ‘Public Electricity and Heat’ accounted for 39% of global emissions in 1999, but electricity is not separated from heat and the total 1999 emissions figure does not include agriculture or ‘Commercial and Public Sectors’. With the figures for advanced industrial countries ranging from 20-40%, and taking into account the comparatively low usage on electricity in developing countries, the global contribution of electricity is certain to be considerably less than 39%.

back to table of contents

- The Uranium Institute (n.d.) states that electricity generation accounts for "about 30%" of all anthropogenic carbon dioxide emissions and that would appear to be a reasonable estimate.

This is not to belittle the importance of electricity as a source of greenhouse gas emissions. Worldwide electricity consumption increased at an average rate of 3.0% per year between 1980-2001, resulting in an overall increase of 88%. Strong future growth is predicted. (Energy Information Administration, 2004.)

On the other hand, acknowledging that electricity counts for only about 30% of greenhouse gas emissions puts pay to the simplistic view that nuclear power alone can 'solve' the climate change problem. According to senior IAEA energy analyst Alan McDonald (2004): "Saying that nuclear power can solve global warming by itself is way over the top".

Even the replacement of all fossil fuel fired electricity plants with nuclear power would lead to only modest reductions of global greenhouse gas emissions – not even close to the 60% reductions required to stabilise atmospheric concentrations of greenhouse gases.

Greenpeace (n.d.) has considered a scenario whereby the contribution of nuclear power to overall electricity generation would double in the space of 25 years. Taking into account growth in demand for energy/electricity, doubling nuclear power's share would require 1,320 new nuclear reactors – an average of one new reactor each week for 25 years.

Friends of the Earth (2004) has calculated that doubling nuclear power in the UK – which currently has 23 power reactors in operation – would reduce greenhouse gas emissions by no more than 8% given that electricity accounts for less than one third of total UK emissions.

Feiveson (2001) calculates that if global nuclear power grew at just over 2% per year until 2050 to an installed capacity in that year of 1000 GWe (about three times greater than current output), total cumulative carbon emissions projected during this period would be reduced by about 8%.

Feiveson (2001) further calculates that if nuclear output was steadily increased such that it reached approximately 20 times the current output by 2100, about 25% of the projected cumulative carbon emissions to 2100 would be avoided. That is of course a

back to table of contents

significant reduction, but it would require the construction of about 9,000 power reactors!

According to the Nuclear Information and Resource Service (n.d.), if nuclear power were to account for 70% of electricity by 2100, 115 reactors (1000 MWe) would have to be built each year – over 10,000 by the end of the century – and still the reduction in total emissions would be just 16%.

Strong growth of nuclear power would lead to strong growth in the production of plutonium. Fieveson (2001) calculates that with a ten-fold increase in nuclear output, to 3500 GWe, and assuming a once-through fuel cycle using light water reactors, about 700 tonnes of plutonium would be produced annually – sufficient for about 70,000 nuclear weapons (or 3.5 million weapons over a 50-year reactor lifespan).

Basing its calculations on a scenario developed by the Intergovernmental Panel on Climate Change, which involves a ten-fold increase in nuclear output by 2100, Greenpeace (n.d.) calculates that the plutonium inventory would reach approximately 100,000 tonnes – sufficient for 10 million nuclear weapons.

2.2. a temporary response

Among nuclear proponents, some are confident that exploration will uncover major uranium deposits, while others argue that limited reserves will necessitate the expansion of fast breeder reactor technology with plutonium as the major fuel source. As an example of the latter view, John Carlson (2000), Director General of the Australian Safeguards and Non-Proliferation Office (and a strong supporter of nuclear power) argues that: "If nuclear energy is to realise its potential as a major source of electricity, however, the efficient use of uranium reserves will require programs based on plutonium breeding and recycle – at current consumption levels the thermal fuel cycle will exhaust low-cost uranium reserves in about 50 years."

According to the Nuclear Energy Agency (NEA) and the IAEA, the total known recoverable uranium reserves – reasonably assured reserves and estimated additional reserves which can be extracted at a cost of less than US$80/kg – amount to 3.5 million tonnes (NEA & IAEA, 2004). At the current rate of usage – 67,000 tonnes per year – these reserves will last for just over 50 years.

back to table of contents

Of course, the nuclear power industry will not come to an immediate halt once the known low-cost reserves have been exhausted. Other relatively high-grade, low-cost ores will be discovered, and lower-grade ores can be used. The NEA and IAEA estimate the total of all conventional reserves to be about 14.4 million tonnes (NEA & IAEA, 2004). The OECD estimates that about 16 million tonnes of uranium are recoverable at costs less than US$260 per kilogram, including 12 million tonnes of "speculative resources" (OECD, 1998; see also Fetter, 1999).

Uranium reserves in the range of 14-16 million tonnes would suffice for about 200 years at the current rate of consumption – but significantly less if nuclear power is to expand to the extent that it makes anything more than a trivial contribution to climate change abatement. The Nuclear Energy Agency (2000) maps out a scenario in which nuclear power grows steadily to reach 1,120 GWe in 2050, just over three times the current level. Uranium production would need to increase by a factor of 4-5 by 2050 to accommodate the demand of 175,000 tonnes of uranium in 2050. Cumulative uranium requirements would reach 5.6 million tonnes of uranium by 2050. As the Nuclear Energy Agency notes, present uranium reserves (reasonably assured resources recoverable at less than US$80/kgU) would be exhausted by 2025, and presently known uranium resources would run out by shortly after 2040. However, total conventional resources recoverable at less than US$130/kgU (15.5 million tonnes of uranium) would suffice to meet cumulative requirements to 2050. Reducing the content of uranium-235 in enrichment plant tailings from 0.3% to 0.15% would reduce the cumulative uranium requirements by 2050 from 5.6 to 4.2 million tonnes. Reprocessing all light-water reactor spent fuel and using the uranium and plutonium in mixed-oxide fuel would reduce the requirement from 5.6 to 5.0 million tonnes.

Large amounts of uranium are also contained in 'unconventional sources' such as granite (4 parts per million), sedimentary rock (2 ppm) and seawater (up to 4000 million tonnes at 0.003 ppm) (Uranium Information Centre, 2004B). The costs of extracting uranium from these unconventional sources is much greater than current costs.

It can be predicted with some confidence that the cost of extracting uranium from various ores (lower grade conventional ores or unconventional sources) will increase.

back to table of contents

However, with fuel costs amounting to only a small percentage of overall nuclear fuel cycle costs (far less than for fossil fuel generated electricity), the decline of ore grades is unlikely to have a major impact on overall nuclear power costs.

There are two problems of much greater significance than the financial implications.

Firstly, increased costs for uranium may lead to the proliferation of reprocessing technology to enable reuse of uranium and/or use of plutonium as fuel. This has significant implications for nuclear weapons proliferation (discussed in Section 3) and safety (discussed Section 5).

Secondly, the mining of lower grade ores is likely to have significant implications in relation to energy usage and greenhouse gas emissions. The energy required to extract uranium from low grade ores may approach the energy gained from the uranium's use in power reactors. Likewise, the increased greenhouse gas emissions from mining and milling low grade ores will narrow nuclear's greenhouse advantage in relation to fossil fuels, and widen nuclear power's greenhouse deficit in comparison to most renewable energy sources.

2.3. energy assessment

Of particular importance to an assessment of the energy implications of mining lower grade ores is the research of scientist Jan-Willem van Leeuwen and nuclear physicist Philip Smith (van Leeuwen and Smith, 2004). They provide detailed calculations comparing the energy input required to allow for the functioning of nuclear power reactors compared to the energy output of those reactors. The energy balance is shown to depend crucially on the grade of the uranium ore. With ores of about 0.02% for 'hard' ores or 0.01% for more easily-mined 'soft' ores, there may be no overall energy gain whatsoever, and no gain in relation to greenhouse gas emissions.

A once-through uranium path is used as the basis for the calculations of van Leeuwen and Smith, primarily, they say, because a realistic assessment of the energy costs and gains from recycling is not available. Given that most uranium and plutonium separated during reprocessing is not reused but is simply stockpiled, considering a 'closed' cycle including reprocessing could not significantly improve the energy assessment.

van Leeuwen and Smith state: "The rich

back to table of contents

ores that are at present exploited need very little energy for exploitation, but the useful energy content of these ores is quite small (under the assumption that only the 235U is "burned"). When they are exhausted the energy needed for the exploitation of leaner ores will require more input energy from fossil fuels than the nuclear power-plant will provide, so that a nuclear power-plant would become a complicated, expensive and inefficient gas burner."

Ores being mined for uranium currently are generally well above the critical value of 0.01% uranium, and average over 0.1%. However, some ores are relatively low grade, such as 0.03 to 0.07% at Olympic Dam in South Australia, and 0.02% in South Africa.

While the van Leeuwen and Smith study has implications for the mining of lower-grade conventional ores, perhaps its major implication is that it indicates that it is unlikely that an energy gain can be obtained by mining the vast quantities of uranium locked up in the lowest grade deposits such as those in granite or sedimentary rock, in which the uranium concentration is orders of magnitude below van Leeuwen and Smith's 'cut off' figure of 0.01-0.02% figure.

;The van Leeuwen and Smith study concerns mining and milling as major energy costs, so is not relevant to the potential extraction of uranium from seawater. Little research is occurring into uranium extraction from seawater, and a number of research programs have been abandoned because of low recovery efficiency (Roberts, 2005). Nevertheless, it may eventuate that the financial cost of extracting uranium from seawater, even if much greater than the current cost for terrestrial uranium, is not prohibitive (Garwin, 2001).

2.4. greenhouse gas emissions assessment

Claims that nuclear power is 'greenhouse free' are false. Substantial greenhouse gas generation occurs across the nuclear fuel cycle – uranium mining, milling, conversion, and enrichment; reactor construction, refurbishment and decommissioning; and waste management (e.g. reprocessing, and/or encasement in glass or cement). In addition, transportation is extensive – for example, Australian uranium may be converted to uranium hexafluoride in Canada, then enriched in France, then fabricated into fuel rods in Japan, and the spent fuel may

back to table of contents

be reprocessed in the UK or France resulting in plutonium, uranium and waste streams which may be subject to further international transportation.

Lifecycle estimates of greenhouse gas emissions per kilowatt-hour of nuclear electricity vary dramatically – from 2-60 grams of carbon dioxide (equivalent) per kilowatt-hour of electricity. A detailed study by the Oko-Institute calculates the figure at 34 grams (Fritsche and Lim, 1997). Other studies calculate the figure at 30-60 grams (WISE/NIRS, 2005).

At the moment, using comparatively rich uranium ores, nuclear power generally emits far less greenhouse gases compared to fossil fuels – about 12 times less than gas power stations and about 30 times less than coal stations (WISE/NIRS, 2005). Again, the figures vary. Nuclear emits just three times less emissions per kilowatt-hour of electricity than large, modern natural gas stations according to van Leeuwen & Smith (2004).

Further, if comparing natural gas cogeneration (electricity plus useful heat) with nuclear (for electricity) plus oil (for heat), gas cogeneration is more greenhouse 'friendly' than nuclear-plus-oil, and biogas cogeneration plants even more so (Fritsche and Lim, 1997).

Greenhouse gas emissions per kilowatt-hour of electricity from nuclear are generally greater than for most renewable energy sources, especially wind and hydroelectricity, though the differences are not great and the emissions from all three sources are far less than most fossil fuel sources. The Oko-Institut study calculates emissions for nuclear at 34 grams/kWh, wind power 20 grams, and hydroelectricity 33 grams (Fritsche and Lim, 1997).

back to table of contents

3. weapons proliferation:

the myth of the peaceful atom

3.1. military use of 'peaceful' nuclear facilities

Several states have developed nuclear weapons arsenals under cover of a 'peaceful' or 'civil' nuclear program. Global expansion of nuclear power could contribute to an increase in the number of nuclear weapons states and in the number of 'threshold' nuclear states – states which could produce weapons in a short space of time drawing on expertise, facilities and materials from their civil nuclear program.

Ostensibly civil nuclear materials and facilities can be – and have been – used in support of nuclear weapons programs in many ways:

- Production of plutonium in reactors followed by separation of plutonium from irradiated material in reprocessing facilities (or smaller facilities, sometimes called hot cells).

- Production of radionuclides other than plutonium for use in weapons, e.g. tritium, used to initiate or boost nuclear weapons.

- Diversion of fresh highly enriched uranium (HEU) research reactor fuel or extraction of HEU from spent fuel.

- Nuclear weapons-related research.

- Development of expertise for parallel or later use in a weapons program.

- Justifying the acquisition of other facilities capable of being used in support of a nuclear weapons program, such as enrichment or reprocessing facilities.

- Establishment or strengthening of a political constituency for nuclear weapons production (a 'bomb lobby').

These are not just hypothetical risks. On the contrary, the use of civil facilities and materials in nuclear weapons research or systematic weapons programs has been commonplace (Nuclear Weapon Archive, n.d.; Green, 2002; Institute for Science and International Security, n.d.). It has occurred in all the following countries: Algeria, Argentina, Australia (see Appendix 5), Brazil, Egypt, India, Iran, Iraq, Israel, Libya, North Korea, Norway, Pakistan, Poland, Romania, South Africa, South Korea, Sweden, Switzerland, Syria, Taiwan, and Yugoslavia.

Overall, civil nuclear facilities and materials have been used for weapons R&D in about one third of all the countries with a nuclear industry of any significance, i.e. with power and/or research reactors. The Institute for Science and International Security (n.d.) collates information on nuclear programs and concludes that about 30 countries have sought nuclear weapons and nine are known to have succeeded – a similar strike rate of about 30%.

In a number of the countries in which civil materials and facilities have been used in support of military objectives, the weapons-related work was short-lived and fell a long way short of the determined pursuit of nuclear weapons. On the other hand, a civil program provided the basis for the development of nuclear arsenals in Israel, India, Pakistan, South Africa, and possibly North Korea. In other cases – with Iraq from the 1970s until 1991 being the most striking example – substantial progress had been made towards a weapons capability under cover of a civil program before the weapons program was terminated.

There are several reasons why numerous states have chosen to clandestinely pursue a nuclear weapons program under the guise of, and in association with, a civil nuclear program as opposed to an overt, dedicated weapons program:

- Nuclear technology and materials are generally much easier to acquire from supplier states if the stated purpose is peaceful and if the recipient country is a signatory to the NPT. Attempts can then be made to circumvent or break conditions imposed by the IAEA and/or the supplier state (or expertise gained through the acquisition and operation of safeguarded facilities can be used in a parallel weapons program).

- Avoiding external political reaction or economic sanctions or domestic political opposition.

- Avoiding a pre-emptive military strike.

Civil and military nuclear programs also overlap to a greater or lesser degree in the five declared weapons states – the US,

back to table of contents

the UK, Russia, China and France. Specific examples – such as the use of a power reactor to produce tritium for weapons in the US – are of less importance than the broad pattern of civil programs providing a large pool of nuclear expertise from which military programs can draw. The five declared nuclear weapons states all have nuclear power reactors and they account for almost 60% of global nuclear power output (1484/2525 billion kilowatt-hours in 2003).

John Carlson (2000) from the Australian Safeguards and Non-Proliferation Office (ASNO) states that "... in some of the countries having nuclear weapons, nuclear power remains insignificant or non-existent." Carlson's attempt to absolve civil nuclear programs from the proliferation problem ignores the well-documented use of civil nuclear facilities and materials in weapons programs as well as the important political 'cover' civil programs provide for military programs.

Of the nine states known to have produced nuclear weapons, only Israel has no power reactors – and even in Israel the pretence of a civil nuclear program provided a rationale for key technology transfers. Pakistan and India have power reactors, and South Africa's weapons program was facilitated by a parallel nuclear power program. North Korea – possibly the tenth nuclear weapons state – has had a nuclear power program and operates an 'Experimental Power Reactor' which is an important component of its weapons program.

Carlson's view also sits uncomfortably with the concentration of nuclear power in weapons states.

3.2. fissile materials – highly enriched uranium

There are three methods of using the cover of a civil nuclear program for the acquisition of HEU for weapons production:

- Diversion of imported HEU. The US alone has exported over 25 tonnes of HEU. An example was the (abandoned) 'crash program' in Iraq in 1991 to build a nuclear weapon using imported HEU.

- Extraction of HEU from spent research reactor fuel. HEU has been used in many research reactors but power reactors use low enriched uranium or in some cases natural uranium.

back to table of contents

- A civil nuclear program can be used to justify the development of enrichment facilities.

The acquisition of enrichment technology and expertise – ostensibly for civil programs – enabled South Africa and Pakistan to produce HEU which has been used for their HEU weapons arsenals.

The nuclear black market centred around the 'father' of the Pakistani bomb Abdul Qadeer Khan involved the transfer of enrichment know-how and/or facilities to North Korea, Iran and Libya.

An expansion of nuclear power would most likely result in the spread (horizontal proliferation) of enrichment technologies, justified by requirements and markets for low enriched uranium for power reactors but also capable of being used to produce HEU for weapons.

3.3. fissile materials – plutonium

Israel and India both have arsenals of plutonium fission weapons, with the plutonium produced in ostensibly civil 'research' reactors. India is also believed to have used power reactors to produce a small fraction of the plutonium for its weapons (Albright and Hibbs, 1992).

Small volumes of plutonium have been produced in 'civil' reactors then separated from irradiated materials in a number of countries including Iraq, Iran, South Korea, North Korea, Taiwan, Yugoslavia, and possibly Romania (Green, 2002). Pakistan announced in 1998 that a powerful 'research' reactor had begun operation at Khusab; if so, the reactor can produce unsafeguarded plutonium.

Power reactors have been responsible for the production of a vast quantity of weapons-useable plutonium. Adding to the proliferation risk is the growing stockpile of separated plutonium, as reprocessing outstrips the use of plutonium in MOX (mixed oxide fuel containing plutonium and uranium).

A typical power reactor (1000 MWe) produces about 300 kilograms of plutonium each year. Total global production of plutonium in power reactors is about 70 tonnes per year. As at the end of 2003, power reactors had produced an estimated 1,600 tonnes of plutonium, of which 240 tonnes was in unirradiated forms (Institute for Science and International Security, 2004). (Unirradiated plutonium includes separated plutonium

back to table of contents

and plutonium in forms such as fresh MOX, whereas irradiated plutonium is contained in operating reactors and in spent fuel. Unirradiated plutonium is more easily diverted for weapons production, all the more so if it is in separated form.)

Using the above figures, and assuming that 10 kilograms of plutonium is required to produce a weapon with a destructive power comparable to that of the plutonium weapon dropped on Nagasaki in 1945:
* The plutonium produced in a single reactor each year is sufficient for 30 weapons.
* Total global plutonium production in power reactors each year is sufficient to produce 7,000 weapons.
* Total accumulated 'civil' plutonium production is sufficient for 160,000 weapons.

(As little as 4 kgs of plutonium may suffice for a weapon if it is high-grade plutonium and if it is in the hands of sophisticated weapons manufacturers. A more conservative figure of 10 kgs is used here to take account of the lower percentage of plutonium-239 in plutonium produced in the civil fuel cycle and also the varying levels of sophistication of actual and potential proliferators.)

If 99% of the 1,600 tonnes of plutonium is indefinitely protected from military use, the remaining 1% would suffice for 1,600 nuclear weapons. If 99% of the 240 tonnes of unirradiated plutonium is indefinitely protected from military use, the remaining 1% would suffice for 240 nuclear weapons.

In sum, the 'peaceful' uses of nuclear energy have generated enough plutonium to produce over 160,000 nuclear weapons. HEU also poses a significant proliferation problem with about 50 tonnes in worldwide civil research and power reactor programs as of the end of 2003 – sufficient for about 2,000 weapons (assuming 25 kg HEU per weapon). HEU stockpiles are decreasing but stockpiles of both irradiated and unirradiated plutonium are growing.

Fieveson (2001) notes that with a ten-fold increase in nuclear output to 3,500 GWe, annual plutonium production would be about 700 tonnes. The Intergovernmental Panel on Climate Change (IPCC, 1995) maps out a scenario whereby installed capacity would grow to about 3,300 GWe in 2100, and the accumulated plutonium inventory would therefore rise to 50-100 thousand tonnes. The security threat posed by such a vast amount of plutonium, the IPCC noted, would be "colossal".

back to table of contents

It is sometimes claimed that it is impossible to use reactor-grade plutonium – produced during the normal operation of a civil reactor – for nuclear weapons. For example the Uranium Information Centre (2004) states that: "The only use for "reactor grade" plutonium is as a nuclear fuel, after it is separated from the high-level wastes by reprocessing. It is not and has never been used for weapons, due to the relatively high rate of spontaneous fission and radiation from the heavier isotopes such as Pu-240 making any such attempted use fraught with great uncertainties."

As discussed in Appendix 3, the US government claims to have successfully tested a weapon using reactor grade plutonium. Further, the overwhelming weight of expert opinion holds that reactor-grade plutonium can be used in weapons, albeit the case that the process may be more dangerous and difficult, and the weapons may have a lower yield compared to weapon grade plutonium. Two important points are not in dispute:

- Below-weapon grade plutonium (reactor grade or fuel grade) can be and has been used in nuclear weapons.
- 'Civil' reactors can produce weapons-useable plutonium if not through their normal operation then certainly by shortening the fuel irradiation time, thereby maximising the production of plutonium-239 relative to other, unwanted plutonium isotopes.

3.4. reprocessing

The production of vast amounts of plutonium in power reactors is problem enough, but the problem is greatly exacerbated by the separation of plutonium in reprocessing plants. Whereas separation of plutonium from spent fuel requires a reprocessing capability and is potentially hazardous because of the radioactivity of spent fuel, the use of separated plutonium for weapons production is far less complicated.

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 and France. There are smaller plants in India, Russia, and Japan, and Japan plans to begin large-scale reprocessing at the Rokkasho plant in 2007.

back to table of contents

Over 80,000 tonnes of spent fuel from commercial power reactors have been reprocessed – about one third of all the spent fuel generated in power reactors. (Hore-Lacey, 2003, ch.5.)

Proponents of reprocessing give the following justifications:

- ‘Recycling’ uranium to reduce reliance on natural reserves.

- Separating plutonium for use in MOX or in plutonium breeder reactors.

- Reducing the high-level waste volume and facilitating its management.

Proponents of reprocessing argue that it reduces the volume of high-level waste to be disposed of compared to direct disposal of spent fuel. While the high-level waste volume is reduced by reprocessing, the overall waste volume (including low- and intermediate-level waste) is increased.

Nor is it clear that reducing the volume of high-level waste will facilitate its disposal – which is in any event an academic argument since no repositories exist for high-level waste from power programs. The high-level waste stream from reprocessing still contains the vast majority of the radioactivity contained in the spent fuel. The toxicity of the high-level waste is more a function of its radioactivity and heat generation than its volume. Reducing the high-level waste volume may not even significantly assist in the narrow aim of reducing volume requirements for repositories, since heat load may be the key variable rather than the volume of the waste.

The primary rationale for reprocessing is reuse of uranium and/or separation of plutonium for use as power sources. It has made little sense to ‘recycle’ uranium when early projections for nuclear power growth were wildly optimistic and uranium is not in short supply. Very little uranium has been recycled because it is more expensive and because uranium recovered from reprocessing contains isotopes such as uranium-232 which complicate its use and pose particular environmental and health risks. (Leventhal and Dolley, 1999.)

Very little plutonium is required for breeder programs since so few breeder reactors are in operation. Some plutonium is used in MOX fuel, which accounts for 2-5% of the world’s reactor fuel usage. (Parliamentary Office of Science and Technology, 2005; Reparaz, 2003.)

back to table of contents

MOX has no advantages over conventional uranium fuel. In fact it is more hazardous and more expensive (Repáraz, 2003). Further, several comparative economic studies – comparing the total fuel cycle costs of a reprocessing-recycling system and an open fuel cycle with direct disposal – have shown the reprocessing-recycle option to be the most costly. (Berkhout, 1997B.) The nuclear power utility British Energy has been attempting to have its reprocessing contracts cancelled in recent years, citing the increased costs associated with reprocessing. Michael Kirwan, British Energy's finance director, said: "As far as we are concerned, reprocessing is an economic nonsense and should stop straight away." (WISE, 2000.)

MOX also poses proliferation risks because it requires the separation of plutonium and the transportation of nuclear materials, and because separating plutonium from MOX is simpler and safer than extracting it from spent fuel.

The IAEA (1997) states in a promotional document that the quantity of separated plutonium would be higher were it not for its use in MOX fuel or in a few fast breeder reactor programmes. That disingenuous statement ignores the fact that the use of plutonium is a major rationale for reprocessing in the first place. Further, the consumption of plutonium in MOX fuelled reactors is modest (because consumption is partly off-set by plutonium production from uranium-238). MOX is regarded as a stepping stone toward the commercial use of fast-breeder reactors with the potential to create more plutonium than they consume. For these and other reasons, MOX (and breeders) are part of the plutonium problem not the solution. (Leventhal and Dolley, 1999; 1999B; Repáraz, 2003.)

The separation of plutonium in reprocessing plants and its use in MOX cannot be justified. A further problem is that the separation of plutonium greatly exceeds its use in MOX and breeders. According to the Uranium Information Centre (2002), only about one third of separated plutonium has been used in MOX over the last 30 years. Thus the stockpile of separated plutonium continues to grow – about 15-20 tonnes of plutonium are separated from spent fuel each year but only 10-15 tonnes are fabricated into MOX fuel. (Albright and Kramer, 2004.)

The IAEA (1997) stated in its promotional document that plutonium stocks should decrease modestly after 1999 (IAEA, 1997;

back to table of contents

Oi, 1998). However the stockpiles continue to grow and there is no longer any serious expectation that the use of MOX will ‘catch up’ to plutonium separation in the near future.

Hence there is a growing stockpile of plutonium in unirradiated forms, currently amounting to about 240 tonnes, with the largest ‘civilian’ plutonium stockpiles in the UK, France and Russia (Berkhout, 1997). In addition to stockpiles held by commercial reprocessors (primarily those in France and the UK), some of the plutonium separated in reprocessing plants has been returned to customer countries (either as separated plutonium or MOX fuel). This raises further proliferation concerns. The countries with holdings of separated ‘civil’ plutonium are: Belgium, Germany, India, Italy, Japan, the Netherlands, Russia, Spain, Sweden, Switzerland, the UK, and the US (Institute for Science and International Security, n.d.)

The plutonium stockpile in France amounted to 43.5 tonnes by the end of 1999 and the amount was still growing despite France being the greatest user of MOX. (Parliamentary Office of Science and Technology, 2005.)

As at 2003, the stockpile of separated plutonium in the UK amounted to 93.7 tonnes, of which 22.5 tonnes belonged to ‘foreign bodies’. An additional 30 tonnes of plutonium was contained in spent fuel at Sellafield. (Department of Trade and Industry, 2003.) Britain’s Royal Society (1998) has warned that “... the chance that the stocks of plutonium might, at some stage, be accessed for illicit weapons production is of extreme concern.”

Options being considered in the UK (Parliamentary Office of Science and Technology, 2005):

- Using plutonium as fuel. However, MOX cannot be used in most British reactors, and overseas demand for plutonium in the form of MOX is limited. Some propose building reactors capable of using MOX fuel – a case of the plutonium tail wagging the nuclear dog.

- Transmutation (changing plutonium into shorter lived or stable elements).

- Immobilising the plutonium in ceramic (e.g. Synroc) or glass, or simply mixing plutonium with high-level waste – and storing or disposing of it as waste.

back to table of contents

The hazards associated with reprocessing were highlighted in April 2005 with the revelation of an accident at the Thorp reprocessing plant operated by BNFL at Sellafield. A broken pipe led to the leaking into a containment structure of 83,000 litres of nitric acid containing dissolved spent fuel. The leakage began in January at the latest, and possibly as early as August 2004. The Thorp plant will be closed for some months as a result of the accident. The accident was classified as category III on the International Nuclear Event Scale – a 'serious incident'. (Anderson, 2005; see Langeland, 2001 on BNFL's many other problems.)

The arguments used to justify the use of MOX fuel are flawed, as is the case for separating plutonium in excess of its use in breeders or MOX. The continuation of reprocessing and MOX usage are largely a result of the following factors:

- Commercial interests involved in reprocessing and MOX have an obvious interest in the continuation of reprocessing policies.

- Long-term reprocessing contracts are in place, some dating from the 1970s and 1980s.

- Reprocessing plants act as long term, de facto storage sites. This suits the interests of nuclear power utilities and national governments in nuclear power generating countries – they can export their high level waste problems to reprocessing countries. The same argument applies to spent fuel from the Lucas Heights research reactor in Australia – the federal government has refused to consider any domestic options or contingency plans for spent fuel management or any non-reprocessing options.

- The capacity to separate plutonium for potential use in weapons is of obvious military interest.

3.5. safeguards

Some countries have pursued covert weapons programs within the umbrella of the NPT to a greater or lesser extent, including Iraq, Romania, Taiwan, Libya, and Yugoslavia. Others have pursued weapons programs outside the NPT – India, Israel, Pakistan and South Africa. North Korea fits both categories.

The many, serious flaws in the IAEA safeguards system were exposed by the Iraqi regime. Iraq signed the NPT in 1968 and ratified the treaty in 1969. However, from the early 1970s until 1991 a civil nuclear program facilitated a covert weapons program which employed thousands of people spread across numerous sites. NPT accession was a net plus for the covert weapons program because it greatly facilitated technology transfer while continued violations of NPT obligations went undetected by the IAEA. Facilities and materials subject to IAEA inspections were used in the covert weapons program (though some apologists for the IAEA's safeguards system deny it), as well as undeclared facilities and materials. The nuclear weapons program was largely or completely abandoned after the 1991 Gulf War.

Despite Iraq's status as an NPT signatory, its nuclear facilities were bombed by three nation states – Iran, Israel, and the US:

- In 1971, when a small research reactor was awaiting shipment from France to Iraq, its core was sabotaged in a warehouse and the person supposed to certify its quality was murdered in a Paris hotel.

- Iran attacked the Osirak nuclear site in Iraq in September 1980 but inflicted little or no damage.

- Israel launched a 'successful' air strike on the Osirak nuclear site in 1981.

- The US attacked and damaged nuclear facilities in Iraq during the 1991 war, including two research reactors.

Iraq itself has targeted 'peaceful' nuclear facilities in other countries. During the Iran-Iraq war in the 1980s, Iraq bombed the Bushehr nuclear plant on at least six occasions. The Iraqi regime also claimed to have targeted Scud missiles at Israel's Dimona nuclear plant during the 1991 Gulf War.

Iraq is by no means the only state to have violated its NPT commitments. North Korea acceded to the NPT in 1985 but has breached its NPT commitments at various stages since then. In 2003, North Korea became the first nation to fully withdraw from the NPT, and it now claims to have nuclear weapons. While failures of the safeguards system cannot be blamed for the North Korean program, and transparent, sanctioned imports played little or no role in the development of the weapons program, the situation does illustrate a fundamental limitation of the safeguards system – nation states can withdraw from the NPT/IAEA at short notice.

back to table of contents

Iran joined the NPT in 1974 but has breached its NPT commitments – examples include undeclared work on a uranium enrichment plant, the undeclared importation of 1.8 tonnes of natural uranium from China, and the conversion of some uranium to metallic form which is not required for any part of the country's declared nuclear program. Iran's status as an NPT signatory has both facilitated its pursuit of weapons-related technology (by facilitating technology transfers) and also hindered it.

Libya pursued a covert weapons program despite ratifying the NPT in 1975 and agreeing to place all nuclear facilities under IAEA safeguards in 1980. The weapons program was based on attempts to develop a uranium enrichment capability by importing natural uranium, centrifuge and conversion equipment, and by constructing pilot-scale centrifuge enrichment facilities. The work was pursued for over a decade, but had not reached an advanced stage by the time it was revealed in December 2003. While the program was largely based on undeclared facilities and materials, Libya's status as an NPT signatory facilitated technology transfers and its civil nuclear program justified the development of nuclear expertise.

Romania ratified the NPT in 1970, but a covert nuclear weapons program was pursued under the Ceausescu regime. Little information is publicly available on the weapons program, but it is known that hot cells were used for experimental plutonium extraction from irradiated research reactor fuel. The weapons program was terminated after Ceausescu's overthrow in 1989. (Spector et al., 1995, pp.83-86.)

A covert weapons programs was pursued in the former Yugoslavia under cover of a nuclear research and nuclear power program. Despite Yugoslavia's accession to the NPT in 1970, a weapons program was pursued from 1974-1987. The program had two aspects. One was a secret military program to address issues such as the use of conventional explosives to trigger nuclear weapons. The other was the expansion of the 'civil' nuclear power and research program and the pursuit of ostensibly 'civil' nuclear projects which would facilitate weapons production. (Koch, 1997; Potter et al., 2000.)

In 2004, South Korea disclosed information about a range of activities which violated its NPT commitments – uranium enrichment from 1979-81, the separation of small

back to table of contents

quantities of plutonium in 1982, uranium enrichment experiments in 2000, and the production of depleted uranium munitions from 1983-1987. (Kang et al., 2005.) The IAEA can take some credit for having accrued evidence of unreported activities, but failed to detect those activities for many years following South Korea's accession to the NPT in 1975. Further, Kang et al. (2005) speculate that North Korea may have learnt via intelligence sources about some of South Korea's weapons-related work and that may have been one motivation for North Korea's weapons program.

Australia has supplied South Korea with uranium following the conclusion of a bilateral agreement in 1979. It is not known – and may never be known – whether Australian-obligated nuclear materials were used in any of the illicit research. South Korea's claim that only local sources of uranium were used has not (and perhaps cannot) be reconciled with the quantity of uranium metal produced nor with its isotopic composition (Kang et al., 1995).

Other countries have carried out weapons-related projects in violation of their NPT agreement, or have carried out permissible activities (possibly connected to military objectives) but failed to meet their reporting requirements. IAEA Director General Mohamed El Baradei (2004) has noted that as a result of improvements in the safeguards regime, other cases such as that in South Korea have surfaced, and will probably continue to surface, in which States have not fulfilled all of their reporting requirements. Taiwan and Egypt are two of the countries to have failed to declare certain nuclear activities (WISE/NIRS, 2005B).

3.6. strengthening safeguards

Motivated by the Iraq fiasco in particular, efforts have been made to improve the IAEA safeguards system through the development of a Strengthened Safeguards Program (Department of Foreign Affairs and Trade, 1998; Uranium Information Centre, 2004; IAEA website <www.iaea.org>).

Improvements include:

- Requiring considerably more information from States party to the NPT about their nuclear facilities as well as information about other relevant sites, material holdings and imports/exports.

back to table of contents

- The increased use of environmental sampling and analysis and remote monitoring.

- Extended access for inspectors, allowing access to any location included on an expanded declaration, and to other locations for the purpose of taking environmental samples.

- Greater use of intelligence and open sources (e.g. commercial satellite imagery).

These improvements are welcome, although a number of problems remain with the NPT /IAEA safeguards system.

Establishing Additional Protocols as the norm for IAEA Safeguards is the goal of IAEA Director Mohamed El Baradei (2005B), who states that: "Without the expanded authority of this protocol, the IAEA's rights of inspection are fairly limited."

However, getting NPT signatory states to sign up to the 'Additional Protocols' of this 'Strengthened Safeguards Program' has been protracted and many states have yet to agree to the program. As at November 2004, 42 States party to the NPT had not fulfilled their obligation to bring into force comprehensive safeguards agreements with the IAEA, and 133 of the 187 States party to the NPT did not have additional protocols in force. According to the Uranium Information Centre (2004), 25 of the 71 countries with significant nuclear activities had yet to bring Additional Protocols into force by mid 2004.

In part the reluctance of some nations to agree to a more intrusive safeguards regime stems from real or professed concerns about commercial confidentiality. This is the stated reason for Brazil's reluctance to accept full IAEA inspections at the enrichment plant under development at Resende. Brazil has also been reluctant to agree to Additional Protocols. Roberto Abdenur, the Brazilian ambassador to the US, noted that the Additional Protocols are subject to variations. He cited the exemptions in the Additional Protocol of the US which contains a broad "national security exemption" and includes provisions for "managed access" to nuclear facilities. (Horner, 2004.)

The NPT/IAEA safeguards system will still face major problems, limitations and contradictions even if Additional Protocols do become the norm. Resource constraints on the IAEA's safeguards program are an ongoing problem – indeed IAEA literature on

back to table of contents

the Strengthened Safeguards Program makes it clear that cost-cutting and doing 'more with less' are key priorities along with the goal of strengthening safeguards (McSorley, 1998).

The Strengthened Safeguards Program does not address some of the fundamental problems and contradictions of the NPT/IAEA system. Some or all of the five declared weapons states are in breach of the spirit and perhaps the letter of their NPT obligation to pursue good-faith negotiations on nuclear disarmament. As the Canberra Commission on the Elimination of Nuclear Weapons noted in its 1996 report: "Nuclear weapons are held by a handful of states which insist that these weapons provide unique security benefits, and yet reserve uniquely to themselves the right to own them. This situation is highly discriminatory and thus unstable; it cannot be sustained. The possession of nuclear weapons by any state is a constant stimulus to other states to acquire them."

Likewise, IAEA Director General Mohamed El Baradei (2005) states: "As long as some countries place strategic reliance on nuclear weapons as a deterrent, other countries will emulate them. We cannot delude ourselves into thinking otherwise."

The IAEA has a dual and contradictory role – promoting the use and spread of nuclear technologies (which can in many cases be used to produce nuclear weapons) while preventing weapons proliferation.

Another concern is that membership of the Board of Governors of the IAEA is weighted in favour of countries with significant nuclear programs. Thirteen of the 35 seats on the Board are reserved for member states which are advanced in nuclear technology in their region of the world (Australia holds one such seat).

The relatively new practice of placing greater reliance on intelligence provided by nation states is viewed by some with scepticism, with some concern that nation states will not be willing to provide intelligence to the IAEA and concern that it will be provided selectively.

An obvious, ongoing limitation of the NPT/IAEA safeguards system is that it is of no relevance to non-NPT states – India, Pakistan, Israel and, since its withdrawal, North Korea.

Another problem is the timeliness of detecting diversions. For material such as plutonium or highly-enriched uranium, it could be diverted

back to table of contents

and incorporated into a nuclear weapon in a short space of time. Subsequent inspection by the IAEA may reveal the detection – but too late to prevent weapons manufacture. Variables such as the overall scale and sophistication of the nation's nuclear, technological and industrial infrastructure are relevant.

Another unresolved (and perhaps unresolvable) proliferation problem is 'Material Unaccounted For' (MUF) – discrepancies between the expected and measured amounts of nuclear materials. Because of the difficulty of precisely measuring amounts of nuclear materials, and because of largely unavoidable losses (e.g. materials stuck in pipes), discrepancies are frequent. The problem is particularly difficult for large-throughput facilities such as large reprocessing plants, enrichment plants, or fuel fabrication plants, from which enough fissile material for several weapons could be diverted without detection (Miller, 1990). Even for smaller facilities, there is the potential for undetected diversion of small amounts of nuclear material over a long period of time such that the total accumulated diversion is of proliferation concern.

There is no resolution to the problem highlighted by North Korea. NPT signatory states can simply withdraw from the NPT. Prior to their withdrawal, they can potentially make full use of their NPT-enshrined "inalienable right" to pursue the full range of nuclear technologies for peaceful nuclear activities despite the obvious proliferation implications of many of the facilities and materials involved. A related problem is that NPT status can absolve supplier states of moral responsibility for dubious sales. These limitations can be illustrated by an aspect of Australia's nuclear history. When the Australian government eventually agreed in 1971 to sign (but not ratify) the NPT, it based its decision on advice from the Department of External Affairs that it was possible for a signatory to develop nuclear technology to the brink of making a nuclear weapon without breaching NPT commitments. Thus the government had open to it a 'sign-and-pursue' option. (Walsh, 1997; see also Hymans, 2000.)

A range of current problems were summarised by IAEA Director General Mohamed El Baradei (2005) at the opening of the 2005 NPT Review Conference: "In five years, the world has changed. Our fears of a deadly nuclear detonation – whatever the

back to table of contents

cause – have been reawakened. In part, these fears are driven by new realities. The rise in terrorism. The discovery of clandestine nuclear programmes. The emergence of a nuclear black market. But these realities have also heightened our awareness of vulnerabilities in the NPT regime. The acquisition by more and more countries of sensitive nuclear know-how and capabilities. The uneven degree of physical protection of nuclear materials from country to country. The limitations in the IAEA's verification authority – particularly in countries without additional protocols in force. The continuing reliance on nuclear deterrence. The ongoing perception of imbalance between the nuclear haves and have-nots. And the sense of insecurity that persists, unaddressed, in a number of regions, most worryingly in the Middle East and the Korean Peninsula."

The IAEA and the US government have recently proposed initiatives aimed at limiting the use and stemming the spread of enrichment and reprocessing facilities.

El Baradei's (2005; 2005B) proposals include developing better options for managing enrichment and reprocessing technologies, such as in regional centres under multinational or international control, and a moratorium on the construction of new enrichment and reprocessing facilities "to address this vulnerability in the regime". The United Nations' High-level Panel on Threats, Challenges and Change has also proposed a moratorium on the construction of new enrichment and reprocessing facilities.

The United States has proposed similar initiatives to the IAEA. President George W. Bush (2004) said in February, 2004: "The world must create a safe, orderly system to fuel civilian nuclear plants without adding to the danger of weapons proliferation. The world's leading nuclear exporters should ensure that states have reliable access at reasonable cost to fuel for civilian reactors, so long as those states renounce enrichment and reprocessing. Enrichment and reprocessing are not necessary for nations seeking to harness nuclear energy for peaceful purposes. The 40 nations of the Nuclear Suppliers Group should refuse to sell enrichment and reprocessing equipment and technologies to any state that does not already possess full-scale functioning enrichment and reprocessing plants."

The Australian Safeguards and Non-Proliferation Office has made proposals similar to those of the IAEA. ASNO (n.d.)

back to table of contents

states: "Clearly it remains prudent to limit the States operating enrichment and reprocessing facilities. ... Containing the spread of sensitive technologies may come under challenge, however, as nuclear power programs grow, and as more States aspire to technological independence and equality. ... In the future, the governments concerned may wish to consider establishing enrichment and reprocessing facilities, as well as plutonium storage and fuel fabrication facilities, on a regional basis – servicing the needs of industries in the region, and operated by regional partnership involving governments and the private sector. This approach would limit the overall number of sensitive facilities, would maintain them under multilateral control, and would remove the economic motivation for establishing such facilities on a national basis."

Even the industry-funded Uranium Information Centre (2004F) recognises a problem in relation to enrichment and reprocessing facilities: "The Iran situation has revived wider concerns about which countries should develop facilities with high proliferation significance – such as enrichment and reprocessing, even under safeguards if there is no evident economic rationale. At some point in the future, such a country could give three months notice of withdrawal from the NPT and reconfigure its facilities for weapons production. The USA asserts that Iran has been in fact developing just such a breakout capability."

While proposals for multinational or international control of enrichment and reprocessing technology have the potential to reduce the risks of horizontal proliferation, there are many problems and obstacles. Even if enrichment and reprocessing were limited to certain states, the potential for diversion of fissile material by customer states (or terrorists) could not be eliminated, in addition to the proliferation potential in the host states. The proposals would most likely be applied selectively (as evidenced by the acquiescence to the unnecessary reprocessing plant at Rokkasho in Japan).

Perhaps the greatest difficulty with proposals to limit the spread of enrichment and reprocessing technology, and to establish multinational or international control, is that they are likely to face insurmountable opposition.

Proposals to stop the development of new enrichment and reprocessing plants have already been put to the test. Brazil is

back to table of contents

developing an enrichment plant, and Japan is planning large-scale reprocessing at Rokkasho from 2007. Opposition to these plants on non-proliferation grounds has been muted or non-existent to date.

A further reason for scepticism is the fact that some of the proponents of these initiatives persist with policies which undermine non-proliferation objectives – such as the permission given by the Australian and US governments for the separation and stockpiling of Australian- and US-obligated plutonium, and Australia's facilitation of Silex uranium enrichment technology.

3.7. alternative fuel cycles

The weapons proliferation problem cannot be satisfactorily resolved. Proliferation-resistant technologies are the subject of much discussion and some research (a number of examples are discussed in Australian Safeguards and Non-Proliferation Office, n.d.)

However, there is little reason to believe that minimising proliferation risks will be a priority in the evolution of nuclear power technology. The growing stockpiles of unirradiated and separated plutonium provide compelling evidence of the low priority given to non-proliferation initiatives. Further, a number of the 'advanced' reactor concepts being studied involve the large-scale use of plutonium and the operation of fast breeder reactors (Burnie, 2005).

The only way to avoid reliance on enrichment plants (with the capacity to produce HEU) is to use non-enriched uranium fuel, which maximises production of the other main alternative ingredient for (fission) nuclear weapons – plutonium. On the other hand, a complete cessation of reprocessing in favour of a once-through cycle would represent a major step forward in relation to overall proliferation risks, but it would require greater uranium resources and potentially lead to the expansion and spread of enrichment technology. (Feiveson, 2001.)

Technical developments in the field of enrichment technology – such as the development of laser enrichment technology by the Silex company at Lucas Heights in Australia – could worsen the situation. Silex will potentially provide proliferators with an ideal enrichment capability as it is expected to have relatively low capital cost and low power consumption, and it is based on relatively simple and practical separation modules. (Greenpeace, 2004; Boureston and Ferguson, 2005.)

back to table of contents

Dr. Tilman Ruff, president-elect of the Medical Association for the Prevention of War, has called on the Australian government to end support for enrichment research in Australia: "The technology which is being developed here in a publicly funded facility ... is of profound concern. What this Silex technology brings is an easier, smaller, simpler, cheaper and more concealable way to enrich uranium. That's of grave concern from a proliferation point of view." (Quoted in Greenpeace, 2005.)

fusion

Fusion power systems remain a distant dream, and fusion also poses a number of weapons proliferation risks including the following:

- The production or supply of tritium which can be diverted for use in boosted nuclear weapons.

- Using neutron radiation to bombard a uranium blanket (leading to the production of fissile plutonium) or a thorium blanket (leading to the production of fissile uranium-233).

- Research in support of a (thermonuclear) weapon program. (Gsponer and Hurni, 2004; WISE/NIRS, 2004; Hirsch et al., 2005.)

The dream of fusion power has already contributed to proliferation problems. According to Khidhir Hamza (1998), a senior nuclear scientist involved in Iraq's weapons program: "Iraq took full advantage of the IAEA's recommendation in the mid 1980s to start a plasma physics program for "peaceful" fusion research. We thought that buying a plasma focus device ... would provide an excellent cover for buying and learning about fast electronics technology, which could be used to trigger atomic bombs."

thorium

The use of thorium-232 as a reactor fuel is sometimes suggested as a long-term energy source, partly because of its relative abundance compared to uranium. Some experience has been gained with the use of thorium in power and research reactors – but far less experience than has been gained with conventional uranium reactors. The Uranium Information Centre (2004E) states that: "Much development work is still required before the thorium fuel cycle can be commercialised, and the effort required seems unlikely while (or where) abundant uranium is available."

back to table of contents

Thorium fuel cycles are promoted on the grounds that they pose less of a proliferation risk compared to conventional reactors. However, whether there is any significant non-proliferation advantage depends on the design of the various thorium-based systems. No thorium system would negate proliferation risks altogether (Friedman, 1997; Feiveson, 2001). Neutron bombardment of thorium (indirectly) produces uranium-233, a fissile material which is subject to the same safeguards requirements as uranium-235. The possible use of highly enriched uranium or plutonium to initiate a thorium-232/uranium-233 reaction is a further proliferation concern. Most proposed thorium fuel cycles require reprocessing with the attendant proliferation risks.

The use of thorium as a power source is most advanced in India, where it is consistent with and possibly connected to military objectives.

plutonium breeder reactors

Breeder reactors rely on plutonium as the primary fuel. There are various possible configurations of breeder systems. Most rely on irradiation of a natural or depleted uranium blanket which produces plutonium which can be separated and used as fuel. Breeder reactors can potentially produce more plutonium than they consume, and the use of uranium is only a tiny fraction of that consumed in conventional reactors. (Hirsch et al., 2005, pp.33-35; von Hippel and Jones, 1997.)

According to the World Nuclear Association (2004), worldwide experience with fast neutron reactors amounts to just 200 reactor-years and only “some” of that experience involves reactors in breeder mode. According to an IAEA scientist, the introduction of breeder reactors into the competitive electricity market is not expected before 2030, at which time breeders are expected to provide 1-2% of nuclear energy output, and this prediction may be “optimistic” (Oi, 1998).

Small breeder R&D programs are ongoing in a few countries (e.g. India, Russia, France) but in other countries the technology has been stalled or abandoned (e.g. the UK, the US, and Germany) or never developed in the first place. Japan’s plans for breeder reactors have been limited and delayed by accidents including the sodium leak and fire at the experimental Monju reactor in 1995. (Leventhal and Dolley, 1999B.)

back to table of contents

One reason for the limited interest in plutonium breeder power sources has been the cheap, plentiful supply of uranium. That situation may change, but while breeder technology certainly holds out the promise of successfully addressing the problem of limited uranium reserves, it is doubtful whether the wider range of technical, economic, safety and proliferation issues can be successfully addressed.

Breeder technology is highly problematic in relation to proliferation because it involves the large-scale production and separation of plutonium (although separation is not required in some proposed configurations). (Feiveson, 2001.) The proliferation of reprocessing capabilities is a likely outcome.

Interest in breeder and reprocessing technology in South Korea and China is arguably driven in part by concerns over Japan's plutonium policies (which involve the large-scale separation and stockpiling of plutonium). (Burnie and Smith, 2001.)

3.8. nuclear smuggling and terrorism

Most countries pursuing a covert nuclear weapons program have attempted to develop a domestic capacity to produce highly enriched uranium and/or plutonium, but the potential for states (or sub-national groups) to steal large quantities of fissile material has become an issue of increasing concern. Hundreds of thefts from both civil and military nuclear facilities around the world have been recorded. This has implications for nuclear weapons proliferation and the spread of material for potential use in radiological 'dirty' bombs.

The IAEA's Illicit Trafficking Database records over 650 confirmed incidents of trafficking in nuclear or other radioactive materials since 1993. In 2004 alone, nearly 100 such incidents occurred, 11 of which involved nuclear material. Most incidents involved deliberate intent to illegally acquire, smuggle, or sell radioactive material. At least 17 incidents involving fissile material – highly enriched uranium or plutonium – have been detected, although none involved sufficient fissile material to be used in a nuclear weapon (unless additional supplies were available) and most amounted to no more than a small percentage of the amount required for a weapon. (IAEA, n.d.; El Baradei, 2005C.)

Most of the detected incidents of smuggling have involved material which could not be

back to table of contents

used in nuclear weapons and would not even be of much value as material for ‘dirty’ bombs in terms of radiological impacts. However, dirty bombs could succeed as ‘weapons of mass disruption’ even if their radiological impact was minimal, because of the engendered fear and the potentially lengthy and costly clean-up.

Civil nuclear plants are potentially “attractive” targets for terrorist attacks involving the use of grenades, missiles, commando-style attacks, car or truck bombs, or planes. This is because of the importance of the electricity supply system, the large radioactive inventories in many facilities, and the potential or actual use of civil nuclear facilities for weapons production.

Irradiated nuclear materials are orders of magnitude more radioactive than ‘front-end’ materials such as natural, enriched or depleted uranium. Therefore, the facilities of most concern are reactors, spent fuel stores, and reprocessing plants, as well as the transportation of spent fuel or high-level waste from reprocessing plants. (Hirsch et al., 2005, pp.98-114). Spent fuel stores are seen by some to be particularly vulnerable because of their high radioactive inventories and generally lower level of protection compared to reactors. (Alvarez, 2002.)

Attacks on nuclear facilities by nation states have been mentioned already – the attacks on nuclear facilities in Iraq by Iran, Israel and the US, and Iraq’s attacks on facilities in Iran and Israel. A number of attacks on nuclear plants by sub-national groups have also occurred, as well as a number of threatened attacks (Hirsch et al., 2005, pp.87-88). Examples include:

- The hijacking of a plane in 1972 and the ensuing threat to crash it into the Oak Ridge nuclear research reactor.

- Basque separatists bombing a nuclear power plant under construction in Spain in 1982.

- ANC guerrilla fighters bombing the Koeberg nuclear plant under construction in South Africa in 1982.

- Sabotage of three of the four off-site power lines leading to the Palo Verde nuclear power plant in Arizona in 1986.

- A man ramming a station wagon under a partly opened door in the turbine building at the Three Mile Island nuclear plant in Pennsylvania in 1993.

back to table of contents

A 2004 study by the Union of Concerned Scientists concluded that a major terrorist attack on the Indian Point reactor in the US could result in as many as 44,000 near-term deaths from acute radiation syndrome and as many as 518,000 long-term deaths from cancer among individuals within fifty miles of the plant. The attack would pose a severe threat to the entire New York metropolitan area. Economic damages could be as great as US$2.1 trillion (Lyman, 2004).

There are also incidents of sabotage, such as the placement of debris inside fuel elements at the Sellafield plant in the UK in 2000. British Nuclear Fuels Ltd. acknowledged that the debris might have interfered with the safe operation of the fuel in a reactor had it not been detected. (Connor, 2000.) Other incidents at Sellafield have included the cutting of wires to five robotic arms in a waste treatment plant (Brown, 2000).

Limitations on civil liberties can be the price paid to adequately secure nuclear facilities and materials. Further, the risks of nuclear terrorism and smuggling can be used as a pretence to enact legislation which targets legitimate protest and whistle-blowing activity. Thus the Australian Nuclear Non-Proliferation (Safeguards) Act 2003 has been strongly criticised by non-governmental organisations because of the penalties is proscribes for protest and whistle-blowing activity. According to Greenpeace and the Australian Conservation Foundation (2003): "The laws will make it harder for environment groups, media, industry whistle-blowers or communities living near nuclear facilities, uranium mines, radioactive waste dumps or waste transport routes to take action or act as a watchdog against these activities."

3.9. Debunking the myths of the peaceful atom

Nuclear proponents too often make false or misleading comments in relation to proliferation. The recurring theme is to distance civil nuclear programs from any connection to military programs.

According to Ian Hore-Lacy from the Uranium Information Centre (2000): "Happily, proliferation is only a fraction of what had been feared when the NPT was set up, and none of the problem arises from the civil nuclear cycle." The Uranium Information Centre (n.d.) claims that: "No nuclear materials such as uranium from the civil nuclear fuel cycle have ever been diverted to make weapons."

back to table of contents

Those disingenuous claims from the Uranium Information Centre ignore the widespread use of ostensibly civil facilities and materials (including safeguarded facilities and materials) for weapons research or in systematic weapons programs.

John Carlson (2000), Director-General of the Australian Safeguards and Non-Proliferation Office, says: "If we look to the history of nuclear weapons development, we can see that those countries with nuclear weapons developed them before they developed nuclear power programs." However, ostensibly civil nuclear programs clearly paved the way for the successful development of nuclear weapons in Israel, India, Pakistan, and in the former nuclear weapons state South Africa.

Sometimes it is claimed that plutonium from power reactors has never been used in weapons. This claim is most likely false as India is believed to have used plutonium from a power reactor in weapons. North Korea's 'Experimental Power Reactor' has been an important component of the regime's weapons program. A test of sub-weapon grade plutonium by the US may have used plutonium from a power reactor. More importantly, the claim that power reactors have not become entangled in weapons programs ignores the pool of expertise required to run a nuclear power program and the actual and potential use of that expertise in military programs. Claims made about power reactors also ignore the fact that 'research' reactors, ostensibly acquired in support of a power program or for other civil purposes, have been the plutonium source in India and Israel with 'research' reactors also involved in weapons programs or weapons research in numerous other countries (Green, 2002).

The IAEA (1997) claims that: "The large scale production of plutonium for nuclear weapons has always been through specially designed plutonium production reactors." However, the 'research' reactors used to produce military plutonium in India, Israel, North Korea and possibly Pakistan are not 'specially designed plutonium production reactors', albeit the case that they are well suited for the purpose of plutonium production.

The IAEA (1997) claims that: "The availability of plutonium for weapons is not dependent on continued civil nuclear power activities." However, civil nuclear programs are a potential source of plutonium for states which want plutonium or want more than they already have.

back to table of contents

The Uranium Information Centre (2004) states that: "Weapons-grade plutonium is not produced in commercial power reactors but in a "production" reactor operated with frequent fuel changes to produce low-burnup material with a high proportion of Pu-239." However, weapon grade plutonium can be produced in civil reactors (though not in the normal course of operation), and sub-weapon grade plutonium can be and has been used in weapons.

The IAEA (1997) states that: "The technology for nuclear weapons production is with us indefinitely, it cannot be undone. The risk of proliferation today is not zero and would not become zero even if nuclear power ceased to exist. It is a continually strengthened non-proliferation regime that will remain the cornerstone of efforts to prevent the spread of nuclear weapons."

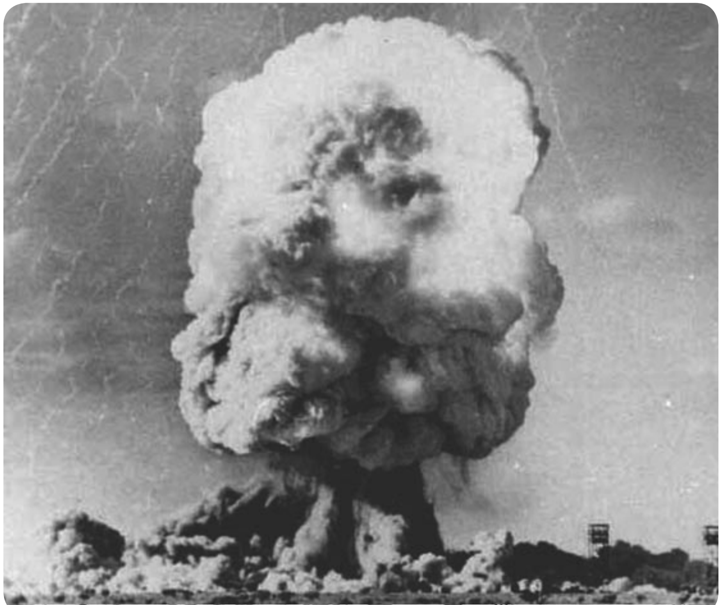
However, other things being equal, proliferation risks will obviously increase if nuclear power expands, and the risks will decrease if nuclear power declines.

John B. Ritch (1999) claims that: "[T]he fear of nuclear proliferation is simply misplaced in the global warming debate. Most current carbon consumption is in countries which already have nuclear weapons or which can be relied on as good-faith parties to the NPT. And the largest growth markets in energy consumption are China and India, both of which already have weapons capabilities. In short, almost everywhere the reduction in carbon emissions could yield important benefits for climate protection, proliferation is not even an issue."

Ritch's logic falls apart unless nuclear power is to be confined to nuclear weapons states. It would also fail to apply in the event of nuclear weapons states disarming, and it fails to acknowledge terrorist and sub-national influences.

Ritch (1999) claims that "... any aspiring proliferator would face a strong probability of detection – and the sure knowledge that a violation would turn it into an international pariah facing collective action by the UN Security Council with a likely military response." The likelihood of detection has certainly increased with the IAEA's Strengthened Safeguards Program, though it is debatable whether there is a strong probability of detection. Moreover, the claim that violations would lead to collective action

back to table of contents



and a likely military response is contradicted by the historical experience of highly varied and selective responses.

This varied and selective response to proliferation threats is also ignored by the Uranium Information Centre (2004), which claims that: “If a nuclear-capable country does leave the NPT it is likely to be reported by IAEA to the UN Security Council, just as if it were in breach of its safeguards agreement. Trade sanctions are then likely.”

Nuclear proponents sometimes attempt to downplay the significance of the dual-use capabilities of nuclear facilities and materials by noting the dual-use capabilities of many non-nuclear materials. For example, steel has a myriad of military and civil uses, and planes can be used as missiles. This overlooks the problem that nuclear weapons are unique in their destructive potential – far more destructive than conventional weapons and considerably more destructive than other ‘weapons of mass destruction’.

back to table of contents

4. radioactive waste

4.1. introduction

Radioactive wastes arise across the nuclear fuel cycle:

- Uranium mines typically generate large volumes of long-lived, low-level waste which is kept on site. For example the Roxby Downs copper/uranium mine in South Australia has a radioactive tailings stockpile of about 60 million tonnes, growing at 10 million tonnes annually.

- Enrichment plants generate large volumes of waste, including depleted uranium.

- Reactors emit radioactive emissions to air and water in addition to the spent fuel they create.

- Reprocessing plants generate a high-level radioactive waste stream and radioactive emissions to air and water, in addition to uranium and (weapons-useable) plutonium.

In addition to the public health and environmental hazards posed by radioactive waste, it also poses military risks, e.g. depleted uranium (used in munitions) is a by-product of enrichment, and spent fuel from power reactors contains large quantities of plutonium.

High-level waste is by far the most hazardous of the waste streams arising from the nuclear fuel cycle. High-level waste includes spent nuclear fuel, and the waste stream from reprocessing. As discussed below, reprocessing poses a significant public health and environmental hazard, as well as a proliferation risk, and little progress has been made with respect to final disposal of spent fuel or high-level reprocessing wastes.

Many of the arguments advanced by nuclear proponents on radioactive waste issues are inconsistent or disingenuous, such as:

- Stating that the volume of radioactive waste generated by nuclear power reactors

back to table of contents

is relatively small compared to gaseous emissions from fossil fuel powered electricity plants. Such statements generally ignore the vast volumes of waste arising across the wider nuclear fuel cycle, not least from uranium mining and enrichment. Moreover, volume is not necessarily a good indicator of hazard. High-level nuclear waste emits a great deal of radioactivity and heat, and in some cases is prone to radionuclidic concentration leading to criticality accidents, as well as the potential separation and military use of plutonium (or the separation and military use of highly-enriched uranium from some research reactor spent fuel).

- Claiming that radioactive wastes are contained. This is false as radioactive emissions to air and/or water are emitted across the nuclear fuel cycle.

- Claiming that the technical problems associated with waste management have been solved and that the only problems concern public acceptance. A myriad of technical problems remain unresolved, and the problem of public acceptance is no less a problem for being of a non-technical nature.

- Claiming that spent fuel is not radioactive waste but an 'asset' or 'resource'. However, only a small fraction of uranium or plutonium recovered from reprocessing is re-used as fuel, and the main purpose of reprocessing plants has been to serve as long-term de facto storage sites – out of sight, out of mind.

- Claiming that reprocessing spent fuel reduces waste volumes and toxicity. In fact reprocessing does nothing whatsoever to reduce overall radioactivity or toxicity. The overall waste volume is increased by reprocessing, albeit the case that the volume of the high-level waste stream is reduced.

- Pretending that repositories or stores for radioactive waste exist even when they do not. For example, the Australian Nuclear Science and Technology Organisation (2001) states that reprocessing wastes from its research reactors "will be returned to Australia for storage at the Commonwealth's national intermediate level waste store" – but no such store exists! Sometimes it is claimed that Finland, Sweden or other countries have final repositories for high-level waste though they do not (see the country profiles at <www.radwaste.org>).

- Claiming that "nuclear power is the only energy-producing industry which takes full responsibility for all its wastes and fully costs

back to table of contents

this into the product." (Hore-Lacey, 2003, ch.5). The claim is demonstrably false as a range of wastes across the nuclear fuel cycle are not factored into costs.

As AMP Capital Investors (2004) notes in its Nuclear Policy Position Paper, the nuclear industry fails the sustainability test as it is transferring nuclear waste problems to future generations: "The waste problems of the uranium mining and power generation are numerous and long lasting. Due to the long half lives and inability ... to find an acceptable final disposal method for radioactive materials, the problem will continue for a long time without a solution. Therefore there are significant concerns about whether an acceptable waste disposal option currently exists. From a sustainability perspective, while the nuclear waste issues remain unresolved, the uranium/nuclear power industry is transferring the risks, costs and responsibility to future generations."

4.2. spent nuclear fuel

A typical power reactor (1000 MWe, light water type) produces 25-30 tonnes of spent nuclear fuel annually. Annually, about 12,000 to 14,000 tonnes of spent fuel are produced by power reactors. By 2010, the total accumulated amount of spent fuel will be about 340,000 tonnes, with about 110,000 tonnes having been reprocessed and the rest stored. (Rosen, 1998.)

Under a scenario mapped out by the Intergovernmental Panel on Climate Change (1995), in which the installed nuclear capacity would grow from to about 3,300 GW in 2100, the total accumulated spent fuel by 2100 would be about 6.3 million tonnes.

The following approaches are being pursued in relation to spent fuel management (Hore-Lacey, 2003, ch.5):

- Reprocessing followed by vitrification of high-level reprocessing wastes with a view to eventual deep underground disposal. This is the policy in the UK, France, Japan, China, and India. (German nuclear utilities no longer send spent fuel to France or the UK for reprocessing from mid-2005.)

- Treating spent fuel as high-level waste with a view to eventual direct disposal. This is the policy in the USA, Canada, and Sweden.

- A number of countries operating nuclear power plants have yet to choose between reprocessing, direct disposal or long-term storage.

back to table of contents

Technologies exist to encapsulate/immobilise radionuclides to a greater or lesser degree, but encapsulated radioactive waste still represents a potential public health and environmental threat for millennia. Synroc – the ceramic immobilisation technology developed in Australia – seems destined to be a permanently 'promising' technology. As nuclear advocate Leslie Kemeny (2005) notes, Synroc "showed great early promise but so far its international marketing and commercialisation agendas have failed".

4.3. reprocessing

Civil reprocessing releases significant quantities of radioactive wastes into the sea and gaseous discharges into the air. Cogema's reprocessing plant at La Hague in France, and BNFL's plant at Sellafield in the UK, are the largest source of radioactive pollution in the European environment (WISE-Paris, 2001). The radioactive contamination from these facilities can be traced through the Irish Sea, the North Sea, along the Norwegian coast into the Arctic and Atlantic Oceans, and gives rise to elevated contamination levels in biota. There is an increase in the rate of childhood leukaemia and other radiation-linked diseases in the vicinity of both Sellafield and La Hague although the link between the reprocessing plants and these increases is contested.

The OSPAR Commission regulates marine pollution in the North-East Atlantic under the terms of the 1992 OSPAR Convention (<www.ospar.org>). Fifteen European countries are parties to the Convention, as is the European Union. Most of the European countries party to the Convention have been calling for a sharp reduction in radioactive emissions from Sellafield and La Hague.

At the Ministerial-level OSPAR meeting in 1998, all parties agreed to progressive and substantial reductions in radioactive discharges to achieve by the year 2020 close to zero concentrations in the marine environment above historic levels.

At the 2000 OSPAR meeting, a resolution was passed stating that: "The current authorisations for discharges or releases of radioactive substances from nuclear reprocessing facilities shall be reviewed as a matter of priority by their competent national authorities with a view to, inter alia, implementing the non-reprocessing option (for example, dry storage) for spent nuclear fuel management at appropriate facilities." (OSPAR, 2000.)

back to table of contents

The 2000 OSPAR resolution was supported by 12 countries – Denmark, Belgium, Finland, Germany, Norway, The Netherlands, Switzerland, Portugal, Spain, Sweden, Iceland, and Ireland – but not by France or the UK.

The serious proliferation issues associated with reprocessing were discussed in Section 2 of this report.

4.4. repositories

Not a single repository exists anywhere in the world for the disposal of high-level waste from nuclear power.

Only a few countries – such as Finland, Sweden, and the US – have identified a repository site. Plans are being advanced in several countries to build deep underground repositories for high-level waste, but as IAEA Director-General Mohamed El Baradei (2000) notes, these plans face significant obstacles: lack of public acceptance; cost; lack of expertise; and lack of suitable sites.

The proposed repository at Yucca Mountain in the US still faces significant legal and political obstacles. A legal limit of 70,000 tonnes of spent fuel equivalent has been established, yet US reactors now operating are expected to generate 105,000 tonnes over their lifetime, possibly considerably more. The Massachusetts Institute of Technology (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 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 single year. The US itself would need additional new capacity of the scale of Yucca Mountain about every 12 years if nuclear output was trebled. (Ansolabehere et al., 2003.)

The MIT Interdisciplinary Study goes on to say that "the organizational and political challenges of siting will surely be formidable." (Ansolabehere et al., 2003.)

The MIT Interdisciplinary Study assumes a major reduction in the volume of spent fuel generated per unit of nuclear output such that an output of 1000 GWe results in the

back to table of contents

generation of 20,000 tonnes of spent fuel annually. That is only about one third higher than the current figure of 12-14,000 tonnes from a global nuclear capacity of 364 GWe. Thus, formidable challenges lie ahead even at the current level of nuclear power output.

Several themes can be identified in recent discussions and debates over final disposal of high-level wastes (some discussed by El Baradei, 2003).

First, a range of alternative technologies (e.g. transmutation – discussed below) or options (e.g. sea-bed disposal) have been discussed. However, all are seen to be non-starters for economic, technological or political reasons. Putting a positive spin on this situation, there is said to be an 'international consensus' on the wisdom of placing high-level waste in deep underground repositories.

Second, deep repositories are promoted as final disposal sites and contrasted with storage or other options which require ongoing vigilance for long periods into the future. However there is some movement within the nuclear industry towards accepting the need for monitoring and 'retrievability' of radioactive waste in case of leaks and other problems. This shift in favour of retrievable waste management is generally supported by environmental organisations, but it undercuts the alleged 'benefit' of disposal by conceding that high-level waste will be a burden on future generations whether or not it is placed in repositories.

Third, partly driven by the failure to establish national repositories, there has been growing interest in attempting to establish multinational/international repositories. However, there is also acknowledgement that multinational repositories could generate more intense public opposition than national repositories, e.g. the fierce opposition to Pangea Resources in Australia. Russia may accept foreign-origin high-level waste for disposal, and the UK may dispose of some wastes previously destined for return to their country of origin.

A number of themes are taken up by Steve Kidd (2004) from the World Nuclear Association: "So what can the industry do in the future to get out of this mess? I would say four things. Number one, don't be afraid to say that you don't know whether spent fuel will be an asset or liability, as you can't be certain what future nuclear fuel markets will look like or how technology will shift. Try to sell the idea of long-term surface storage to

back to table of contents

the public on the basis that you are passing a potential asset onto the next generation, not a certain liability. Secondly, continue to investigate and demonstrate the technical merit of deep repositories as, whatever occurs, some of these are going to be needed in the future. Thirdly, look positively at the concept of international repositories. There are significant regulatory (and perhaps public acceptability) problems with these, but the idea of each nuclear country having its own looks ludicrous from several angles. Finally, actively pursue research in improved reprocessing technology, which should take place at a limited number of safeguarded sites around the world (as has also been suggested for enrichment facilities). The world could well be short of nuclear fuel in the coming decades, as was originally predicted, so this option must be investigated."

4.5. transmutation

Transmutation is a technological 'solution' sometimes proposed to deal with high-level, long-lived waste. The aim is to use reactors, spallation technology or particle accelerators to generate beams of neutrons or charged particles to transform long-lived radionuclides into shorter-lived or stable isotopes. For example, neutron bombardment of radioactive iodine-129 results (indirectly) in its conversion to stable, non-radioactive xenon. And neutron bombardment of plutonium and neptunium leads to their fission which converts them into shorter-lived radionuclides.

Problems with transmutation include the following (Zerriffi and Makhijani, 2000; Makhijani, 2001; Ansolabehere et al., 2003; Gibson, 1991):

- The technology is immature and its future is uncertain.

- It is useful only for certain types and forms of waste. It does not do away with the need for long-term management (storage or disposal) of the resulting wastes.

- It may require the use of reactors (with the attendant proliferation, public health and environmental risks).

- It may require reprocessing (with the attendant proliferation, public health and environmental risks) to separate waste streams prior to selective treatment. Failure to separate/partition can lead to unwanted outcomes such as conversion of stable isotopes into radioactive isotopes.

back to table of contents

A report from the UK's government's Radioactive Waste Management Advisory Committee (2003) concluded that partitioning (separation of different radionuclides) followed by transmutation could deal with only a small fraction of the UK's higher-activity wastes, it would be costly, and would require new nuclear reactors and reprocessing plants.

The MIT Interdisciplinary Study concludes that: "Decisions about partitioning and transmutation must ... consider the incremental economic costs and safety, environmental, and proliferation risks of introducing the additional fuel cycle stages and facilities necessary for the task. These activities will be a source of additional risk to those working in the plants, as well as the general public, and will also generate considerable volumes of non-high-level waste contaminated with significant quantities of transuranics. Much of this waste, because of its long toxic lifetime, will ultimately need to be disposed of in high-level waste repositories. Moreover, even the most economical partitioning and transmutation schemes are likely to add significantly to the cost of the once-through fuel cycle." (Ansolabehere et al., 2003.)

back to table of contents

5. hazards of the nuclear fuel cycle

5.1. introduction

There have been at least eight nuclear accidents involving damage to or malfunction of the reactor core. The Uranium Information Centre (2004C) lists the following reactor core accidents:

- NRX, Canada, 40 MWt research reactor, 1952.

- Windscale-1, UK, fire in plutonium production reactor, 1957, widespread contamination. (The National Radiological Protection Board estimated 33 premature deaths.)

- SL-1, USA, 3 MWt experimental/military reactor, 1961, three operators killed.

- Fermi-1, USA, 66 MWe experimental breeder reactor, 1966.

- Lucens, Switzerland, 7.5 MWe experimental reactor, 1969.

- Three Mile Island-2, USA, 880 MWe commercial power reactor, 1979, significant core meltdown but limited off-site release of radiation.

- Saint Laurent-A2, France, 450 MWe commercial power reactor, 1980.

- Chernobyl-4, Ukraine, 950 MWe commercial power reactor, 1986.

The Uranium Information Centre (2004C) notes two other serious reactor accidents which did not involve core damage or malfunction:

- Browns Ferry, USA, 2 x 1080 MWe commercial power reactors, 1975, fire damaged control cables resulting in an 18-month shutdown.

- Vandellos-1, Spain, 480 MWe commercial power reactor, 1989, a turbine fire led to the permanent closure of the reactor.

back to table of contents

In addition, there have been a number of ‘near misses’. For example, inspection of the Davis-Besse (USA) reactor vessel head in 2002 revealed a large cavity in the vessel head adjacent to a reactor control rod drive mechanisms, caused by acid leakage and corrosion. The cavity – discovered before the restart of the reactor – seriously jeopardised the integrity of the reactor vessel. (Ansolabehere et al., 2003.) Similar problems (on a lesser scale) have been discovered in other Pressurised Water Reactors in the US, France, Sweden, and Switzerland (Hirsch et al., 2005).

In addition, there have been many nuclear fuel cycle accidents not involving reactors, including serious accidents such as:

- Chelyabinsk, Soviet Union, reprocessing waste explosion, 1957.

- Hanford, USA, waste storage tank leakage, 1970.

- Tokaimura, Japan, nuclear criticality incident in a fuel fabrication facility, 1999, resulting in two deaths – despite the operator JCO having previously insisted that a criticality accident at the fuel plant was “impossible” (Leventhal and Dolley, 1999).

The Uranium Information Centre (2004C) says there have been “many” (non-reactor) criticality accidents such as the 1999 Tokaimura accident, “practically all in military facilities prior to 1980”.
The MIT Interdisciplinary Study expresses particular concern about reprocessing plants because of the large radioactive material inventories and because the accident frequency of reprocessing plants is much higher than for reactors (Ansolabehere et al., 2003).

In addition to the hazards posed by accidents, radioactive emissions are routinely generated across the nuclear fuel cycle. The United Nations Scientific Committee on the Effects of Atomic Radiation (1994) has estimated the collective effective dose to the world population over a 50-year period of operation of nuclear power reactors and associated nuclear fuel cycle facilities to be two million person-Sieverts. Applying a standard risk estimate of 0.04 fatal cancers per person-Sievert gives a total of 80,000 fatal cancers.

Garwin (2001) arrives at figures of similar magnitude. He draws on official figures on radiation doses from nuclear fuel cycle facilities, and applies a risk estimate of 0.04 fatal cancers per person-Sievert, to calculate

back to table of contents

that a once-through cycle results in six cancer deaths per gigawatt-year of nuclear output, or 14 deaths with reprocessing. Total installed capacity is currently about 364 GWe giving a total of 2160—5040 cancer deaths per year (assuming full capacity is utilised).

Risk estimates for low-level radiation exposure are based on the Linear No Threshold (LNT) model of radiological risk assessment. The LNT model holds that the adverse health risks arising from radiation exposure are proportional to the radiation dose and that there is no level of exposure below which radiation is safe. An important recent study by the US National Research Council (2005) has added significant weight to the LNT model and the associated risk estimates. Chair of the Council's research panel, Professor Richard Monson, concluded: "The scientific research base shows that there is no threshold of exposure below which low levels of ionizing radiation can be demonstrated to be harmless or beneficial."

5.2. comparing alternative energy sources

Comparing the public health risks of nuclear power and fossil fuel fired electricity systems is complicated because the risks are of a different nature. In fossil fuel fired electricity systems, the risks arise primarily through the routine emission of large volumes of toxic gases and particulates from the burning of fossil fuels. These emissions have significant public health effects and contribute significantly to the increase in atmospheric greenhouse gas concentrations and to the myriad of environmental and public health hazards associated with climate change.

For nuclear power, the major risks arise from the potential for a single reactor accident to kill tens or hundreds of thousands of people – orders of magnitude more than fossil fuel facility accidents. Nuclear power is also unique in its connection to nuclear weapons proliferation.

The Uranium Information Centre (2003) presents information which purports to demonstrate that nuclear power is far safer than alternative energy sources. For the period 1970-92, the Uranium Information Centre gives the following figures on

back to table of contents

"immediate" fatalities:

- Coal – 6400 fatalities – 342 fatalities per TWy (million MWe operating for one year)
- Natural gas – 1200 fatalities – 85 fatalities per TWy
- Hydroelectricity – 4000 fatalities – 883 fatalities per TWy
- Nuclear – 31 fatalities (Chernobyl) – 8 fatalities per TWy.

However, a very different picture emerges if the scope extends beyond immediate fatalities. Such a study would need to estimate the (large) number of fatalities arising from the extensive gaseous emissions from fossil fuel fired electricity plants. The impacts of nuclear power would need to include an estimate of fatalities arising from routine radioactive emissions from nuclear fuel cycle facilities (about 80,000 fatal cancers using the UNSCEAR estimate of collective dose) as well as long-term deaths caused by exposure to radiation from nuclear accidents – a large majority of which would be attributed to the Chernobyl accident. Compared to the overall fatalities from fossil fuel electricity or nuclear power, renewable energy sources – including hydroelectricity – are much safer.

5.3. chernobyl

Pro-nuclear advocates frequently claim that the death toll from the April 1986 Chernobyl nuclear reactor disaster was 30-60 deaths. They also claim, as the Uranium Information Centre (2004D) does, that "there is no scientific evidence of any significant radiation-related health effects to most people exposed" to fallout from Chernobyl.

Such claims are ill-informed and/or misleading. It is widely acknowledged that it is difficult for epidemiological studies to demonstrate statistically significant increases in cancers or other pathologies caused by Chernobyl fallout for various reasons such as the relatively high incidence of the diseases, the latency period of cancers, and limited data on disease incidence. However, difficulties in measuring impacts is no justification for trivialising or ignoring them.

The Uranium Information Centre (2004D) states that a "greater, though not statistically discernible" incidence of leukaemia and other cancers is expected as a result of Chernobyl fallout. There is little expectation, however, of statistically significant results. Further, when statistically significant results are obtained, explanations other than Chernobyl can easily

back to table of contents

be suggested. For example, it is widely accepted that Chernobyl fallout has caused about 1800 cases of thyroid cancer but it has also been suggested that the rapid increase in thyroid cancers may be in part an artefact of the screening process (Uranium Information Centre, 2004D). Likewise, a study attributing over 800 cancers in Sweden to Chernobyl fallout has been disputed (Anon., 2004). Another example is a debate over increased rates of infant leukaemia in several countries (Low Level Radiation Campaign, n.d.).

Some of the difficulties were described by Elizabeth Cardis (1996) from the International Agency for Research on Cancer: "Although some increases in the frequency of cancer in exposed populations have been reported, these results are difficult to interpret, mainly because of differences in the intensity and method of follow-up between exposed populations and the general population with which they are compared. ... The total lifetime numbers of excess cancers will be greatest among the 'liquidators' (emergency and recovery workers) and among the residents of 'contaminated' territories, of the order of 2000 to 4600 among each group (the size of the exposed populations is 200,000 liquidators and 6,800,000 residents of 'contaminated' areas). These increases would be difficult to detect epidemiologically against an expected background number of 41,500 and 800,000 cases of cancer respectively among the two groups."

Similarly, the report of a major international conference in 1996 stated: "Among the 7.1 million residents of 'contaminated' territories and 'strict control zones', the number of fatal cancers due to the accident is calculated, using the predictive models, to be of the order of 6600 over the next 85 years, against a spontaneous number of 870,000 deaths due to cancer. Future increases over the natural incidence of all cancers, except for thyroid cancer, or hereditary effects among the public would be difficult to discern, even with large and well designed long term epidemiological studies". (EC/IAEA/WHO, 1996.)

Given the limitations of epidemiological studies, the only way to arrive at an estimate of the total numbers of cancers caused by the radioactive fallout from Chernobyl is to estimate the total collective dose and to apply standard risk estimates. Thus the IAEA (1996) estimate of a collective dose of 600,000 person-Sieverts over 50 years from Chernobyl fallout can be multiplied by a standard risk estimate of 0.04 fatal cancers per person-Sievert to give a total estimate

back to table of contents

of 24,000 fatal cancers. (The recent study by the US National Research Council (2005) lends weight to the Linear No Threshold model upon which the risk estimate is based.)

While the Chernobyl death toll is subject to uncertainty, the broader social impacts are all too clear, including those resulting from the permanent relocation of about 220,000 people from Belarus, the Russian Federation, and the Ukraine. As the OECD's Nuclear Energy Agency (2002) notes, Chernobyl "had serious radiological, health and socio-economic consequences for the populations of Belarus, Ukraine and Russia, which still suffer from these consequences."

5.4. current safety issues: social and technical factors

Inadequate attention to safety is not peculiar to ex-Soviet states, as is commonly claimed. The recent history of the nuclear power industry in Japan is a case in point. The Japanese industry has been in turmoil since the August 2002 revelations of 29 cases of false reporting of cracks in reactor components at numerous reactors owned by Tepco dating back to the 1980s. Tepco also faked pressure tests by manipulating valves to reduce leak rates during containment testing in 1991 and 1992. The scandal affecting the Japanese nuclear industry widened to include utilities Chubu Electric, Tohoku Electric and Japan Atomic Power Co., which also failed to report faults in their reactors. (WISE/NIRS, 2002; Anon., 2002; Anon., 2002B.)

There have been a number of accidents at Japanese nuclear facilities over the past decade (WISE/NIRS, 2002; Anon., 2002; Anon., 2002B):

- Sodium leak at the Monju fast breeder in December 1995 – the reactor is still shut-down.

- The Tokai reprocessing waste explosion in March 1997.

- In 1999, 50 tonnes of primary coolant leaked from a reactor at Tsuruga, leading to a sharp increase of radiation levels inside the reactor building.

- Following a criticality accident at a uranium conversion plant at Tokaimura in 1999, two people died and hundreds were irradiated.

- In 2001, a water pipe at Hamaoka-1 exploded, releasing radioactive steam into the

back to table of contents

containment building

- In 2002, 16 workers were irradiated after a water pipe leak at Hamaoka-2.

- On 9 August 2004, five workers were killed after a steam leak at the Mihama-3 station.

Commercial pressures have clearly played some part in the flawed safety standards in Japan, and such pressures will pose an ever greater concern as privatisation and liberalisation of electricity markets proceeds. There is also concern over the capacity and skill base of the nuclear workforce with an estimated 26,000 workers having left the US nuclear industry over the past eight years (WISE, 2005).

Inadequate nuclear regulation has also been a problem in Japan, but the problem is by no means confined to Japan. In Australia in the late 1990s, for example, the federal government deliberately 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 to sit on the panel which interviewed applicants for the position of CEO of ARPANSA.

The Australian National Audit Office (ANAO, 2005) has written a report critical of many aspects of ARPANSA's operations. The Audit Office's overall conclusions were as follows:

"The ANAO concluded that improvements are required in the management of ARPANSA's regulatory function. While initial under-resourcing impacted adversely on regulatory performance, ARPANSA's systems and procedures are still not sufficiently mature to adequately support the cost-effective delivery of regulatory responsibilities.

"In particular, 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.

"As well, procedures for licensing and monitoring of compliance have not been sufficient, particularly as a licence continues in force until it is cancelled or surrendered. Current arrangements do not adequately support the setting of fees in a user-pays environment, nor ARPANSA's responsibilities for transparently managing the potential for conflict of interest."

back to table of contents

A further nuclear safety problem is the ageing of the global cohort of power reactors (Hirsch et al., 2005, pp.8-9, 62-85). Much concern has focussed on the older Soviet-designed reactors, but Western reactors are also ageing. The average age of the global cohort of power reactors is 21. Frequently, regulatory standards are weakened to allow for the ongoing operation of reactors which would otherwise either require refurbishment or be shut down.

5.5. evolutionary and revolutionary reactor designs

According to Steve Fetter (1999) from Stanford University's Centre for International Security and Cooperation, the probability of reactor core damage is less than one in ten thousand per reactor per year for current US light water reactors, and the probability of a significant release of radioactivity is about ten times smaller. In a world with 1,000 such reactors, Fetter notes that accidents resulting in core damage would occur once per decade. With a ten-fold increase in the number of nuclear reactors (a scenario considered by the Intergovernmental Panel on Climate Change), accidents resulting in reactor core damage would occur once every 2-3 years on average.

The MIT Interdisciplinary Study notes that there has been one reactor core damage accident in the US nuclear power industry (Three Mile Island) giving a core damage frequency for US reactors of one in 2679 reactor-years (Ansolabehere et al., 2003). The study also notes that expert opinion using Probabilistic Risk Assessment (PRA) estimates core damage frequency to be about 1 in 10,000 reactor-years for nuclear reactors in the US. (PRA estimates the frequency of possible failures that could lead to core damage such as pipe breaks or loss of coolant flow.)

Like Fetter, the MIT Study team envisages a growth scenario leading to a near-tripling of nuclear output by 2055 to 1000 GWe (1000 reactors averaging 1000 MWe per reactor). The MIT Study states that: "With regard to implementation of the global growth scenario during the period 2005-2055, both the historical and the PRA data show an unacceptable accident frequency. The expected number of core damage accidents during the scenario with current technology would be 4."

back to table of contents

If it is agreed that a frequency of one reactor core damage accident per decade is unacceptable, the question becomes: can the risk be reduced to a level that would be considered acceptable? It is beyond the scope of this report to explore the question in detail, but the salient points can be summarised.

New reactor types are envisaged which are being promoted as fundamentally safe. However, the claims are overstated and untested, and development of new reactor types would require billions of dollars, with uncertain outcomes.

Passive or 'inherent' safety systems can improve overall plant safety, such as the use of gravity rather than (failure-prone) pumps to feed coolant into the plant as required. However, safety will remain dependent on a range of technical factors and on proper operation (which in turn is dependent on proper management and regulation).

The MIT Study 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." (Ansolabehere et al., 2003, p.9.)

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." (Ansolabehere et al., 2003)

Safety improvements are likely to increase the cost of nuclear power. The costs increases may be so great as to make nuclear power economically non-competitive, and there is a serious concern that utilities will compromise safety in an attempt to reduce costs.

While the nuclear industry is promoting a new generation of 'passively safe' reactors, closer inspection reveals that that much of the talk is little more than speculation. Improved safety features fall a long way short of the sweeping claims being made, and in some cases the technology is not even new. (For a detailed discussion on new reactor designs, see Hirsch et al., 2005, pp.39-58.)

At least some 'new' reactor types are modified versions of old, failed technology. For example, Pebble Bed Modular Reactor

back to table of contents

(PBMR) technology is a variation on the theme of High Temperature Reactors (HTR), which have been investigated by many countries, abandoned in most, and successful in none (Hirsch et al., 2005, pp.41-42; NIRS, n.d.; Thomas, 1999). The safety advantages of PBMR technology include a greater ability to retain fissile products in the event of a loss-of-coolant accident. However, the advantages can be undermined by familiar commercial pressures; for example there are plans to develop PBMR reactors with no containment building. US company Exelon has proposed other cost-cutting measures for PBMR technology including no emergency core cooling system and a reduced emergency planning zone. Despite the limited number of HTR/PBMR reactors built, there has been at least one accident resulting in the off-site release of radioactivity, in Germany.

Hirsch et al. (2005, p.55) summarise the gap between rhetoric and reality in relation to advanced reactor designs, the so-called Generation IV designs: "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, and the actual basic driving force behind the initiative, which is economic competitiveness."

Generation IV reactors are unlikely to be deployed until the middle of the century, if at all. Even nuclear industry representatives are sceptical about the hype, one noting that: "We know that the paper-moderated, ink-cooled reactor is the safest of all. All kinds of unexpected problems may occur after a project has been launched." (Quoted in Hirsch et al., 2005.)

Indeed very little experience has been gained with Generation III reactor designs, most of which are modified versions of the Generation II reactor types currently in operation. Only in Japan are there any commercial-scale Generation III reactors in operation – Advanced Boiling Water Reactors. The next most advanced design is the European Pressurised Water Reactor, which is being built in Finland and may also be built in France.

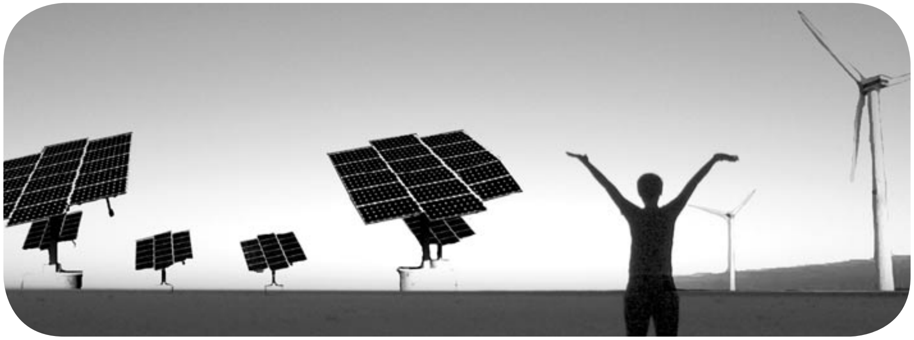
back to table of contents

Hirsch et al. (2005) summarise Generation III technology: “All in all, ‘Generation III’ appears as a heterogeneous collection of different reactor concepts. Some are barely evolved from the current Generation II, with modifications aiming primarily at better economics, yet bearing the label of being safer than current reactors in the hope of improving public acceptance. Others are mostly theoretical concepts so far, with a mixture of innovative and conventional features, which are being used to underpin the promise of a safe and bright nuclear future – while also not forgetting about simplification and cost-cutting.”

back to table of contents

6. reducing greenhouse gas emissions without nuclear power

6.1. renewable energy



Renewable energy and energy efficiency can deliver the power we need – without the problems. An AMP (2003) policy paper on the nuclear fuel cycle concluded: "Nuclear power and the uranium industry are neither financially or environmentally sustainable. ... The positive greenhouse impacts could be equally, and arguably better, obtained from investment in, or support of, the renewable energy sector. It is critical that the nuclear industry does not manipulate the climate change threat to divert government policy and finance away from the intrinsically safe renewable sources of electricity."

The argument that nuclear power can reduce greenhouse gas emissions assumes that the comparison is with fossil fuels, but of course other comparisons are required.

The European Commission argues that 312 million tonnes of carbon dioxide emissions are avoided through the use of nuclear power, using a combined cycle gas fired power plant as the reference point. However, as Schneider (2001) notes, the 312 million tonnes 'saved' would drop to:

- about half, if the comparison is with a natural gas cogeneration plant;
- zero, if the comparison is with hydroelectricity;
- a negative value, if the comparison is with a range of energy efficiency options or with a number of renewable energy sources such as wind power or various forms of biogas.

back to table of contents

Renewable energy, mostly hydroelectricity, already supplies 19% of world electricity compared to nuclear's 16%. The share of renewables is increasing, while the nuclear share is decreasing.

Worldwide, there were only 26 nuclear reactors under construction at the end of 2004, with only one in Western Europe and none in the USA. Nuclear power capacity in Europe is already falling, and is expected to drop 25% over the next 15 years. In 2004, renewable energy generation added nearly more than three times as much net generating capacity as nuclear power. (ACF, 2005.) The projected growth of nuclear power in a small number of countries, such as China and India, will not substantially change nuclear power's global pattern of stagnation and decline (see Appendix 6).

By contrast, wind power and solar power are growing by 20-30% every year. In 2004, renewable energy added nearly three times as much net generating capacity as nuclear power. (ACF, 2005.)

Europe is planning to get 22% of its electricity from renewable sources by 2010, creating nearly a million additional jobs (ACF, 2005):

- Germany is on track to supply 13% of its electricity from renewables by 2010, while nuclear power is being phased out.

- Spain expects to get 26% of electricity from renewable energy by 2010.

- Sweden already supplies 48% of its electricity from renewable sources (mostly hydroelectricity) and expects renewables to provide 60% by 2010 with increased use of wind and bioenergy sources. Sweden plans to phase out nuclear power and has shut two reactors since 1999.

- Denmark already supplies 13% of its electricity from wind, and intends to supply 29% of electricity from renewables by 2010.

Many other countries are setting ambitious renewable energy targets. However, in Australia, only 8% of electricity is from renewable energy – down from 10% in 1999. With the political commitment, we could achieve much greater usage of renewable energy, and also go a long way to solving energy and greenhouse problems through energy efficiency measures. As a short- to medium-term target, Australia could and should generate at least 20% of our electricity from renewables, and put in place

back to table of contents

energy efficiency equivalent to up to five nuclear power stations, by 2020.

A clean energy future will include a range of technologies including wind, wave and tidal power, small scale hydro schemes, biomass and solar technologies. The Australian Conservation Foundation (2005) notes the potential of some of these options:
"* Wind power: Australia could get 10% of its electricity from wind without major modifications to the electricity grid. This would create about 37,000 job years in construction and manufacturing and up to 1,000 fulltime jobs in operation and maintenance. In NSW, for example, this would mean installing 3,000 megawatts of wind (about 35 wind farms). These would only take up land equivalent to 0.5% of the pastures and grasslands in the state.
* Bioenergy: Bioenergy (energy from organic matter, including non native forest wood, energy crops, sewage, or wastes) could provide 30% of our electricity in the long term – but only if we plan for it. This would need about 14,000 MW of bioenergy and would create up to 46,000 permanent rural jobs in operation and maintenance, and a further 140,000 short term construction jobs.
* Solar electricity (Photovoltaics): Solar electricity has a huge potential to provide electricity for Australia. According to the PV Industry Roadmap we could supply 6,700 MW capacity by 2020. This would be equivalent to building two 600 MW nuclear power stations. The solar electricity option would create 31,000 jobs."

The argument that nuclear power could be a "bridging" energy source while renewables are further developed is erroneous. Nuclear expansion would require such vast expenditure that renewables would fall by the wayside. Of the funds spent by 26 OECD member states between 1991 and 2001 on energy R&D, 50% was spent on nuclear power and only 8% to renewable energy. (Schneider and Froggatt, 2004.)

We need to make a clear choice for a clean energy future based on renewables and energy efficiency. As former US and UN environment advisor Professor Frank Muller (2005) notes: "Nuclear power and sustainable energy involve future paths for electricity systems that diverge. Nuclear power reinforces conventional grids dominated by central power stations and powerful supply-side institutions – a pattern that we have inherited from an era of more centralised economic decision making. The sustainable energy vision is for these grids to evolve

back to table of contents

into more decentralised consumer-oriented networks. Investment would be directed to the lowest cost options for meeting customer needs, on either the supply or demand sides, rather than into an inexorable expansion of supply."

6.2. energy efficiency

Energy efficiency is a far more cost-effective method of reducing greenhouse gas emissions than nuclear power, as the Australian Conservation Foundation (2005B) notes: "Australia has enormous opportunities to use energy more wisely. Government reports have shown that reductions in energy consumption of up to 70% are cost effective in some sectors of the economy. McLennan Magasanik Associates Pty Ltd analysed the economic, social and environmental impacts of government's adopting a national energy efficiency target (NEET) and concluded that the economic benefits of an energy efficiency target ranged from $2.4 billion to $6.6 billion. By 2017, investment in installed capacity would be reduced by between 2,500 MW and 5,000 MW (equal to about 2-5 large nuclear power stations), and collective greenhouse gas emission savings over the period 2004 to 2025 would be equal to or greater than national greenhouse gas emissions for 2004."

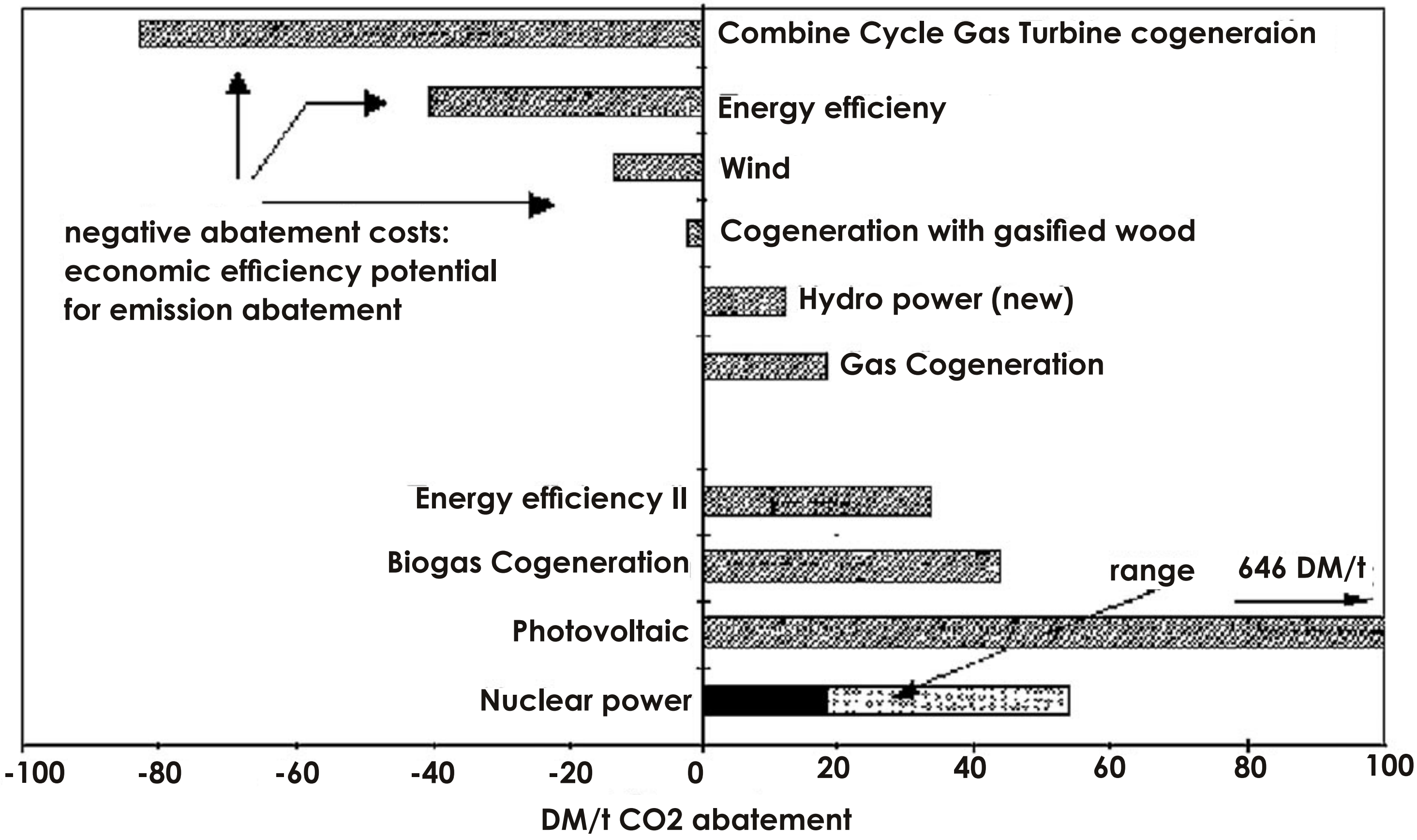
A study by the German Oko-Institut calculates carbon abatement costs relative to coal-fired power (Fritsche and Lim, 1997). As the authors of the study note, the data is drawn from Germany but the results are widely applicable. The study finds that some alternatives to coal are shown to have a negative abatement cost per tonne of carbon dioxide reduction – combined cycle gas turbine cogeneration, wind, cogeneration with gasified wood and simple energy efficiency. In other words, these alternatives are both economically and environmentally superior to coal. The abatement cost for nuclear power is similar to new hydropower, gas cogeneration, advanced energy efficiency, and biogas cogeneration.

The same Oko-Institut study also compared greenhouse gas emissions from cogeneration plants (also known as Combined Heat and Power plants) with nuclear power. Because nuclear cogeneration is rarely used, and because of the poor prospects for its greater use because of distance and efficiency issues, the Oko-Institut compares gas cogeneration with the combined emissions from producing 1 kWh nuclear electricity and 2 kWh of heat from oil (chosen because emissions from oil fall between those of gas and coal). The emissions from gas cogeneration are

back to table of contents

shown to be similar to the emissions from nuclear and oil. Coal fares far worse, whereas biogas cogeneration and wood-gas cogeneration are by far the most efficient of all the options studied. These results are shown in the following table:

Specific CO2-Abatement costs



graph: www.oeko.de

back to table of contents

Another important study compared the carbon abatement costs of nuclear power and energy efficiency (Keepin and Kats, 1988; see also Schneider, 2000.) The study by Keepin and Kats made a number of assumptions highly favourable to nuclear power – a low cost estimate, operating costs half those applying in the US at the time, and no consideration of nuclear waste treatment and storage costs or decommissioning costs. In addition, the study ignored all the energy required to build and operate reactors and other nuclear fuel cycle facilities.

Despite the use of those assumptions, nuclear power was shown by Keepin and Kats to be far more expensive than energy efficiency measures as a carbon abatement strategy. The main conclusions from the study were as follows:

“Improving electrical efficiency is nearly seven times more cost-effective than nuclear power for abating CO2 emissions, in the USA.

“In fact, end-use energy efficiency is the single most important technological factor determining future energy consumption levels, and therefore also future CO2 emissions. This has been shown repeatedly in a number of sensitivity analyses and uncertainty studies with global models. Opportunities for efficiency gains are so compelling that they suggest that global warming can best be avoided by concentrating on efficiency rather than on a rapid expansion of nuclear power.”

Since energy efficiency displaces nearly seven times more carbon dioxide than nuclear power, investment in nuclear power would incur major opportunity costs compared to efficiency measures. Keepin and Kats calculate that for every $100 invested in nuclear power, one tonne of carbon is released into the atmosphere that would have been avoided had the same investment been made into efficiency. Compared to energy efficiency, nuclear power worsens climate change in addition to creating other problems such as the production of high-level waste and weapons-useable plutonium.

While the Keepin and Kats study dates from the late 1980s, the central arguments remain valid. Efficiency opportunities that actually save money while reducing greenhouse gas emissions are abundant. For instance, the Australian Ministerial Council on Energy (2003) has identified that energy consumption in the manufacturing, commercial and residential sectors could

back to table of contents

be reduced by 20-30% with the adoption of current commercially available technologies with an average payback of four years.

The Climate Action Network of Australia (n.d.) summarises some other Australian research:

"A recent report commissioned by the South Australian Government found as a "highly conservative" estimate that South Australia could cut its energy use by 20% over a 20 year period and create up to 2700 jobs.

"An ongoing national study (SEAV and Allen Consulting Group) has found that implementing 50% of the currently commercially available energy efficiency measures would — over 12 years — reduce stationary energy use by 9%, create an extra 9000 jobs and increase GDP by $1.8 billion.

"A 2002 report concluded that mandatory five star energy efficiency rating for homes in Victoria "would have many positive economic benefits for Victoria in a range of areas including Gross State Product, employment and economic welfare".

"Cool Communities, the Federal Government's national household energy efficiency program, has found that by taking simple, cost effective actions, householders can reduce greenhouse emissions by one tonne per year."

A report from AEA Technology to the UK Department of Trade and Industry demonstrates how the cost of large reductions in greenhouse gas emissions can be ameliorated by the serious pursuit of energy efficiency (Marsh et al., 2003). The study, envisages broadly equal reductions in emissions from the supply and demand sides and calculates that annual abatement costs of about 0.5% GDP will suffice to achieve emissions reductions of 60-70%, and that over a 50 year period, annual growth of GDP is only reduced by about 0.01% p.a.

6.3. 'deep cuts' studies

Numerous studies have detailed how major reductions in greenhouse gas emissions can be achieved through a combination of energy efficiency and renewable energy sources (see Appendix 1 for a list of references).

While there are significant variations between the studies, they typically involve a significant reduction or phase-out of most uses of fossil fuel energy sources, and place no reliance on nuclear power growth.

back to table of contents

The Clean Energy Future Group examines eight of these 'deep cuts' studies (Saddler et al., 2004, ch.13; see also Friends of the Earth (UK), 2002; Hansen et al., 2000; Climate Action Network of Australia, n.d.) Almost all of the studies demonstrate that large reductions in greenhouse gas emissions can be achieved by a combination of a strong commitment to energy efficiency combined with decarbonisation of supply. All regard energy efficiency measures as important and necessary means of achieving emissions reductions (often at very little or no cost), but energy efficiency measures alone are insufficient. It is also necessary to reduce the relative usage of the most polluting fossil fuels in favour of more efficient uses of fossil fuels (e.g. gas cogeneration plants) and renewable energy sources. The main difference between the studies concerns energy supply options – some studies envisage much greater use of renewable energy sources, while others envisage smaller contributions from renewables and one focusses on reducing emissions from fossil fuels.

Studies on the means by which large emissions reductions can best be achieved demonstrate the importance of matching solutions to the prevailing circumstances. Solutions which are highly effective in one region may be far less so elsewhere – for example, some countries are far better placed to make greater use of solar or wind power than others.

How best to achieve large emissions reductions in Australia? Two 'deep cuts' studies are summarised below, both concerned with achieving large reductions in greenhouse gas emissions in Australia (and doing so without resorting to nuclear power). One was written by the Clean Energy Future Group (Saddler et al., 2004), the other by The Australia Institute (Turton et al., 2002).

Both studies are conservative in their assumptions. For example, they restrict their recommendations to the use of existing, well-developed technologies. Yet they both map out plausible plans to achieve 'deep cuts' to greenhouse gas emissions in Australia while reducing reliance on fossil fuel energy sources and without any reliance on nuclear power.

Similar research has been carried out for particular Australian states. For example Diesendorf (2005) analysed alternatives to new coal-fired electricity plants in New South Wales and concluded: "In short, there is no technical or economic barrier to ceasing

back to table of contents

to build new coal-fired power stations and commencing the transition to a much cleaner electricity system based on efficient energy use, renewable energy and natural gas. The real barriers are institutional, organisational and political." (Diesendorf, 2005.)

The Australia Institute study

The Australia Institute has published a report detailing how a 60% reduction in greenhouse gas emissions can be achieved in Australia by 2050 (Turton et al., 2002).

The parameters for the study include the following:

- The study covers all sectors of the Australian economy: agriculture, land use and forestry; the industrial and commercial sectors; the residential sector; transportation; waste and fugitive emissions; and energy supply. The study then develops projections for the growth or decline of each sector of the economy and provides an analysis of opportunities for reducing emissions in each sector by implementing efficient energy use and fuel switching.

- The study assumes that Australia's GDP will increase by almost 180 per cent in real terms between 2000 and 2050, based on a labour productivity growth rate of 1.75 per cent per annum and a growing workforce driven by population growth to almost 25 million in 2050.

- The study factors in predicted economic changes such as ongoing growth of the commercial and services sector and an ongoing decline in the relative share of manufacturing to GDP.

- It requires that technologies used in 2050 be already proven, although not necessarily currently commercial.

- It requires that energy production technologies in 2050 must have unit prices no greater than the prices of electricity or transport fuels that currently prevail in Western Europe.

- The study focuses on the end-point in 2050 rather than the paths by which it could be reached, with the timeframe allowing for most of the current stock of energy-using equipment and buildings to be replaced.

- The study presents only one of many possible end-points that achieve major reductions in greenhouse gas emissions. A

back to table of contents

number of possibilities were not considered because they involve unpredictable technological advances or challenging social choices – including reliance on a technological 'magic bullet' such as nuclear fusion; carbon sequestration including large-scale geosequestration; purchasing permits to emit greenhouse gases from abroad; nuclear power; and major lifestyle change.

- The analysis incorporates the effects on Australia's trade of a global deep-cuts scenario where other countries are seeking to stabilise global atmospheric greenhouse gas concentrations.

The report notes that a 60% cut in Australia's total 1999 emissions by 2050 would result in per capita emissions in Australia reduced from 27.9 to 11.2 tonnes of carbon dioxide equivalent per annum. Global convergence at a per capita entitlement of 11.2 tonnes would represent a modest increase in emissions for the UK, Japan and France, a 45% reduction for the United States, and a very large increase for developing countries such as China (currently three tonnes) and India (less than one tonne).

The report notes (pp.8-9): *"The improvements in energy efficiency anticipated between now and 2050 will likely offset any increase in unit costs, resulting in households and industry paying less for energy in 2050. In other words, while unit prices of energy may rise, energy bills are likely to fall as a share of expenditure."*

The report analyses the following sectors:

Agriculture, land use and forestry. The value of Australian agricultural output is expected to grow by about 120% by 2050, driven mainly by exports. Growth in global demand for beef will mean that, by 2050, emissions from beef cattle will alone be responsible for over half of the emissions from agriculture, land-use change and forestry combined. An end to land clearing will make a major contribution to reducing emissions. A range of other modifications and efficiencies in the agricultural sector will also reduce emissions. Overall, a 60% reduction in the agricultural sector is not envisaged, hence a greater than 60% reduction is required in other sectors to enable the national target to be met.

Industrial sector. Growth in chemical, non-ferrous metal, wood, paper and other products will drive energy demand in and increase emissions from the industrial

back to table of contents

sector. A contraction in coal, oil and gas extraction and petroleum and coal product manufacturing will partially offset growth in other areas. Reductions in the industrial sector occur predominantly from energy efficiency measures. Fuel switching to gas and biomass fuels where possible, and a shift to cogeneration, will further reduce demand for fossil fuels.

Commercial sector. Strong growth in the commercial and services sector will be offset mainly by improvements in building design, large-scale uptake of cogeneration, more efficient heating equipment (such as heat pumps), and a range of other modifications.

Residential sector. Growth in energy demand and emissions will be driven by increased population and a predicted 54% growth in the number of households. Offsets include improvements in building design and uptake of high-efficiency appliances. Large-scale uptake of solar thermal water heating and gas-fired cogeneration (fuel cell or microturbine) for electricity generation and space and water heating will further reduce emissions.

Transport. Growth in demand will be driven by increased economic activity, higher incomes and population growth. However, major technology improvements are expected, and the relatively fast turnover of the vehicle fleet will facilitate a rapid and large-scale uptake of these technologies, which include hybrids, fuel cells and biofuels. Fuel cell technology is assumed to have achieved a 50% penetration of road transport with a similar proportion of fuel sourced from renewable energy used to produce hydrogen. Only a small decrease in emissions is predicted from increased patronage of public transport.

The refining industry will shift from mainly processing crude oil to converting biomass into biogas and liquid biofuels, and using electricity to produce hydrogen from water via electrolysis. The fuel production industry will partially relocate and rescale to make best use of cropping, waste and forestry fuel sources. Biomass will grow to the extent that it produces biodiesel, hydrogen, petroleum and methanol/ethanol sufficient to meet all transportation needs, while also producing biogas to feed into the reticulated gas network.

Energy supply and demand. By 2050 the utilities sector is projected to have undergone a major transformation from a fossil-based

back to table of contents

system to one designed to use and deliver renewable energy. Wind energy will play a major role, hydroelectricity will be significant, solar photovoltaics will supply certain niches. There will be a shift away from large-scale thermal generators isolated from load centres towards distributed cogeneration, meeting both electricity and heat needs at load centres.

The study assumes that there will be no large fossil fuel fired electricity generators located away from heat load centres by 2050, and all fossil-only generators will be used to cogenerate electricity and heat. A large amount of fuel for cogeneration will be gas produced from biomass.

An expansion in wind generation, underpinned by decreasing costs, is expected to supply 50% of gross electricity needs. This will require the installation of more than 11,000 wind turbines, or about 500-600 wind farms – on the coast, inland and off-shore. The report notes that identifying such a large number of suitable sites will pose a significant challenge.

Photovoltaic electricity generation is expected to remain one of the more expensive forms of renewable energy and is expected to satisfy demand only to a limited degree – for example in remote areas or to help meet peak demand in summer. Solar thermal technology is expected to supply a much larger amount of electricity as well as its use for water and space heating.

Hydroelectricity will continue to play a significant role in baseload electricity generation.

Biomass is expected to be a significant energy source. The equivalent of 6-7 million hectares of dedicated arable land would be required, although much can be supplied from plantation forests and agricultural and food industry wastes. The federal government is currently aiming to increase the plantation stock to three million hectares by 2020 with a further five million hectares of land suitable for farm forestry – so by 2050 it is expected that about eight million hectares of forest plantations could be available. The study assumes that all eight million hectares are forested and about half the annual biomass production will be used for energy (and the other half for wood and paper products). In addition, there is greater utilisation of crop and food industry wastes and cultivation of 1-2 million hectares of other energy crops would be sufficient to supply the required quantity of biomass.

back to table of contents

Other than the availability of suitable land, there are other considerations and constraints in relation to biomass: resource inputs such as water and fertilisers; the environmental implications of a large expansion of biomass production, processing and combustion; transport issues; and the effects of climate change on plant growth.

The amount of energy obtained from biomass in the Australia Institute's scenario for 2050 is about 70% of the amount currently used in Brazil.

Output of natural gas (including LNG) is expected to rise continuously through to 2050, with global demand projected to be more than three times the current level by then. Declining global demand for black coal is predicted to reduce Australian production by 50% and brown coal production is expected to fall to zero.

The shift from concentrated fossil energy to more dispersed renewables is expected to require a larger energy infrastructure. However, data on the expected costs of energy suggest that the transition to a low emission economy would not come at a large cost, particularly given that increases in energy efficiency will offset increases in energy unit costs.

Clean Energy Future Group study

The Clean Energy Future Group – which comprises renewable energy, and natural gas industries and WWF Australia – has produced a comprehensive paper called "A Clean Energy Future for Australia" (Saddler et al., 2004). The report details how energy demand can be met using various commercially-proven fuels and technologies while cutting greenhouse gas emissions by 50% by 2040 in the stationary energy sector.

The report focusses on stationary energy, which includes energy for commercial and residential uses, and for heat, power and engines in industry – in other words, all energy except that used for transportation. Stationary energy is the single largest producer of greenhouse gas emissions in Australia, accounting for about half of all emissions, and emissions from this sector have grown faster than those from any other sector since 1990.

The study assumes that economic growth will continue at 2% annually between now and 2040, with Gross Domestic Product per

back to table of contents

person 86% higher in real terms in 2040 compared to 2004. The study also accounts for population growth, assuming a population of 25 million people in 2040.

The report proposes two broad strategies to achieve major greenhouse gas emissions reductions – reducing energy waste through increased efficiency, and changing the mix of source fuels for energy.

The report outlines policies which would contain energy demand to a modest 25% increase between 2001 and 2040. Some of the energy efficiency improvements identified in the report are:

- more efficient industrial equipment such as boilers, kilns, furnaces and electric motors;
- improved waste recovery and associated use of waste products as fuel;
- improved building design and construction, hence reduced need for heating and air conditioning;
- improvements in the efficiency of electrical and gas appliances and equipment, such as lights; and
- a shift from electric water heating to gas and solar water heating.

The second set of measures involves changing the energy mix. The report identifies four key areas:

- a change in the mix of electricity generation technologies away from coal in favour of natural gas and renewable energy sources;
- the introduction of solar heating into the supply of steam and hot water in industrial and commercial applications, and widespread use of solar hot water in the housing sector;
- substitution of natural gas for coal in almost all non-metallurgical applications; and
- widespread adoption of cogeneration (the combined production of electricity and heat, using turbines and engines on the site where energy is used).

The report proposes that biomass (excluding native forests), natural gas, wind, hydroelectricity and solar heat should be the main contributors to a clean energy mix by 2040. All these technologies are cheaper than the International Energy Agency’s projected costs of coal-fired electricity with geosequestration.

back to table of contents

It should be noted that the role of gas as a transitional fuel is the subject of debate, because of differing assessments of the greenhouse gas emissions associated with its use and the fact that in Australia most gas-fired power stations are open cycle and hence relatively inefficient. The greenhouse gas contribution of Australia's gas resources over the time period assessed in the Clean Energy Future report will depend on the type of gas-fired power stations developed and the extent of gas development. If there is continual government subsidisation of fossil fuel industries, including gas, there is a risk that this government support will undermine and supplant support for renewables.

The renewable technologies recommended in the report are all commercially well established and in most cases are widely deployed already. Other renewable technologies – such as wave power, tidal power, solar chimneys and hot dry rock systems – are not included as they are considered to be too immature, as is the cheap storage and transportation of (renewable) energy in the form of hydrogen.

The study does not presume early closure of existing coal fired power stations, and it presumes a 30 to 40 year lifespan so those stations built recently are still operating in 2040. The report assumes that no new conventional coal fired power stations are approved and built from 2004 onwards, and that by 2040 all but three of the 24 existing baseload coal fired power stations have closed. The coal industry is actually projected to increase, but the increase is driven by exports not domestic consumption. Likewise, production of LNG, steel and non-ferrous metals is projected to be higher in 2040 to meet overseas demand.

The cost of the Clean Energy Future Group's proposals are likely to be modest, in part because the timeframe for the plan is long enough to allow for the gradual replacement of almost all coal fired energy supply infrastructure with less greenhouse intensive options. The timeframe is also compatible with large-scale refurbishment and to some extent replacement of existing residential and commercial buildings.

The report notes that while delivered electricity prices to customers are likely to rise under the Clean Energy scenario, that price rise could be more than off-set by energy efficiency measures resulting in a projected 28% reduction in electricity consumption.

back to table of contents

The Clean Energy proposals offer a range of advantages over a business-as-usual scenario:

- The proposals can be achieved without any significant technological breakthroughs.

- They take account of limited land area and limited reserves of oil and, in the longer term, natural gas.

- They would not impose any significant economic burden, and would support projected levels of economic growth.

- The proposals can be implemented rapidly. For example, renewable energy systems can be built within a 1-3 year time-frame rather than 5-6 years for coal fired power generation (and about 10 years for nuclear power reactors).

- Renewable energy systems produce little of the emissions associated with coal – such as greenhouse gases, acid rain, smog, and various other toxic chemicals (and of course renewable energy sources generate none of the high-level radioactive waste or weapons-useable fissile material associated with nuclear power).

- Renewable energy systems typically generate more jobs per unit of energy generation than fossil fuels – for example, wind energy developments provide 2-3 times more jobs than coal for each unit of electricity generated. Employment in coal fired electricity has declined by 50% since 1991. The Clean Energy proposals would generate significant rural employment.

- The proposals would lead to growth in exports, particularly to developing countries where two billion people do not have access to electricity infrastructure.

The report notes that the barrier to the realisation of a clean energy future is not that the proposed technologies cannot produce enough energy at affordable prices. Rather, the barrier is the current lack of political will to break from the past and to begin work on a clean energy future. The report advocates a range of policies and strategies including economic instruments, regulations and standards, institutional/organisational change, direct funding, and education.

Chapter 12 of Clean Energy report lists 40 recommendations, including:

- Substantially increase the Mandatory

back to table of contents

Renewable Energy Target (MRET);

- Change the MRET regulation to encourage dedicated tree energy crops for the purpose of growing biomass fuel on land that was cleared before 1990;

- Mandate strict greenhouse intensity limits on any proposal to build a new coal fired power station or to refurbish an existing one;

- Implement national mandatory minimum energy and greenhouse performance standards and labelling for all appliances and equipment with capacity to use 50 watts or greater of electricity, with standards made increasingly stringent every 5 years;

- Mandate minimum energy and greenhouse performance standards for all commercial buildings, based on the Australian Building Greenhouse Rating Scheme;

- Mandate that a solar, heat pump or solar compatible natural gas hot water system with low standby losses be installed in every proposal for a new or substantially renovated residential building;

- Establish a target for cogeneration and provide grants on a dollar for dollar basis to assist in funding feasibility studies for specific projects;

- Provide specific support for the development and implementation of a biomass roadmap for Australia and its implementation;

- Consult widely on, develop and implement consistent planning guidelines across all levels of government for the establishment of wind farms; and

- Revise the National Electricity Code to ensure distributed generators receive fair network access and pricing, considering location of generators and time of day of generation.

- Government policies which provide a framework for continued investment in research and development as more significant emissions reductions are required beyond 2040.

back to table of contents

APPENDIX 1.
greenhouse gas emissions reductions studies

All of the studies listed below analyse and propose methods of achieving large reductions in greenhouse gas emissions. Most of the studies do not envisage a role for nuclear power, though a small number consider scenarios with or without nuclear power. A number of these studies are summarised by Saddler et al., 2004, ch.13.

australian studies

Climate Action Network of Australia, n.d., "Australia's Climate Change Strategy: The Real Way Forward", <www.cana.net.au/documents/real_way_forward.pdf>.

Diesendorf, Mark, 2005, "Towards New South Wales' Clean Energy Future", A Report for the Clean Energy Future Group, <wwf.org.au/News_and_information/Publications/PDF/Report/nswcefreport2005.pdf>.

Saddler, Hugh, Richard Denniss and Mark Diesendorf, 2004, "A Clean Energy Future for Australia", Report for the Clean Energy Future Group, <www.wwf.org.au/News_and_information/Features/feature10.php>.

Turton Hal, Jinlong Ma, Hugh Saddler and Clive Hamilton, October 2002, "Long-Term Greenhouse Gas Scenarios: A pilot study of how Australia can achieve deep cuts in emissions", Discussion Paper No. 48, The Australia Institute, Canberra. Summary at: <www.tai.org.au/WhatsNew_Files/WhatsNew/DP48sum.pdf>.

Naughten B., P. Pakravan , J. Dlugosz J., and A. Dickson, 1994, *"Reductions in greenhouse gas emissions from the Australian energy system: a report on modelling experiments using ABARE's MENSA model"*, Canberra: ABARE.

international studies

Bailie A., S. Bernow, B. Castelli, P. O'Connor, and J. Romm, April 2003, "The Path to Carbon Dioxide-Free Power: Switching to Clean Energy in the Utility Sector", a study by Tellus Institute and Center for Energy and Climate Solutions for World Wildlife Fund, USA, <worldwildlife.org/climate/projects/powerSwitch.cfm>.

Bailie, Alison, Stephen Bernow, William Dougherty, Michael Lazarus and Sivan Kartha,

back to table of contents

July 2001, “The American Way to the Kyoto Protocol: An Economic Analysis to Reduce Carbon Pollution”, report by Tellus Institute and Stockholm Environment Institute – Boston Center, for World Wildlife Fund, <www.panda.org/downloads/climate_change/usreport.doc>.

Department of Trade and Industry (UK), 2003, “Our Energy Future – Creating a Low Carbon Economy”, Energy White Paper, Version 11, <www.dti.gov.uk/energy/whitepaper>.

Friends of the Earth (UK), September 2002, “Tackling climate change without nuclear power: A report detailing how climate targets in the power sector can be met without replacing existing nuclear capacity”, <www.foe.co.uk/campaigns/climate/resource/general_readers.html#nuclear_power>.

Hansen, J., M. Sato, R. Ruedy, A. Lacis and V. Oinas., 2000, *“Global warming in the twenty-first century: An alternative scenario”*, Proc. Natl. Acad. Sci., 97, pp.9875–9880.

Harmelink, M., W. Graus, K. Blok, and M. Voogt, 2003, *“Low Carbon Electricity Systems: Methodology & Results for the EU”*, report by Ecofys for World Wide Fund for Nature.

Interlaboratory Working Group on Energy-Efficient and Clean-Energy Technologies (USA), November 2000, “Scenarios for a Clean Energy Future”, Prepared for Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, <www.ornl.gov/sci/eere/cef>.

Mintzer, Irving, J. Amber Leonard, Peter Schwartz, July 2003, “U.S. Energy Scenarios for the 21st Century”, prepared for the Pew Center on Global Climate Change, <www.pewclimate.org/global-warming-in-depth/all_reports/energy_scenarios/index.cfm>.

Royal Commission on Environmental Pollution (UK), 2000, “Energy – The Changing Climate”, <www.rcep.org.uk/energy.htm>.

Torrie, Ralph, Richard Parfett and Paul Steenhof, October 2002, “Kyoto and Beyond: The low-emission path to innovation and efficiency”, prepared by Torrie Smith Associates for the David Suzuki Foundation and the Canadian Climate Action Network Canada. <www.davidsuzuki.org/publications/climate_change_reports> or to download directly: <www.davidsuzuki.org/files/Kyoto_72.pdf>.

back to table of contents

APPENDIX 2.

environmentalists do not support nuclear power

A feature of Australian media commentary in the past year has been the repeated assertion that environmentalists are turning in support of nuclear power because of its potential to replace fossil fuels and thereby contribute to greenhouse gas emissions reductions.

Beyond a very small number of high-profile individuals – such as scientist and author James Lovelock, Hugh Montefiore (formerly with Friends of the Earth, UK) and Patrick Moore (formerly with Greenpeace) – it is difficult to ascertain any support for nuclear power among environmentalists.

An organisation which calls itself 'Environmentalists for Nuclear Energy' has existed since 1996, and claims to have over 6,000 members and supporters <www.ecolo.org>. However, there is no way of verifying the numbers of members or supporters, much less their environmental credentials. Would-be members and supporters can 'join' the organisation at no cost by filling in a brief website form.

Similarly, the African-American Environmentalist Association supports nuclear power, but it is impossible to determine if the organisation represents a significant sentiment among African-American environmentalists in the United States – it may reflect little or nothing more than the views of its controversial president <www.aaenvironment.com>.

By contrast, there is abundant evidence of strong and unwavering environmental opposition to nuclear power – and that includes many environmental organisations primarily concerned with climate change. The Climate Action Network, an international network of 340 non-governmental organisations, opposes nuclear power and has waged an ongoing battle against proposals to subsidise nuclear power through Kyoto Protocol mechanisms and other avenues such as international financial institutions and export credit agencies. (Climate Action Network, 1998; 2000.)

Likewise, in June 2005 a statement from over 270 environmental groups was released rejecting nuclear power as a 'solution' to climate change (<www.nirs.org>).

back to table of contents

To give one further example, in January 2005, 48 environmental, business, anti-nuclear, sustainable energy, and energy policy organisations wrote an open letter to US President George W. Bush disputing his claim that nuclear power is a renewable energy source. (Sustainable Energy Coalition, 2005.)

Professor James Lovelock, author of 'The Gaia Theory', is the best known of the small number of pro-nuclear environmentalists. A collection of Lovelock's articles is on the internet at: <www.ecolo.org/lovelock/index.htm>. A survey of those articles reveals the following.

Lovelock does not address, even in passing, the crucial issue of the contribution of nuclear power to nuclear weapons proliferation.

Lovelock (2004) argues that *"we can not continue drawing energy from fossil fuels and there is no chance that the renewables, wind, tide and water power can provide enough energy and in time."* However, numerous studies have demonstrated that reducing energy demand, energy efficiency and renewable energy sources are capable of achieving major reductions in greenhouse gas emissions.

Lovelock (2004) argues: *"By all means, let us use the small input from renewables sensibly, but only one immediately available source does not cause global warming and that is nuclear energy."* However, the nuclear fuel cycle does generate significant greenhouse gas emissions, and emissions are predicted to rise significantly as uranium ore grades decline.

Lovelock argues in favour of nuclear power on the grounds that the volume of fuel is much smaller when compared to fossil fuels (Lovelock and Comby, 2005), and the volume of waste is far smaller (Lovelock, 2005). However, volume is a poor indicator of public health and environmental hazard. High-level nuclear waste emits a great deal of radioactivity and heat, and in some cases is prone to radionuclidic concentration leading to criticality accidents, as well as the potential separation and military use of plutonium (or the separation and military use of highly-enriched uranium from some research reactor spent fuel).

Lovelock (2004) argues that: *"Opposition to nuclear energy is based on irrational fear fed by Hollywood-style fiction, the Green lobbies and the media. These fears are unjustified, and nuclear energy from its start in 1952 has proved to be the safest of all energy sources."*

Opposition to nuclear power is in large part driven by a number of rational objections, a number of them discussed in this paper. Nuclear electricity was first fed into an electricity grid not in 1952 but in 1956 – at Calder Hall in

back to table of contents

the UK, using a reactor designed primarily to produce plutonium for weapons.

Renewable energy sources are generally safer than nuclear power. Further, the risk of nuclear weapons proliferation must be factored into any safety assessment.

Safety assessments are also complicated by complex, unresolved scientific debates over the health effects of low-level radiation, which feed into debates over the impacts of nuclear accidents such as the Chernobyl explosion. Lovelock is not bothered by the science. He argues that:

"The Chernobyl accident is painted as one of the great industrial disasters of the twentieth century. ... In fact, only 42 people died and they were mostly firemen and plant workers. Since the explosion, UN experts have found no evidence of birth defects, cancers or other health effects, with one exception. Some 1,800 non-fatal thyroid cancers have been found in people who were children at the time." (Lovelock, 2005.)

Likewise, Lovelock argues that: "The real dangers to humanity and the ecosystems of the earth from nuclear power are almost negligible. You get things like Chernobyl but what happens? Thirty-odd brave firemen died who needn't have died but its general effect on the world population is almost negligible." (Quoted in Radford, 2000.)

As discussed in Section 5 of this paper, the collective dose from Chernobyl has been estimated at 600,000 person-Sieverts, which, applying a standard risk estimate, yields a predicted 24,000 fatal cancers.

More generally, to describe the global impact of Chernobyl as "almost negligible" is absurd given the myriad of well-documented social and environmental impacts.

A self-confessed eccentric, Lovelock says:
"The land around the failed Chernobyl power station was evacuated because its high radiation intensity made it unsafe for people, but the land is now rich in wildlife, much more so than the neighbouring populated areas. ... We call the ash from nuclear power nuclear waste and worry about its safe disposal. I wonder if instead we should use it as an incorruptible guardian of the beautiful places on Earth. Who would dare cut down a forest which was a storage place of nuclear ash?"
(Quoted in Walsh, 2005.)

Lovelock further argues that:
"I have told the BNFL ... that I would happily take the full output of one of their big power stations. I think the high-level waste is a stainless steel cube of about a metre in size

back to table of contents

and I would be very happy to have a concrete pit that they would dig." The waste would serve two purposes, Lovelock says: "One would be home heating. You would get free home heat from it. And the other would be to sterilise the stuff from the supermarket, the chicken and whatnot, full of salmonella. Just drop it down through a hole. I'm not saying this tongue-in-cheek. I am quite serious."
(Quoted in Radford, 2000.)

Lovelock has added nothing to the nuclear debate other than colourful and eccentric variations of the flawed arguments promulgated by the industry itself.

Kokatha women protesting agaisnt uranium mining on their land, South Australia, 2005

back to table of contents

APPENDIX 3.

the use of reactor grade plutonium in nuclear weapons

In addition to the potential to use reactor grade plutonium produced in a normal power reactor operating cycle for weapons production, there is the option of using civil power or research reactors to irradiate uranium for a much shorter period of time to produce weapon grade plutonium ideally suited to weapons manufacture.

Hundreds of tonnes of plutonium have been produced in power reactors (and to a lesser extent research reactors), hence the importance of the debate over the use of reactor grade plutonium in weapons.

Definitions of plutonium usually refer to the level of the unwanted plutonium-240 isotope:

- Weapon grade plutonium contains less than 7% plutonium-240.

- Fuel grade plutonium contains 7-18% plutonium-240

- Reactor grade plutonium contains over 18% plutonium-240.

Plutonium in spent fuel removed from a commercial power reactor typically contains 55-70% plutonium-239, 20-25% plutonium-240 and smaller quantities of other plutonium isotopes.

For weapons, the ideal plutonium is low burn-up plutonium with a very high proportion of plutonium-239. As neutron irradiation of uranium-238 proceeds, the greater the quantity of isotopes such as plutonium-240, plutonium-241, plutonium-242 and americium-241, and the greater the quantity of plutonium-238 formed (indirectly) from uranium-235. These unwanted isotopes in high burn-up plutonium make it more difficult and dangerous to produce nuclear weapons.

The use of reactor grade plutonium in weapons manufacture poses several additional problems compared to the use of weapon grade plutonium (see Gorwitz, 1998 for discussion and references). The difficulties associated with the use of reactor grade plutonium are as follows.

Spent fuel from power reactors running on a normal operating cycle will be considerably

back to table of contents

more radioactive and hotter than low burn-up spent fuel. Thus high burn-up spent fuel and the separated reactor grade plutonium are more hazardous – though it is not difficult to envisage scenarios whereby proliferators place little emphasis on worker safety. It may also be more time consuming and expensive to separate reactor grade plutonium.

Weapons with reactor grade plutonium are likely to be inferior in relation to reliability and yield when compared to weapon grade plutonium.

A greater quantity of reactor grade plutonium may be required to produce a weapon of similar yield, or conversely there will be a lower yield for reactor grade plutonium compared to a similar amount of weapon grade plutonium.

A strong majority of informed opinion holds that reactor grade plutonium can indeed be used for the manufacture of nuclear weapons despite the above-mentioned problems.

A report from the US Department of Energy (1997) puts the following view:

"Virtually any combination of plutonium isotopes – the different forms of an element having different numbers of neutrons in their nuclei – can be used to make a nuclear weapon. ...

"At the lowest level of sophistication, a potential proliferating state or subnational group using designs and technologies no more sophisticated than those used in first-generation nuclear weapons could build a nuclear weapon from reactor-grade plutonium that would have an assured, reliable yield of one or a few kilotons (and a probable yield significantly higher than that). ...

"In short, reactor-grade plutonium is weapons-usable, whether by unsophisticated proliferators or by advanced nuclear weapon states."

The broad thrust of the US Department of Energy's position is supported by, among others:

- An expert committee drawn from the major US nuclear laboratories (Hinton et al., 1996).
- Robert Seldon (1976), of the Lawrence Livermore Laboratory.
- J. Carson Mark (1993), former director of the Theoretical Division at Los Alamos National Laboratory.
- Matthew Bunn (1997), chair of the US National Academy of Sciences' analysis of options for the disposal of plutonium removed from nuclear weapons.
- Prof. Marvin Miller, from the MIT Defense and Arms Control Studies Program (quoted in Dolley, 1997).
- The Office of Arms Control and

back to table of contents

Nonproliferation, US Department of Energy (quoted in Dolley, 1997).
- Steve Fetter (1999) from Stanford University's Centre for International Security and Cooperation.
- the IAEA's Department of Safeguards (Shea and Chitumbo, 1993).

With the exception of plutonium comprising 80% or more of the isotope plutonium-238, all plutonium is defined by the IAEA as a "direct use" material, that is, "nuclear material that can be used for the manufacture of nuclear explosives components without transmutation or further enrichment", and is subject to equal levels of safeguards.

According to Hans Blix, then IAEA Director General: "On the basis of advice provided to it by its Member States and by the Standing Advisory Group on Safeguards Implementation (SAGSI), the Agency considers high burn-up reactor-grade plutonium and in general plutonium of any isotopic composition with the exception of plutonium containing more than 80 percent Pu-238 to be capable of use in a nuclear explosive device. There is no debate on the matter in the Agency's Department of Safeguards." (Blix, 1990; see also Anon., 1990).

Nuclear tests using reactor grade or fuel grade plutonium

The US government has acknowledged that a successful test using 'reactor grade' plutonium was carried out at the Nevada Test Site in 1962 (US Department of Energy, 1994). The information was declassified in July 1977. The yield of the blast was less than 20 kilotons.

The US Department of Energy (1994) states: "The test confirmed that reactor-grade plutonium could be used to make a nuclear explosive. ... The United States maintains an extensive nuclear test data base and predictive capabilities. This information, combined with the results of this low yield test, reveals that weapons can be constructed with reactor-grade plutonium."

The exact isotopic composition of the plutonium used in the 1962 test remains classified. It has been suggested (e.g. by Carlson et al., 1997) that because of changing classification systems, the plutonium used in the 1962 test may have been fuel grade plutonium using current classifications.

Regardless of the debate over the quality of the plutonium used in the 1962 test, and the more general debate over the suitability of reactor grade plutonium for weapons, it is worth noting again that civil power and research reactors can certainly be used to produce weapon grade

back to table of contents

or fuel grade plutonium simply by limiting the irradiation time.

Hore-Lacey (2003) from the Uranium Information Centre claims that: "Design and construction of nuclear explosives based on normal reactor-grade plutonium ... has not so far been done." The Australian Safeguards and Non-proliferation Office also claims that there has been no "practical demonstration" of the use of reactor grade plutonium in nuclear weapons (ASNO, 1998-99). Those claims are not supported by the available evidence. All that can be said with confidence about the 1962 test is that it used below-weapon-grade plutonium, i.e. reactor grade or fuel grade plutonium.

At least one of the two 'Totem' nuclear tests at Emu Field in South Australia in 1953 used below-weapon-grade plutonium (very likely fuel grade plutonium using current classifications) (De Volpi, 1996). The Totem test yields were 7.1 and 9.1 kilotons, roughly half the yields of the bombs which devastated Hiroshima and Nagasaki.

India Today reported in 1998 that one or more of the 1998 tests in India used reactor grade plutonium (Anon., 1998). All of the plutonium used in India's nuclear arsenal is produced in 'civil' research reactors (with a possible contribution from power reactors).

Implications

The potentially catastrophic implications of nuclear weapons proliferation demands that a conservative approach be adopted to the question of reactor grade plutonium. For the purposes of public policy it should be assumed that reactor grade plutonium can be used to make nuclear weapons and that the difficulties and dangers of so doing would pose only a minimal deterrent.

Carlson et al. (1997), from the Australian Safeguards and Non-Proliferation Office, state: *"[P]roduction of separated weapons-grade material by a non-nuclear-weapon State should not be accepted as a normal activity. ... A proscription on the production – or separation – of plutonium at or near weapons-grade would be an important confidence-building measure in support of the disarmament and non-proliferation regime."*

Applying the conservative principle, ASNO's arguments should be extended to include reactor grade plutonium. Its production should be minimised (e.g. with a phase-out of nuclear power). Separation of any grade of plutonium from spent fuel or other irradiated materials ought to prohibited immediately.

(For a more detailed version of this discussion on reactor grade plutonium, see <www.geocities.com/jimgreen3/rgpu.html>.)

back to table of contents

APPENDIX 4

australian uranium and weapons proliferation

The regime designed to attempt to prevent military misuse of Australian obligated-nuclear material (AONM) – mainly uranium and uranium derivatives such as plutonium – involves:

- Uranium exports are subject to Australian Safeguards and Non-Proliferation Office (ASNO) audits.
- Consignment weights are recorded and passed on to IAEA.
- All recipient countries must be NPT signatories and the AONM must be subject to IAEA safeguards inspections in both declared nuclear weapons states and non-weapons states.
- In addition, without Australian government consent there can be no on-transfer of AONM to a third country, no reprocessing and no enrichment above 20% uranium-235.

A detailed critique of the safeguarding of Australian uranium is provided by Prof. Richard Broinowski in his book 'Fact or Fission? The Truth About Australia's Nuclear Ambitions' (Broinowski, 2003). Broinowski details how Prime Minister Fraser's 1977 safeguards regime was gradually weakened in various ways to accommodate uranium exporting companies and their customers. Mike Rann (1982), now South Australian Premier, wrote:

"Again and again, it has been demonstrated here and overseas that when problems over safeguards prove difficult, commercial considerations will come first."

Broinowski (2003, ch.11) discusses problems with the current safeguards system. He states (p.256): "Terms such as 'fungibility' and 'equivalence' are used by Australian nuclear officials to explain the fact that Australian uranium cannot be identified once it leaves Australian shores and enters the commercial international nuclear fuel cycle. Instead, it becomes a book-keeping entry. This is meant to ensure that somewhere in the complex international fuel cycle system, in some country, and in some form, an equivalent amount of material is not being used to make nuclear weapons. But the accounting method is tenuous, and subject to distortion or abuse."

back to table of contents

Broinowski notes the difficulty of safeguarding AONM because of its quantity, the variety of its forms, and the variety of locations and circumstances in which it is held. ASNO (2003-04) provides the following information on the 105,245 tonnes of AONM held overseas in its 2003-04 Annual Report:

- Natural uranium – 20,262 tonnes (Canada, Euratom, Japan, South Korea, USA)

- Uranium in enrichment plants – 8,025 tonnes (Euratom, Japan, USA)

- Depleted uranium – 67,823 tonnes (Euratom, Japan, USA)

- Low enriched uranium – 9,056 tonnes (Canada, Euratom, Japan, South Korea, USA, Switzerland, Mexico)

- Irradiated plutonium – 78 tonnes (Canada, Euratom, Japan, South Korea, USA, Switzerland)

- Separated plutonium – 0.6 tonnes (Euratom, Japan)

Broinowski further states (2003, p.257): *"Despite assurances of the Safeguards Office to the contrary, it is not credible that none of this material has been lost through accounting errors, illegally diverted, or otherwise mishandled without detection."*
Incidents of large-scale Material Unaccounted For have occurred in countries which hold AONM – such as Japan and the UK.

The Uranium Information Centre (2004) states: *"A further concern is that countries may develop various sensitive nuclear fuel cycle facilities and research reactors under full safeguards and then subsequently opt out of the NPT. Bilateral agreements such as insisted upon by Australia and Canada for sale of uranium address this by including fallback provisions, but many countries are outside the scope of these agreements."* However, it is unlikely that any nation state willing to pull out of the NPT would be concerned about abrogating its responsibilities under a bilateral agreement.

A potential risk with uranium exports is that even if the uranium (or derivatives such as plutonium) is not used directly in military programs, it potentially frees other sources of uranium (most likely indigenous sources) for use in military programs.

According to Carlson (1998), *"One of the features of Australian policy ... is very careful selection of our treaty partners. We have concluded bilateral arrangements only with countries whose credentials are impeccable in this area."* However, Australia sells uranium to

back to table of contents

nuclear weapons states which pay lip-service to their NPT disarmament obligations. South Korea is another customer whose behaviour has been far from 'impeccable'. Japan could not be said to be 'impeccable' because of its plutonium program and its plutonium stockpiling.

The Uranium Information Centre (2004) states: *"Australia's position as a major uranium exporter is influential in the ongoing development of international safeguards and other non-proliferation measures, through membership of the IAEA Board of Governors, participation in international expert groups and its safeguards research program in support of the IAEA."*

However, successive Australian governments have used whatever influence they enjoy in support of flawed policies which undermine non-proliferation and disarmament objectives. The flawed policies can be attributed in large part to the commercial interests of the Australian uranium export industry and also to the military-nuclear alliance between Australia and the US. As Professor Broinowski (2005) notes: *"Australian diplomats may argue with their American colleagues at the margins, for example, over the desirability of the US ratifying the comprehensive nuclear test ban treaty, or interpretation of the Fissile Materials Cut-Off Treaty. But what really shapes their position is the unstated but well-understood Australian Government policy that its great protector – the US – should never forfeit its overwhelming superiority over all other nations in nuclear weaponry."*

Examples of flawed policies include the focus on non-proliferation with far less attention given to the problem of disarmament by nuclear weapons states, or granting approval for reprocessing even when that is likely to result in plutonium stockpiling.

It is frequently claimed that the "stringent" conditions placed on AONM encourage a strengthening of non-proliferation measures generally, and that the more uranium exported from Australia the better because it means that a significant proportion of the world's uranium trade is covered by Australia's "stringent" conditions. However, by permitting the stockpiling of plutonium the Australian government is not 'raising the bar' but setting a poor example and encouraging other uranium exporters to adopt or persist with equally irresponsible policies. (The Australian government does not have the authority to prohibit stockpiling itself, but it does have the authority to permit transfers and reprocessing and could therefore put an end to the stockpiling of Australian-obligated plutonium.)

Successive Australian government have appeared to want to take credit for opposing

back to table of contents

stockpiling even while they grant permission to stockpile. Thus the majority (Coalition/Labor) report from the Senate Select Committee on Uranium Mining and Milling (1997) stated that: *"Stockpiles of plutonium are a concern to Australia and it supports moves to avoid them."*

Australian-obligated separated plutonium is held in Japan and (unspecified) Euratom countries. There is no justification for supporting plutonium programs in Europe (such as reprocessing or the use of MOX fuel). Permission should be withdrawn for the reprocessing of all spent fuel containing Australian-obligated plutonium. At the very least, permission should be withdrawn in circumstances of plutonium stockpiling.

Australian uranium & north-east Asia

North-east Asia is a "nuclear disaster waiting to happen" according to Professor Broinowski (2003, p.261).

Japan and South Korea are major customers of Australian uranium. In the five years to mid 2004, about 12,500 tonnes of uranium were exported to Japan, and about 5,000 tonnes to South Korea. In total, exports to Japan and South Korea accounted for 40% of all uranium exports from Australia. (Uranium Information Centre, 2005.)

Australia, through its uranium sales and associated policies, is implicated in civil nuclear programs in north-east Asia and in the attendant proliferation risks and tensions. Australian-obligated nuclear materials – including separated plutonium stockpiled in Japan – could be used as fissile material in nuclear weapons. Even in the absence of a systematic nuclear weapons program, Japan's plutonium program exacerbates regional tensions in north-east Asia. Successive Australian governments have permitted the separation and stockpiling of Australian-obligated plutonium by Japan though the bilateral nuclear agreement contains provisions for Australia to prohibit the reprocessing or the transfer of Australian-obligated nuclear materials including plutonium.

There has been some degree of high-level political support for the construction of nuclear weapons in Japan since the 1950s, motivated largely by regional concerns over China and the Korean peninsula (Leventhal and Dolley, 1999). Recent developments have added to such concerns, such as Japan's involvement in 'theatre missile defence' programs (potentially complementary to a nuclear weapons program), and North Korea's apparent pursuit of nuclear weapons.

While the construction of nuclear weapons by Japan is an unlikely development, it cannot be

back to table of contents

discounted and the assessment could change quickly, for example in the event of a North Korean nuclear test. Australian Foreign Minister Alexander Downer acknowledged in February 2005 that North Korea's claim to have nuclear weapons would lead some people in Tokyo or Seoul to argue for nuclear weapons, and he noted that the importance of North Korea's nuclear program was not only due to *"the danger of the weapons systems themselves but also because of the risk of contributing to proliferation"*. (ABC, 2005.) It can hardly be denied that Japan's plutonium program has a similar regional impact.

Further, it is not difficult to find examples of incorrect assessments of a state's perception of its interests. For example, ASNO's John Carlson said in November 2002 that: *"The North Koreans have to come to a realisation that building up nuclear weapons is not in their interest."* (Quoted in Koutsoukis, 2002.)

Japan could construct nuclear weapons in a short space of time because of its advanced nuclear program, its rocket/missile capabilities, and its wider scientific and technological capabilities (Miller, 2002).

Japan's plutonium program is of particular concern because it is a likely source of fissile material should Japan build weapons. That program involves the production of large quantities of plutonium in power reactors as a by-product of electricity generation, reprocessing spent fuel from power reactors in reprocessing plants in Europe and Japan, the stockpiling of plutonium, (largely stalled) plans for MOX usage, and a program to develop plutonium breeder reactors.

Importantly, the separation and stockpiling of plutonium occurs in far greater quantities than can be justified by Japan's limited use of plutonium in MOX fuel or in its troubled breeder program. Claims that the plutonium program is fully consistent with a peaceful program are met with understandable scepticism. For example, a 1992 shipment of 1.7 tonnes of separated plutonium from Europe to Japan was said to be urgently needed for the Monju breeder reactor – but when the shipment was underway it was announced that the plutonium was to be stockpiled (Leventhal and Dolley, 1999).

Diplomatic cables in 1993 and 1994 from US Ambassadors in Tokyo describe Japan's accumulation of plutonium as "massive" and questioned the rationale for the stockpiling of so much plutonium since it appeared to be economically unjustified. A March 1993 diplomatic cable from US Ambassador Armacost in Tokyo to Secretary of State Warren Christopher, obtained under the U.S. Freedom of Information Act, posed these questions:

back to table of contents

"Can Japan expect that if it embarks on a massive plutonium recycling program that Korea and other nations would not press ahead with reprocessing programs ? Would not the perception of Japan's being awash in plutonium and possessing leading edge rocket technology create anxiety in the region?" (Greenpeace, 1999.)

As at the end of 2003, Japan's holdings of unirradiated plutonium amounted to 5.4 tonnes, in addition to 35.2 tonnes of civil unirradiated plutonium held overseas and 105 tonnes of plutonium in spent fuel at reactor sites and reprocessing plants. (IAEA, 2004B.)

Despite this huge stockpile of plutonium, Japan's nuclear utilities plan to begin commercial operation of a reprocessing plant at Rokkasho in 2007. The plant will have the capacity to separate about eight tonnes of plutonium per year. It will be the first large-scale reprocessing plant in a country not currently possessing nuclear weapons.

Regardless of the intentions driving Japan's plutonium program, it certainly enhances Japan's capacity to quickly produce nuclear weapons. That latent potential is an ongoing source of tension in north-east Asia – it provides both an incentive and an excuse for countries such as North Korea, South Korea and Taiwan to pursue nuclear weapons programs or to steer ostensibly civil nuclear programs in such a way as to reduce the lead-time for weapons production (e.g. the development of reprocessing capabilities). It generates resentment when South Korea and Taiwan are prevented from pursuing similar policies to Japan.

Kang et al. (2005) state that: *"South Korea's hidden actions exemplify the impulse toward proliferation that arises in response to the discriminatory treatment the United States shows to different states, permitting, for example, Japan to have tons of plutonium while South Korea may have none, and Japan to explore mixed oxide fuels for reactors while South Korea may not. The disparity in the application of ostensibly universal nonproliferation norms is felt keenly by Koreans who remain resentful of Japan's big-power status and its colonial aggression in Korea."*

Japan's plutonium program may be partly responsible for the series of illicit and/or unreported nuclear weapons research activities in South Korea. Conversely, Japan's plutonium program may be partly motivated by South Korea's nuclear program. Either way, it is clear that the nuclear industry is fuelling regional uncertainty.

Kang et al. (1995) state that: *"[T]he fact that South Korea has not kept to the spirit and*

back to table of contents

letter of the NPT-IAEA safeguards system stirs already troubled waters in Japan, Korea, and Taiwan about the future of their nuclear status. Japan's security culture is already shifting away from its historical commitment to sole reliance on U.S. nuclear deterrence. The notion of a Korean bomb, whether of North or South origin, is one more factor suggesting that the nonproliferation regime is in trouble in East Asia."

China is all the less likely to take its NPT Article VI disarmament obligations seriously because of Japan's plutonium program – and Japan is all the less likely to abandon its program while China pays lip-service to its disarmament obligations. (For discussion on the regional implications of Japan's plutonium program, see Leventhal and Dolley, 1999, 1999B; Kang et al., 1995; von Hippel and Jones, 1997.)

An obvious source of fissile material for a weapons program in Japan would be the stockpile of separated plutonium. In April 2002, the then leader of Japan's Liberal Party, Ichiro Ozawa, said Japan should consider building nuclear weapons to counter China and suggested a source of fissile material: *"If China gets too inflated the Japanese people will get hysterical. It would be so easy for us to produce nuclear warheads; we have plutonium at nuclear power plants in Japan, enough to make several thousand such warheads."* (Quoted in Koutsoukis, 2002), The plutonium stockpile is not the only potential source of fissile material in Japan (Miller, 2002, discusses the various options). However the existing stockpile would be available immediately Japan chose to use it. NPT obligations would be breached regardless of the source of fissile material (unless Japan withdrew from the NPT). The breaching of bilateral safeguards agreements (including the Australia-Japan agreement) would be of little concern given that NPT obligations were also being breached.

That much of Japan's plutonium is 'reactor grade' rather than weapon grade would be of little consequence. Physicist Marvin Miller (2002) notes that: *"... a study of Japanese work in such areas as high-explosive technology, inertial fusion, and production and handling of hydrogen isotopes leads me to the conclusion that they are capable of solving the problems involved in using [reactor grade plutonium] in weapons, specifically predetonation."*

Following the shipment of 1.7 tonnes of separated plutonium from Europe to Japan in 1992, far from taking action to prevent stockpiling in Japan, the then Labor government in Australia took steps to facilitate it. In a September 1993 treaty-level exchange of notes, Australia agreed to provide advance consent on a generic basis for the transfer of Australian-obligated plutonium from Europe to Japan,

back to table of contents

whereas previously case-by-case consent was required. In 1998 this advance generic consent was further extended to cover the small fraction of Australian-obligated plutonium which is not also US-obligated.

The Australian government refuses to state how much Australian-obligated plutonium has been stockpiled in Japan, but some non-country-specific figures are published. ASNO provides the following information in its 2003-04 Annual Report (Annex C):

- 78 tonnes of irradiated Australian-obligated plutonium are held overseas, in Canada, Euratom, Japan, South Korea, USA, and Switzerland. This includes plutonium contained in spent power reactor fuel, or plutonium reloaded in a power reactor following reprocessing.

- Japan and Euratom countries hold about 600 kilograms of Australian-obligated separated plutonium. This comprises plutonium separated from spent fuel from reactors in Euratom countries and in Japan, and the separated plutonium itself is in both Euratom and Japan.

Australian consent to the separation of Australian-obligated plutonium and its stockpiling in Japan should be withdrawn on proliferation grounds. That consent should also be withdrawn on the basis of the unacceptable safety record of Japan's plutonium/reprocessing program over the past decade.

Shipments of spent fuel from Japan to Europe for reprocessing, and the on-shipments and return shipments of plutonium, high-level waste and MOX fuel all present risks of accidents, attacks, or the theft of plutonium and its potential use in weapons. Adam Cobb, from advisory firm Stratwar.com, states: "These shipments are vulnerable targets for terrorist organisations like Al Qaeda. Part of that radioactive material is Australian-sourced and in that sense is our responsibility." (Quoted in Koutsoukis, 2002.)

Australia's involvement in South Korea is also problematic. The 2004 revelations of a number of undeclared activities is one concern. South Korea's pursuit of reprocessing and breeder technology is also cause for concern. The development of reprocessing and breeder expertise has been assisted by the US Department of Energy, the IAEA and the OECD's Nuclear Energy Agency (Burnie, 2005).

ASNO's John Carlson says: *"To simply leave our uranium in the ground would be of no benefit to anyone. And it certainly wouldn't benefit the non-proliferation cause. It would have a neutral effect and there's no point in that."* (Quoted in Koutsoukis, 2002.) However, using bilateral treaty provisions to prevent (or greatly restrict)

back to table of contents

the stockpiling of Australian-obligated plutonium, combined with concerted diplomacy, could reduce stockpiling. And if it failed to curb stockpiling and led to a reduction or cessation of exports, Australia would at least enjoy the credibility that would come with a principled approach to the plutonium proliferation problem.

As the situation stands, nations such as the US and Australia talk about limiting the spread of reprocessing while at the same time providing permission for the reprocessing and stockpiling of plutonium.

APPENDIX 5

australia's historical pursuit of nuclear weapons

During the 1950s and 1960s, the Australian government made several efforts to obtain nuclear weapons from the US or the UK. Nothing eventuated from the negotiations although the UK was reasonably supportive of the idea at times.

From the mid 1960s to the early 1970s, there was greater interest in the domestic manufacture of nuclear weapons. The government never took a decision to systematically pursue a nuclear weapons program, but it repeatedly took steps to lessen the lead time for weapons production by pursuing civil nuclear projects. Consideration was also given to delivery systems – for example the 1963 contract to buy F-111s bombers from the US was partly motivated by the capacity to modify them to carry nuclear weapons.

The Australian Atomic Energy Commission's (AAEC) major research project from the mid 1950s to mid 1960s concerned the potential use of beryllium (or beryllium compounds) as a moderator in civil reactors. The AAEC's first reactor, the High Flux Australian Reactor (HIFAR), was one of the instruments used for this research. Historian Wayne Reynolds (2000, p.27) suggests that the beryllium research may

back to table of contents

also have been connected to British interest in thermonuclear weapons.

In 1962, the federal Cabinet approved an increase in the staff of the AAEC from 950 to 1050 because, in the words of the Minister of National Development William Spooner, *"a body of nuclear scientists and engineer skilled in nuclear energy represents a positive asset which would be available at any time if the government decided to develop a nuclear defence potential."* (Reynolds, 2000, p.194.)

Despite the glut in the uranium market overseas, the Minister for National Development announced in 1967 that uranium companies would henceforth have to keep half of their known reserves for Australian use, and he acknowledged in public that this decision was taken because of a desire to have a domestic uranium source in case it was needed for nuclear weapons.

The intention to leave open the nuclear weapons option was evident in the government's approach to the NPT from 1969-71. Prime Minister John Gorton was determined not to sign the NPT, and he had some powerful allies such as Philip Baxter, Chair of the AAEC. The Minister for National Development admitted that a sticking point was a desire not to close off the weapons option. When the Government eventually signed (but did not ratify) the NPT in 1971, it was influenced by an assurance from the Department of External Affairs that it was possible for a signatory to develop nuclear technology to the brink of making nuclear weapons without contravening the NPT.

In the late 1960s, the AAEC set up a Plowshare Committee to investigate the potential uses of peaceful nuclear explosives in civil engineering projects. Plans to use peaceful nuclear explosives were never realised, partly because of the implications for the Partial Test Ban Treaty (to which Australia was a signatory), and the Plowshare Committee was disbanded in the early 1970s.

In 1969, Australia signed a secret nuclear cooperation agreement with France. The Sydney Morning Herald (June 18, 1969) reported that the agreement covered cooperation in the field of fast breeder power reactors (which produce more plutonium than they consume). The AAEC had begun preliminary research into building a plutonium separation plant by 1969, although this was never pursued.

A split table critical facility – built in 1972 at Lucas Heights but conceived in the late 1960s – was connected to the interest in fast breeder reactors and was possibly connected to the interest in weapons production. The facility was supplied by France. It proved to be difficult to secure supplies of enriched uranium or

back to table of contents

plutonium for experiments using the critical facility, which was widely regarded as a "white elephant" and was later dismantled.

In 1968, government officials and AAEC scientists studied and reported on the costs of a nuclear weapons program. They outlined two possible programs: a power reactor program capable of producing enough weapon grade plutonium for 30 fission weapons annually; and a uranium enrichment program capable of producing enough uranium-235 for the initiators of at least 10 thermonuclear weapons per year.

In 1969, federal Cabinet approved a plan to build a power reactor at Jervis Bay on the south coast of New South Wales. There is a wealth of evidence – some of it contained in Cabinet documents – revealing that the Jervis Bay project was motivated, in part, by a desire to bring Australia closer to a weapons capability. Then Prime Minister Gorton later acknowledged that the intention was not only to produce electricity but also to produce plutonium to bring Australia closer to a nuclear weapons capability. After Gorton was replaced as leader of the Liberal Party by William McMahon in 1971, the Jervis Bay project was reassessed and deferred. The Labor government, elected in 1972, did nothing to revive the Jervis Bay project, and Australia ratified the NPT in 1973.

Even before the cancellation of the Jervis Bay project, Baxter was making efforts to promote an Australian uranium enrichment plant, building on a small enrichment research program begun in secret at the AAEC in 1965. Baxter's interest in the plant was largely military, as revealed by his written notes calculating how much HEU – and how many HEU weapons – could potentially be produced with an expanded enrichment program. Early, experimental work would of course have to be expanded to achieve Baxter's aim, and the process modified, but these were not insurmountable obstacles. As Tony Wood (2000), former head of the AAEC's Division of Reactors and Engineering, noted: *"Although the Australian research team contained only a small number of centrifuge units, it is not a secret that one particular arrangement of a large number of centrifuge units could be capable of producing enriched uranium suitable to make a bomb of the Hiroshima type."*

Dr. Clarence Hardy (1996, p.31), a senior scientist at the AAEC (and from 1987 its successor the Australian Nuclear Science and Technology Organisation – ANSTO) from 1971-1991, has noted that the enrichment project was given the code name "The Whistle Project" and was carried out initially in the basement of Building 21. Former AAEC scientist Keith Alder (1996, p.30) noted that the enrichment project was kept secret *"because of the possible uses of such technology to produce weapons-grade*

back to table of contents

enriched uranium". The project was not publicly revealed until a passing mention was made of it in the AAEC's 1967-68 Annual Report.

A feasibility study into a joint Australian/French enrichment program was nearing completion in 1972 but collaboration with the French on nuclear matters was not supported by the incoming Labor government.

Since the early 1970s, there has been little high level support for the pursuit of a domestic nuclear weapons capability. However, there have been indications of a degree of ongoing support for the view that nuclear weapons should not be ruled out of defence policy altogether and that Australia should be able to build nuclear weapons as quickly as any neighbour that looks like doing so. For example, this current of thought was evident in a leaked 1984 defence document called The Strategic Basis of Australian Defence Policy.

Bill Hayden, then the Foreign Minister, attempted to persuade Prime Minister Bob Hawke in 1984 that Australia should develop a "pre-nuclear weapons capability" which would involve an upgrade of Australia's modest nuclear infrastructure. Hayden's views found little or no support. Moreover the AAEC's uranium enrichment research, by then the major project at Lucas Heights, and pursued in the post-Baxter period with the aim of "value adding" to Australia's uranium exports, was terminated by government directive in the mid 1980s.

Several reasons can be given for the declining interest in nuclear weapons acquisition or production from the early 1970s onwards. Arguably, the development of the military alliance between the US and Australia is the key reason. Australia effectively became a nuclear weapons state "by proxy", relying on the US nuclear umbrella.

(The above summary is drawn from Green, 2002. The most detailed analyses of the pursuit of nuclear weapons in Australia are those of Cawte, 1992; Hymans, 2000; Walsh, 1997; Reynolds, 2000.)

back to table of contents

APPENDIX 6

status of nuclear power worldwide

Most of the following information is drawn from: Mycle Schneider and Antony Froggatt, December 2004, "World Nuclear Industry Status Report 2004", commissioned by Greens-EFA Group in the European Parliament, <www.greens-efa.org/pdf/documents/greensefa_documents_106_en.pdf>.

The IAEA estimated in 1974 that in the year 2000, nuclear output would be 4,450 GW. Output in the year 2000 was 352 GW. The IAEA estimate was out by a factor of 12.6 or 1260%.

A total of 440 reactors operating in 31 countries generate 16% of the world's electricity, 6% of the commercial primary energy and 2-3% of the final energy.

The average age of operating nuclear power plants is 21 years and has been increasing steadily. In total, 107 reactors have been permanently shut down, and their average age was also about 21 years.

From 1992-2004, 32 reactors were shut down and 52 were connected to the grid.

Nuclear reactors are operating in less than one in six countries. The largest nuclear power generators – the US, France, Japan, Germany, Russia, and South Korea – produce about three quarters of the world's total. The five declared nuclear weapon states – the US, Russia, France, the UK and China – account for almost 60% of global nuclear power output.

The historical peak of 294 operating reactors in Western Europe and North America was reached as early as 1989.

Twenty-two of the last 31 reactors connected to the grid have been built in Asia. Of the reactors under construction, 18 of the 27 are located in Asia, with almost no new construction in Western European or North America.

Assuming a reactor operating lifetime of 40 years, a total of 280 reactors would have to be built to keep pace with shut downs over the next 20 years.

Of the US$ 87.6 billion spent by 26 OECD member states between 1991 and 2001 on energy R&D, half went to nuclear research. Oil,

back to table of contents

coal and gas accounted for a total of 10%, and renewable energy 8%.

africa

South Africa operates two power reactors – the only operating power reactors in Africa.

north & south america

South America. Argentina and Brazil each operate two power reactors with another power reactor planned in each country.

Canada. Twenty-one power reactors are in operation. Ontario Hydro temporarily shut down seven reactors for overhauls, one having been temporarily shut down in 1995. Only three of the eight reactors had returned to operation as at October 2004.

United States. The US has 103 power reactors in operation. The number of cancelled projects is even larger – 138. The last time a reactor was ordered which was followed through to operation was October 1973. Twenty-six reactors have been granted licences to extend their operating lives, and applications or letters of intent have been submitted to extend the operating lives of another 50 reactors.

asia

China operates 10 power reactors that generate about 2% of the its electricity. Four reactors are under construction and eight are planned.

India operates 14 reactors with nine reactors listed as being under construction. In 1985, India's goal have 10,000 MWe of operating nuclear capacity installed by the year 2000 – but failed to meet the goal by a large margin with installed capacity at 2,200 MWe in the year 2000 and actual operating capacity about 1,500 MWe.

Japan operates 54 reactors, with two under construction and 12 planned.

Pakistan operates two reactors and one is planned.

South Korea operates 20 reactors and eight are planned but the expansion program has faced problems from strong public opposition to proposed nuclear dumping and further problems with the 2004 revelations about numerous illicit and/or unreported weapons-related research projects stretching back to the 1980s.

North Korea has no operating power reactors.

western europe

As at October 2004, 13 of the 25 countries in the enlarged European Union (EU25) operated 151 reactors, down from 172 reactors in 1989. Of the 151 reactors, 132 are located in eight of

back to table of contents

the western European (EU15) countries. Three countries have a total of 100 operating reactors – France (59), the UK (23), and Germany (18).

Only one reactor is under construction in western Europe – in Finland. Other than construction of one reactor in France beginning in 1991, no new reactor order had been placed in western Europe since 1980.

Austria held a referendum in November 1978 and decided not to open up an already -built power reactor.

Belgium operates seven reactors with none under construction and none planned. In 2002, the Belgian parliament passed nuclear phase-out legislation requiring the shut-down of reactors after 40 years of operation.

Finland operates four power reactors with one planned. Electricity consumption per capita is 2.4 times the German figure. If per capita consumption was reduced to the German level, the saved energy would be twice the output of the four operating reactors.

France operates 59 reactors. No reactors are under construction or planned, though one new reactor is listed as "proposed".

Germany operates 18 reactors with none under construction and none planned. A nuclear phase-out agreement between the government and nuclear utilities provides for a gradual phase-out of nuclear power with reactors to be shut down at an average age of 32 years. As at May 2005, two reactors had been shut down. Spent fuel will no longer be sent for reprocessing from mid-2005.

Italy permanently shut down four reactors after the Chernobyl accident in 1986 and scrapped plans for more reactors.

The Netherlands operates one reactor with none under construction or planned.

Spain operates nine reactors with none under construction or planned. Current Spanish Premier Jose Luis Zapatero has made a phase out of nuclear power one of his government's key goals.

Sweden operates 11 reactors with none under construction or planned.

Switzerland operates five reactors with none under construction or planned.

The United Kingdom operates 23 reactors with none under construction or planned.

eastern europe

In May 2004 ten new countries joined the European Union including five nations with

back to table of contents

nuclear power: Czech Republic, Hungary, Lithuania, Slovakia and Slovenia. Two other countries expected to join the EU, Bulgaria and Romania, operate power reactors.

Bulgaria operates four power reactors with none under construction and one reactor listed as "proposed".

The Czech Republic has six reactors in operation with none under construction or planned.

Hungary has four reactors with none under construction or planned. A potentially disastrous criticality accident was narrowly averted on April 10, 2003 during a cleaning process in a tank outside the reactor pressure vessel.

Lithuania has one reactor with none under construction or planned.

Romania has one power reactor, another under construction, and three listed as "proposed".

Slovakia has six power reactors, none under construction, and two reactors listed as "proposed".

Slovenia operates one reactor with none under construction or planned.

Russia and the Former Soviet Union

Russia operates 31 power reactors with four under construction, one planned and eight proposed.

Armenia has operates one power reactor with none under construction or planned.

Ukraine operates 15 power reactors with one more planned or on order.

back to table of contents

further reading

Friends of the Earth (UK), November 2004, *"Why nuclear power is not an achievable and safe answer to climate change"*, <www.foe.co.uk/resource/briefings/nuclear_power_answer_climate_change.pdf>.

Friends of the Earth (UK), September 2002, *"Tackling climate change without nuclear power: A report detailing how climate targets in the power sector can be met without replacing existing nuclear capacity"*, <www.foe.co.uk/resource/reports/ climate_chnge_without_nuke.pdf>.

WISE/NIRS – World Information Service on Energy and the Nuclear Information & Resource Service, February 2005, *"A back door comeback: Nuclear energy as a solution for climate change?"*, Nuclear Monitor #621 & #622, <www.antenna.nl/wise/621-22/621-22_en.pdf>.

Mycle Schneider (WISE Paris), April 2000, *"Climate Change and Nuclear Power"*, published by World Wide Fund for Nature, <www.panda.org/downloads/climate_ change/fullnuclearreprotwwf.pdf>.

Greenpeace, n.d. (undated), *"Nuclear Energy: No Solution to Climate Change"*, <archive.greenpeace.org/comms/no.nukes/nenstcc.html>.

World Information Service on Energy, *"Climate Change and Nuclear Power"*, <www.antenna.nl/wise/climate>.

back to table of contents

references

Anon., November 12, 1990, "Blix Says IAEA Does Not Dispute Utility of Reactor-Grade Pu for Weapons," Nuclear Fuel, p.8.

Anon., October 10, 1998, "The H-Bomb", India Today.

Anon., 2002, "Tepco admits leaktightness falsification", Nuclear Engineering International, November 5, <www.ConnectingPower.com/s.asp?s=2016804>.

Anon., 2002B, "Four more Japanese utilities in inspection cover-up", Nuclear Engineering International, November 5, <www.ConnectingPower.com/s.asp?s=2016803>.

Anon., November 20, 2004, "Study Suggests Chernobyl Affected Sweden", Associated Press, <www.nytimes.com/aponline/international/AP-Sweden-Chernobyl-Cancer.html>.

ABC (Australian Broadcasting Corporation), February 10, 2005, Lateline, <www.abc.net.au/lateline/content/2005/s1300407.htm>.

ACF – See Australian Conservation Foundation.

Albright, David, and Mark Hibbs, September 1992, "India's silent bomb", Bulletin of the Atomic Scientists, Vol.48, No.07, pp.27-31, <www.thebulletin.org/article.php?art_ofn=sep92albright>.

Albright, David, and Kimberly Kramer, November/December 2004, "Fissile material: Stockpiles still growing", Bulletin of the Atomic Scientists, Vol.60, No.6, pp.14-16, <www.thebulletin.org/article.php?art_ofn=nd04albright_016>.

Alder, Keith, 1996, "Australia's Uranium Opportunities", Sydney: P.M. Alder.

Alvarez, Robert, January/February 2002, "What about the spent fuel?", Bulletin of the Atomic Scientists, Vol.58, No.1, pp. 45-47, www.thebulletin.org/article.php?art_ofn=jf02alvarez>.

AMP Capital Investors, May 2004, "The Nuclear Fuel Cycle Position Paper", written by Sarah Kim and Ian Woods from the

back to table of contents

AMP Capital Sustainable Funds Team, <www.ampcapital.com.au/adviserproducts/sri/papers.asp>.

Anderson, David, 1997, "Nuclear Safeguards", Parliamentary Research Service report to Senate Uranium Mining and Milling Committee, <www.aph.gov.au/senate/committee/uranium_ctte/report/c12.htm>.

Anderson, Tom, May 29, 2005, "Plutonium was left lying in a puddle on the floor for nine months", The Independent (UK), <www.news.independent.co.uk/uk/environment/story.jsp?story=642357>.

Ansolabehere, Stephen, et al., 2003, "The Future of Nuclear Power: An Interdisciplinary MIT Study", <web.mit.edu/nuclearpower>.

ASNO – see Australian Safeguards and Non-Proliferation Office.

Australian Conservation Foundation, July 2005, "Nuclear Energy: No solution to climate change", <www.acfonline.org.au/docs/general/an_background.pdf>.

Australian Conservation Foundation, 2005B, "Nuking the Climate? ACF's Perspective on the Nuclear Power – Climate Change debate", 20 April, <www.acfonline.org.au/asp/pages/document.asp?IdDoc=2369>.

Australian Conservation Foundation, 2005C, Submission to Standing Committee on Industry and Resources, Inquiry into Developing Australia's Non-fossil Fuel Energy Industry, <www.aph.gov.au/house/committee/isr/uranium/subs.htm>

Australian Greenhouse Office, July 2000, "Overview: 1998 National Greenhouse Gas Inventory, <www.greenhouse.gov.au>.

Australian Ministerial Council on Energy, November 2003, "Towards a National Framework for Energy Efficiency – Issues and Challenges", Discussion Paper, ISBN 1 920825 02 9, <www.seav.vic.gov.au/ftp/energy_efficiency/nfee/nfee_discussionpaper.pdf>.

Australian National Audit Office, March 2, 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/WebSite.nsf/Publications/CBC2DCF7CEB0EBFBCA256FB700792A8E>.

Australian Nuclear Science and Technology Organisation, March 29, 2001, "ANSTO Briefing – Reprocessing of research reactor spent fuel", <www.ansto.gov.au/info/press/2001b/b03.html>.

back to table of contents

Australian Safeguards and Non-Proliferation Office, n.d., "The Nuclear Non-Proliferation Regime: An overview of Institutional & Technical Issues", <www.asno.dfat.gov.au/nuclear_safeguards.html>.

Australian Safeguards and Non-Proliferation Office, 1998-99, Annual Report, pp.55-59. <www.uic.com.au/nip18.htm>.

Australian Safeguards and Non-Proliferation Office, 2001-02, Annual Report, <www.asno.dfat.gov.au/annual_report_0102/asno_annual_report_2001_2002.pdf>.

Australian Safeguards and Non-Proliferation Office, 2003-04, Annual Report, Annex C, <www.asno.dfat.gov.au/annual_report_0304/ASNO_2004_AR.pdf>.

Berkhout, Frans, 1997, "The International Civilian Reprocessing Business", in Institute for Energy and Environmental Research, Energy and Security, Issue Number 2, <www.ieer.org/ensec/no-2/nr2.html>.

Berkhout, Frans, 1997B, "The Economics of Reprocessing", in Institute for Energy and Environmental Research, Energy and Security, Issue Number 2, <www.ieer.org/ensec/no-2/nr2.html>.

Blix, H., November 1, 1990, Letter to the Nuclear Control Institute, Washington DC.

Boureston, Jack, and Charles D. Ferguson, March/April 2005, "Laser enrichment: Separation anxiety", Bulletin of the Atomic Scientists, Vol.61, No.2, pp.14-18, <www.thebulletin.org/article.php?art_ofn=ma05boureston>.

Broinowski, Richard, 2003, "Fact or Fission? The Truth About Australia's Nuclear Ambitions", Melbourne: Scribe.

Broinowski, Richard, 2003B, "Going nuclear, Japan?", The Diplomat, June/July 2003, pp.16-17.

Broinowski, Richard, March 21, 2005, "Danger nuclear mistakes will be repeated", Sydney Morning Herald, <www.smh.com.au/news/Opinion/Danger-nuclear-mistakes-will-be-repeated/2005/03/20/1111253882668.html>.

Brown, Paul, July 14, 2000, "The night Sellafield turned into a shooting gallery", The Guardian (UK).

Bunn, M., June 1997, paper presented at International Atomic Energy Agency Conference, Vienna.

Burnie, Shaun and Aileen Mioko Smith, May/June 2001, "Japan's nuclear twilight zone", Bulletin of the Atomic Scientists, vol. 57, no.03, pp.58-62, <www.thebulletin.org/article.php?art_ofn=mj01burnie>.

Burnie, Shaun, April 2005, "Proliferation Report: sensitive nuclear technology and plutonium technologies in the Republic of Korea and Japan", Greenpeace report, <www.greenpeace.org/international/press/reports/Proliferation-Korea-Japan>.

Busby, John, February 2005, "Why nuclear power is not the answer to global warming", <www.onlineopinion.com.au/view.asp?article=3039> and <www.onlineopinion.com.au/forum/thread.asp?article=3039>.

Bush, George W., February 11, 2004, "Speech on the Spread of Nuclear Weapons", <www.nytimes.com/2004/02/11/politics/10WEB-PTEX.html>.

Butler, Richard, March 8, 2005, "Heavily armed duo in no position to lay down law on proliferation", Sydney Morning Herald, <www.smh.com.au/news/Opinion/Heavily-armed-duo-in-no-position-to-lay-down-law-on-proliferation/2005/03/07/1110160750281.html>.

Cardis, Elizabeth, April 1996, "Estimated Long Term Health Effects of the Chernobyl Accident", Proceedings of international conference, One Decade After Chernobyl – Summing up the consequences of the accident, Vienna, April 1996, sponsored by EU, IAEA & WHO. <www.uic.com.au/nip22app.htm#cardis>.

Carlson, John, December 21, 1998, Evidence before Joint Committee on Treaties, <www.aph.gov.au/hansard/joint/commttee/j2022.pdf>.

Carlson, John, 2000, "Nuclear Energy and Non-proliferation – Issues and Challenges: An Australian Perspective", Paper prepared for JAIF Symposium on Peaceful Uses of Nuclear Energy and Non-Proliferation, Tokyo, 9-10 March 2000.

Carlson, J., J. Bardsley, V. Bragin and J. Hill (Australian Safeguards and Non-Proliferation Office), "Plutonium isotopics – non-proliferation and safeguards issues", Paper presented to the IAEA Symposium on International Safeguards, Vienna, Austria, 13-17 October, 1997, <www.asno.dfat.gov.au/O_9705.html>.

Carson Mark, J., 1993, "Explosive Properties of Reactor-Grade Plutonium", <ccnr.org/Findings_plute.html>.

Cawte, Alice, 1992, "Atomic Australia: 1944-1990", Sydney: New South Wales University Press.

back to table of contents

Climate Action Network, 1998, "Climate Action Network Recommendations to Ministers at COP4", <www.climnet.org/pubs/canlong.html>.

Climate Action Network, November 2000, "COP6 POSITION PAPER", <www.climatenetwork.org/docs/CAN-COP6-all-web.pdf>.

Climate Action Network of Australia, n.d., "Australia's Climate Change Strategy: The Real Way Forward", <www.cana.net.au/documents/real_way_forward.pdf>.

Connor, Steve, June 20, 2000, "Sellafield sabotage 'was intended to divert Mox inquiry'", The Independent.

De Volpi, Alex, October 1996, "A Cover-up of Nuclear-Test Information", APS Forum on Physics and Society, Vol. 25, No. 4. <www.aps.org/units/fps/newsletters/1996/october/aoct96.cfm#a2>.

Department of Foreign Affairs and Trade, 1998, "Current and Future Safeguards Developments", <www.dfat.gov.au/aso/topics/strength/htm>.

Department of Trade and Industry (UK), July 19, 2003, "Annual civil plutonium and uranium figures", <www.dti.gov.uk/energy/nuclear/technology/plutofigs.shtml>.

Diesendorf, Mark, 2005, "Towards New South Wales' Clean Energy Future", A Report for the Clean Energy Future Group, <wwf.org.au/News_and_information/ Publications/PDF/Report/nswcefreport2005.pdf>.

Dolley, Steven, March 28, 1997, Using warhead plutonium as reactor fuel does not make it unusable in nuclear bombs, <www.nci.org/i/ib32897c.htm>.

El Baradei, Mohamed, 2000, "Signs of progress: IAEA perspectives on radioactive waste management", IAEA Bulletin, 42/3/2000.

El Baradei, Mohamed, 2003, "Geological Repositories: The Last Nuclear Frontier", Statement to International Conference on Geological Repositories: Political and Technical Progress, 8-10 December 2003, Stockholm, Sweden, <www.iaea.org/NewsCenter/Statements/2003/ebsp2003n028.html>.

El Baradei, Mohamed, November 25, 2004, "Introductory Statement to the Board of Governors", <www.iaea.org/NewsCenter/Statements/2004/ebsp2004n016.html>.

El Baradei, Mohamed, May 2, 2005, Statement to 2005 Review Conference of the Treaty on the Non-Proliferation of Nuclear Weapons,

back to table of contents

<www.iaea.org/NewsCenter/Statements/2005/ebsp2005n006.html>.

El Baradei, Mohamed, 2005B, "Curbing the Nuclear Threat", February 2, <www.iaea.org/NewsCenter/Statements/2005/ebsp2005n001.html>).

El Baradei, Mohamed, 2005C, "Nuclear Terrorism: Identifying and Combating the Risks", March 16, <www.iaea.org/NewsCenter/Statements/2005/ebsp2005n003.html>.

EC/IAEA/WHO (European Commission, International Atomic Energy Agency, World Health Organisation), 1996, International Conference: One Decade after Chernobyl: Summing up the Consequences of the Accident", Vienna, Austria 8-12 April, 1996, <www.iaea.org/worldatom/Programmes/Safety/Chernobyl/concls17.html>.

Energy Information Administration (US), May 2004, "World Energy Use and Carbon Dioxide Emissions, 1980-2001", <www.eia.doe.gov/emeu/cabs/carbonemiss/index.html>.

Feiveson, Harold, 2001, "The Search for Proliferation-Resistant Nuclear Power", The Journal of the Federation of American Scientists, September/October 2001, Volume 54, Number 5, <www.fas.org/faspir/2001/v54n5/nuclear.htm>.

Fetter, Steve, 1999, "Climate Change and the Transformation of World Energy Supply", Stanford University – Centre for International Security and Cooperation Report, <www.cisac.stanford.edu/publications/10228>.

Fetter, Steve, July/August 2000, "Energy 2050", Bulletin of the Atomic Scientists, Vol.56, No.04, pp.28-38, <www.thebulletin.org/article.php?art_ofn=ja00fetter>.

Friedman, John S., 1997, "More power to thorium?", Bulletin of the Atomic Scientists, Vol. 53, No.5, September/October .

Friends of the Earth (UK), September 2002, "Tackling climate change without nuclear power: A report detailing how climate targets in the power sector can be met without replacing existing nuclear capacity", <www.foe.co.uk/resource/reports/ climate_chnge_without_nuke.pdf>.

Friends of the Earth (UK), November 2004, "Why nuclear power is not an achievable and safe answer to climate change", <www.foe.co.uk/resource/briefings/nuclear_power_answer_climate_change.pdf>.

Fritsche, Uwe R. and Sui-San Lim (Oko-Institut), November 1997, "Comparing

back to table of contents

Greenhouse-Gas Emissions and Abatement Costs of Nuclear and Alternative Energy Options from a Lifecycle Perspective", paper presented at the CNIC Conference on Nuclear Energy and Greenhouse Gas Emissions, Tokyo. <www.oeko.de/service/gemis/files/info/nuke_co2_en.pdf>.

Garwin, Richard L., 2001, "Can the World Live With Nuclear Power?", <www.nci.org/conf/garwin/index.htm>.

Gibson, Daniel, July/August 1991, "Can alchemy solve the nuclear waste problem?", Bulletin of the Atomic Scientists, Vol. 47, No. 6.

Goldschmidt, Pierre July 17, 2000, "IAEA Safeguards: Evolution or Revolution?".

Gorwitz, Mark, 1996, "The Plutonium Special Isotope Separation Program: An Open Literature Analysis".

Gorwitz, Mark, 1998, "Foreign Assistance to Iran's Nuclear and Missile Programs", <www.globalsecurity.org/wmd/library/report/1998/iran-fa.htm>. See Appendix A and references.

Green, Jim, 2002, "Research Reactors and Nuclear Weapons", paper prepared for the Medical Association for the Prevention of War, <www.mapw.org.au/nuclear-reactors/02green.html>.

Greenpeace, n.d. (undated), "Nuclear Energy: No Solution to Climate Change", <archive.greenpeace.org/comms/no.nukes/nenstcc.html>.

Greenpeace, September 1, 1999, "Confidential diplomatic documents reveal U.S. proliferation concerns over Japan's plutonium program", media release, <archive.greenpeace.org/pressreleases/nuctrans/1999sep1.html>.

Greenpeace, 2004, "Secrets, Lies and Uranium Enrichment: The Classified Silex Project at Lucas Heights", <www.greenpeace.org.au/frontpage/pdf/silex_report.pdf>.

Greenpeace, May 3, 2005, "Risky research on our own turf", Media Release, <www.greenpeace.org.au/features/features_details.html?site_id=45&news_id=1651>.

Greenpeace and the Australian Conservation Foundation, November 28, 2003, Media Release, "Nuclear laws target media, community groups".

Gsponer, A., and J-P. Hurni, 2004 "ITER: The International Thermonuclear Experimental Reactor and the Nuclear Weapons Proliferation Implications of Thermonuclear-Fusion Energy Systems", Independent Scientific Research Institute report number ISRI-04-01, <http://arxiv.org/abs/physics/0401110>.

back to table of contents

Hamza, Khidhir, 1998, "Inside Saddam's secret nuclear program", Bulletin of the Atomic Scientists, September/October, Vol.54, No.5, <www.thebulletin.org/article.php?art_ofn=so98hamza>.

Hansen, J., M. Sato, R. Ruedy, A. Lacis and V. Oinas., 2000, "Global warming in the twenty-first century: An alternative scenario", Proc. Natl. Acad. Sci., 97, pp.9875–9880.

Hardy, Clarence, 1996, "Enriching Experiences", NSW: Glen Haven.

Hinton, J.P., October 1996, "Proliferation Vulnerability", Red Team Report. Sandia National Laboratories Publication, SAND 97-8203, <www.ccnr.org/plute_sandia.html>.

Hirsch, Helmut, 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>.

Hore-Lacy, Ian, 2000, "The Future of Nuclear Energy", <www.uic.com.au/opinion6.html>.

Hore-Lacy, Ian, 2003, "Nuclear Electricity", Seventh Edition, published by Uranium Information Centre Ltd and World Nuclear Association, <www.uic.com.au/ne.htm>.

Horner, Daniel, May 24, 2004, "Brazil defends limits on SWU plant inspections", Nuclear Fuel, Volume 11 , Number 11.

Hymans, Jacques E. C., 2000, "Isotopes and Identity: Australia and the Nuclear Weapons Option, 1949-1999", Nonproliferation Review, Vol.7, No.1, Spring, pp.1-23.

IAEA – see International Atomic Energy Agency.

Institute for Science and International Security, n.d., "Nuclear Weapons Programs Worldwide: An Historical Overview", <www.isis-online.org/mapproject/introduction.html>.

Institute for Science and International Security, 2004, "Civil Plutonium Produced in Power Reactors", <www.isis-online.org/global_stocks/civil_pu.html>.

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 Intergovernmental Panel on Climate Change, R.T.Watson, M.C.Zinyowera, R.H.Moss (eds), Cambridge University Press: UK.

back to table of contents

International Atomic Energy Agency, n.d., "Illicit Nuclear Trafficking Statistics: January 1993 – December 2003", <www.iaea.org/NewsCenter/Features/RadSources/Fact_Figures.html>.

International Atomic Energy Agency, 1996, "Long-term Committed Doses from Man-made Sources," IAEA Bulletin, Vol.38, No.1.

International Atomic Energy Agency, 1997, "Sustainable Development & Nuclear Power", Vienna: IAEA, <www.iaea.org/Publications/Booklets/Development>.

International Atomic Energy Agency, 1997B, "Fourth consolidated report of the Director General of the International Atomic Energy Agency under paragraph 16 of Security Council resolution 1051 (1996)", IAEA Document S/1997/779, Vienna, Austria: IAEA, October, <www.iaea.org/worldatom/Programmes/ActionTeam/reports/s_1997_779.pdf>.

International Atomic Energy Agency, 2004, "Implementation of the NPT Safeguards Agreement in the Republic of Korea", Report by the Director General to the Board of Governors, GOV/2004/84, November 11, <www.iaea.org/NewsCenter/News/2004/south_korea.html>.

International Atomic Energy Agency, 2004B, "Communication Received from Japan Concerning Its Policies Regarding the Management of Plutonium", Information Circular, December 23, <www.iaea.org/Publications/Documents/Infcircs/2004/infcirc549a1-7.pdf>.

IPCC – see Intergovernmental Panel on Climate Change

Kang, Jungmin, Peter Hayes, Li Bin, Tatsujiro Suzuki and Richard Tanter, 2005, "South Korea's nuclear surprise", Bulletin of the Atomic Scientists, January/February, Vol.61, No.01, pp.40-49, <www.thebulletin.org/article.php?art_ofn=jf05kang>.

Keepin, Bill and Gregory Kats, December 1988, "Greenhouse warming: comparative analysis of nuclear and efficiency abatement strategies Energy Policy" Energy Policy, Vol.16, No.6, pp.538-561.

Kemeny, Leslie, April 15, 2005, "Power to the People", The Australian Financial Review, <www.uic.com.au/KemenyAFR.htm>.

Kidd, Steve, May 11, 2004, "Achilles heel or own goal?", Nuclear Engineering International, <www.neimagazine.com/story.asp?sectionCode=147&storyCode=2023239>.

back to table of contents

Koch, Andrew 1997, "Yugoslavia's Nuclear Legacy: Should We Worry?", Nonproliferation Review, Spring/Summer, pp.123-24.

Koutsoukis, Jason, November 9, 2002, "Has anybody seen Australia's uranium?", Australian Financial Review, pg. 21.

Langeland, Terje, November/December 2001, "Here, there, everywhere: How did the British government get so deeply involved in the U.S. weapons complex cleanup?", Bulletin of the Atomic Scientists, Vol.57, No.06, pp.57-64, <www.thebulletin.org/article.php?art_ofn=nd01langeland>.

Leventhal, Paul, and Steven Dolley, 1999, "Understanding Japan's Nuclear Transports: The Plutonium Context", paper presented to the Conference on Carriage of Ultrahazardous Radioactive Cargo by Sea: Implications and Responses, Malaysia, October 18, 1999, <www.nci.org/k-m/mmi.htm>.

Leventhal, Paul, and Steven Dolley, 1999B, "The Reprocessing Fallacy: An Update", presented to Waste Management 99 Conference, Tucson, Arizona, March 1, 1999, <www.nci.org/p/pl-wm99.htm>.

Lovelock, James, May 24, 2004, "Nuclear power is the only green solution", The Independent (UK), <www.ecolo.org/media/articles/articles.in.english/love-indep-24-05-04.htm> or <comment.independent.co.uk/commentators/story.jsp?story=524230>.

Lovelock, James, April 2005, "Our Nuclear Lifeline", Reader's Digest, <www.ecolo.org/lovelock/Nuclear_lifeline_05.pdf>.

Lovelock, James, and Bruno Comby, 2005, "About tsunamis, gaia, and ecology", <www.ecolo.org/lovelock/gaia_tsunamis-article-01_05.htm>.

Low Level Radiation Campaign, n.d., "Shooting the Miners' Canary", <www.llrc.org/index.html>.

Lyman, Edwin S. (Union of Concerned Scientists), September 2004, "Chernobyl on the Hudson? The Health and Economic Impacts of a Terrorist Attack at the Indian Point Nuclear Plant", Commissioned by Riverkeeper, Inc., <www.ucsusa.org/global_security/nuclear_terrorism/page.cfm?pageID=1508>.

McDonald, Alan, 2004, quoted in The Independent (UK), 28 June.

McSorley, Jean, 1998, "The New Reactor: National Interest & Nuclear Intrigues", A Response to the Submission of the Department of Foreign Affairs & Trade and the Australian Safeguards Office to the Senate Economics

back to table of contents

Reference Committee, <www.geocities.com/jimgreen3/mcsorley.html>.

Makhijani, Arjun, Hisham Zerriffi and Annie Makhijani, "Magical Thinking: another go at transmutation", Bulletin of the Atomic Scientists, March/April 2001, Vol. 57, No. 2, pp. 34-41, <www.thebulletin.org/issues/2001/ma01/ma01makhijani.html>.

Marsh G, P. Taylor, D. Anderson, M. Leach and R. Gross, 2003, "Options for a Low Carbon Future – Phase 2". Report to UK Department of Trade and Industry.

Miller, Marvin M., August 1990, "Are IAEA Safeguards on Plutonium Bulk-handling Facilities Effective?", Nuclear Control Institute, <www.nci.org/k-m/mmsgrds.htm>.

Miller, Marvin, March 27, 2002, "Japan, Nuclear Weapons, and Reactor-Grade Plutonium", <www.nci.org/02NCI/04/mm-jpu-paper.htm>.

MITRE, 2004, "Overview report", published by the European Commission, p.13.

Muller, Frank, June 30, 2005, "Global Contest", ABC Radio National 'Perspective', <www.abc.net.au/rn/talks/perspective/stories/s1404276.htm>.

National Research Council (of the US National Academy of Sciences), 2005, "Health Risks from Exposure to Low Levels of Ionizing Radiation (BEIR VII – Phase 2)", written by the NRC's Board on Radiation Research Effects, <www.nap.edu/books/030909156X/html>.

Nuclear Energy Agency, 2000, "Nuclear Power and Climate Change", <www.nea.fr/html/ndd/climate/climate.pdf>.

Nuclear Energy Agency, 2002, "Chernobyl: Assessment of Radiological and Health Impacts: 2002 Update of Chernobyl: Ten Years On", <www.nea.fr/html/rp/chernobyl/chernobyl.html>.

Nuclear Energy Agency (NEA) and International Atomic Energy Agency (NEA & IAEA), 2004, "Uranium 2003: Resources, Production and Demand". Paris: OECD.

Nuclear Information and Resource Service, n.d., "Nuclear power can't stop climate change", <www.nirs.org/factsheets/climatenukes.pdf>.

NIRS, n.d., "The Pebble Bed Modular Reactor: Old Wine in a New Bottle", <www.nirs.org/factsheets/pbmrfactsheet.htm>.

Nuclear Weapon Archive, n.d., "Nuclear Weapon Nations and Arsenals", <nuclearweaponarchive.org/Nwfaq/Nfaq7.html>.

back to table of contents

Oi, Noboru, March 1998, "Plutonium Challenges: Changing Dimensions of Global Cooperation", IAEA Bulletin, <www.iaea.org/Publications/Magazines/Bulletin/Bull401/article3.html>.

Organisation for Economic Cooperation and Development, 1998, "Uranium 1997: Resources, Production and Demand", Paris: OECD.

OSPAR, 2000, "OSPAR Decision 2000/1 on Substantial Reductions and Elimination of Discharges, Emissions and Losses of Radioactive Substances, with Special Emphasis on Nuclear Reprocessing", <www.ospar.org/v_ospar/strategy.asp?v0=5&lang=1>.

Parliamentary Office of Science and Technology (UK), February 2005, "Managing the UK Plutonium Stockpile", Report Number 237, <www.parliament.uk/documents/upload/POSTpn237.pdf>.

Potter, William C., Djuro Miljanic and Ivo Slaus, 2000, "Tito's nuclear legacy", Bulletin of the Atomic Scientists, March/April, Vol.56, No.2, pp.63-70, <www.thebulletin.org/issues/2000/ma00/ma00potter.html>.

Radford, Tim, September 16, 2000, "The whole world in our hands", The Guardian (UK), <www.ecolo.org/lovelock/world-in-our-hands.html>.

Radioactive Waste Management Advisory Committee (UK), December 2003, "Advice to Ministers on the Application of Partitioning and Transmutation in the UK", <www.defra.gov.uk/rwmac/reports/part-trans/index.htm>.

Rann, Mike, March 1982, "Uranium: Play It Safe", Special Supplement to Labor Forum.

Repáraz, Adolfo, September/October 2003, "Between MOX and a hard place", Vol.59, No.5, pp.46-51, <www.thebulletin.org/article.php?art_ofn=so03reparaz>.

Reynolds, Wayne, 2000, "Australia's bid for the atomic bomb", Melbourne University Press.

Ritch, John B., 1999, "Nuclear green", <www.uic.com.au/NuclearGreen-Ritch.htm>.

Roberts, Alan, 2005, "The Phantom Solution: Climate Change and Nuclear Power", Arena Journal, No.23, pp.161-187.

Rosen, Morris, 1998, "Managing Radioactive Waste: Issues and Misunderstandings", Uranium Institute: 1998 Symposium, <www.world-nuclear.org/sym/1998/rosen.htm>.

Royal Society, 1998, "The Management of Separated Plutonium", Summary.

back to table of contents

Saddler, Hugh, Richard Denniss and Mark Diesendorf, 2004, "A Clean Energy Future for Australia", Report for the Clean Energy Future Group, <www.wwf.org.au/News_and_information/Features/feature10.php>.

Sawin, J., 2004, "Mainstreaming Renewable Energy in the 21st Century", Worldwatch paper #169.

Schneider, Mycle (WISE Paris), April 2000, "Climate Change and Nuclear Power", published by World Wide Fund for Nature, <www.panda.org/downloads/climate_ change/fullnuclearreprotwwf.pdf>.

Schneider, Mycle, April 2001, "15 Years After Chernobyl – Nuclear Power AND Climate Change?", report for the Greens/European Free Alliance in the European Parliament, <www.wise-paris.org/english/reports/15YearsChernobyl.pdf>.

Schneider, Mycle and Antony Froggatt, December 2004, "World Nuclear Industry Status Report 2004", commissioned by Greens-EFA Group in the European Parliament, <www.greens-efa.org/pdf/documents/greensefa_documents_106_en.pdf>.

Selden, R. W., 1976, "Reactor Plutonium and Nuclear Explosives", Lawrence Livermore Laboratory, California.

Senate Select Committee on Uranium Mining and Milling, 1997, <www.aph.gov.au/senate/committee/uranium_ctte/report/c06.htm>.

Senate References and Legislation Committee, October 2003, "Regulating the Ranger, Jabiluka, Beverly and Honeymoon uranium mines", <www.aph.gov.au/senate/committee/ecita_ctte/completed_inquiries/2002-04/uranium/report/index.htm>.

Shea, T.E. and K. Chitumbo, "Safeguarding Sensitive Nuclear Materials: Reinforced Approaches", IAEA Bulletin, #3, 1993, p.23.

Spector, Leonard S., Mark G. McDonough, with Evan S. Medeiros, 1995, Tracking Nuclear Proliferation, Washington: Brookings Institution / Carnegie Endowment for International Peace, pp.83-86.

Sustainable Energy Coalition, 2005, "48 Groups Refute US President's Claim That Nuclear Energy Is 'A Renewable Source of Energy'", <www.energybulletin.net/4284.html>.

Thomas, Steve, 1999, "Arguments on the Construction of Pebble Bed Modular Reactors in South Africa", <www.sussex.ac.uk/Units/spru/environment/research/pbmr.html>.

back to table of contents

Traub, James, June 13, 2004, "The Netherworld of Nonproliferation", New York Times.

Turton, Hal, Jinlong Ma, Hugh Saddler and Clive Hamilton, October 2002, "Long-Term Greenhouse Gas Scenarios: A pilot study of how Australia can achieve deep cuts in emissions", Discussion Paper No. 48, The Australia Institute, Canberra. Summary at: <www.tai.org.au/WhatsNew_Files/WhatsNew/DP48sum.pdf>.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1994, "Ionising Radiation: Sources and Biological Effects", New York: UNSCEAR.

Uranium Information Centre, n.d., "Overview of Nuclear Energy" <www.uic.com.au/introduction.htm>.

Uranium Information Centre, 2002, "Plutonium", Nuclear Issues Briefing Paper 18, <www.uic.com.au/nip18.htm>.

Uranium Information Centre, November 2003, "Safety of Nuclear Power Reactors", <www.uic.com.au/nip14.htm>.

Uranium Information Centre, October 2004, "Safeguards to Prevent Nuclear Proliferation", Nuclear Issues Briefing Paper 5, <www.uic.com.au/nip05.htm>.

Uranium Information Centre, 2004B, "Supply of Uranium", Nuclear Issues Briefing Paper # 75, <www.uic.com.au/nip75.htm>.

Uranium Information Centre, 2004C, "Safety of Nuclear Power Reactors: Appendix to Nuclear Issues Briefing Paper 14", <www.uic.com.au/nip14app.htm>.

Uranium Information Centre, 2004D, "Chernobyl Accident", Nuclear Issues Briefing Paper 22, <www.uic.com.au/nip22.htm>.

Uranium Information Centre, 2004E, "Thorium", Nuclear Issues Briefing Paper # 67, November, <www.uic.com.au/nip67.htm>.

Uranium Information Centre, 2004F, "Iraq, North Korea & Iran – Implications for Safeguards", Appendix to Safeguards Briefing Paper, Nuclear Issues Briefing Paper 15, <www.uic.com.au/nip15.htm>.

Uranium Information Centre, February 2005, "Australia's Uranium and Who Buys It", Nuclear Issues Briefing Paper 1, <www.uic.com.au/nip01.htm>.

Uranium Institute, n.d., "Responding to Global Climate Change: The Potential Contribution of Nuclear Power".

back to table of contents

US Department of Energy, June 1994, Office of the Press Secretary, "Additional Information Concerning Underground Nuclear Weapon Test of Reactor-Grade Plutonium", DOE Facts (1994) 186-7. Reproduced on the US Office of Scientific and Technical Information website, <www.osti.gov/html/osti/opennet/document/press/pc29.html>. Also available at: <www.ccnr.org/plute_bomb.html>.

US Department of Energy, 1997, Office of Arms Control and Nonproliferation, January, "Final Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives", Washington, DC: DOE, DOE/NN-0007, pp.37-39. <www.ccnr.org/plute.html>.

van Leeuwen, Jan-Willem and Philip Smith, 2004, "Can nuclear power provide energy for the future; would it solve the CO2-emission problem?", <http://beheer.oprit.rug.nl/deenen>.

von Hippel, Frank, and Suzanne Jones, 1997, "The slow death of the fast breeder", Bulletin of the Atomic Scientists, Vol.53, No.5, September/October.

Walsh, Max, February 2005, "Nuclear parks", The Bulletin, <www.bulletin.ninemsn.com.au/bulletin/site/webAllArticles/85C0ED932DDF21DCCA256F960082594E>.

Walsh, Jim, 1997, 'Surprise Down Under: The Secret History of Australia's Nuclear Ambitions', The Nonproliferation Review, Fall, pp.1-20.

WISE (World Information Service on Energy), May 26, 2000, "OSPAR 2000: End to reprocessing at Sellafield and La Hague?", WISE News Communique, #530, <www.antenna.nl/wise/530/index.html>.

WISE/NIRS (Nuclear Information & Resource Service), 4 October, 2002, "Japan: nuclear scandal widens and deepens", WISE/NIRS Nuclear Monitor, <www.antenna.nl/wise/574/index.html>.

WISE/NIRS, February 13, 2004, "The Proliferation Risks of ITER", WISE/NIRS Nuclear Monitor, #603, <www.antenna.nl/wise/603/index.php>.

WISE/NIRS: World Information Service on Energy (WISE) and the Nuclear Information & Resource Service (NIRS), February 2005, "A back door comeback: Nuclear energy as a solution for climate change?", Nuclear Monitor #621 & #622, <www.antenna.nl/wise/621-22/621-22_en.pdf>.

WISE/NIRS, 2005B, "25 Years Ago", Nuclear Monitor #623, March 4, <www.antenna.nl/wise/623/index.php>.

back to table of contents

WISE-Paris, 2001, "Possible Toxic Effects from the Nuclear Reprocessing Plants at Sellafield and Cap de la Hague", European Parliament Directorate General for Research, <www.wise-paris.org/english/stoa_en.html>.

WISE-Paris, March 4, 2002, "New figures for plutonium stocks worldwide", <www.wise-paris.org/index.html?/english/ournews/year_2002/ournews020305.html>.

Wood, Tony, May 2, 2000, Letter, St. George and Sutherland Shire Leader.

World Nuclear Association, January 2004, "Energy Analysis of Power Systems", <world-nuclear.org/info/printable_information_papers/inf11print.htm>.

World Resources Institute, (n.d.), "Greenhouse Gas Emissions by Sector 2003", <www.earthtrends.wri.org/pdf_library/data_tables/cli2_2003.pdf>.

Zerriffi, Hisham and Annie Makhijani, May 2000, "Nuclear Alchemy Gamble: An Assessment of Transmutation as a Nuclear Waste Management Strategy", Prepared for the Institute for Energy and Environmental Research, <www.ieer.org/reports/transm/summary.html>.

back to table of contents

If nuclear power is the answer, it must have been a pretty **stupid question**

Ian Lowe
President, ACF

back to table of contents