NUCLEAR POWER
CURE OR CURSE?
A DISCUSSION PAPER

LUKE K VAUGHAN

Nuclear power: cure or curse?

A discussion paper

by
Luke K Vaughan

Luke Vaughan completed his Bachelor of International Relations at La Trobe University in Melbourne, 2006.

This project was commissioned by Catholic Social Services Victoria and the Melbourne Catholic Commission for Justice, Development and Peace. The project was supervised by Bruce Duncan CSsR, and endorsed by the Social Questions Commission of the Victorian Council of Churches.

Published by Catholic Social Services Victoria and the Justice Unit, Archdiocese of Melbourne.
383 Albert Street
(P.O. Box 146)
East Melbourne VIC 8002
Phone: (03) 9287-5566
Email: office@css.org.au
Web: www.css.org.au

First published in November 2007

Cover design by Ramesh Weereratne, Catholic Communications Melbourne
Pre-press production by Damon Carr, Catholic Communications Melbourne
Printed by On-Demand Printing

Vaughan, Luke K.
Nuclear power: cure or curse?
Bibliography
Subjects: Nuclear energy.
333.7924

ISBN: 978-0-9579064-6-4

Note: Monetary figures are expressed in US dollars unless otherwise stated.

Contents

Preface

Questions around the use of nuclear energy pose new and difficult dilemmas: about its role in reducing global warming, about its links with proliferation of nuclear weapons, about the danger of accidents or from terrorism, and about problems of safety and waste disposal. These issues are particularly acute for Australia since we possess such large reserves of uranium and so share responsibility for how it is used.

The issues surrounding nuclear power pose urgent challenges to the wellbeing of human beings everywhere, and hence are profoundly moral in nature. They are also relatively new, and we need to listen carefully to expert opinion on the various aspects involved, and to take part in a full and open public conversation.

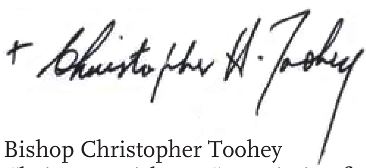
Nuclear power: cure or curse? by Luke K. Vaughan is a discussion paper drawing together much of the scientific and public commentary on key aspects of the debate. It aims to take us beyond the advocacy of powerful sectional interests to assess issues on their merits, in the light of available evidence.

For many centuries the churches have tried to limit violence and warfare, especially through the just war and pacifist traditions. In recent decades, there has been renewed concern about even more ominous threats to human life. In our nuclear age, it has become imperative as far as possible to outlaw war altogether.

This study was initiated by the Catholic social agencies in Victoria, but within the context of the inter-faith networks in Melbourne, and especially the marvellous ecumenical collaboration fostered by the Social Questions Commission of the Victorian Council of Churches. This must be one of the most hopeful signs of our times, that people of good will of all faiths and beliefs can join together in the struggle to secure a peaceful future for humankind.

As a modest contribution to current discussion, this study is endorsed by the various agencies, including the Justice and International Mission Unit of the Synod of Victoria and Tasmania, Uniting Church in Australia. It complements other recent studies, such as the eminently readable Climate Change: Faith and Action, by Cath James, Andrew Wilson and Mark Zirnsak for the Uniting Church in Victoria in late 2006.

No one can be in any doubt that failure on our part to provide really excellent answers to these questions around nuclear power could have most dire consequences, not just for ourselves, but for generations into the future. Many years from now, will people commend us for our foresight, or curse us for our blindness?



Bishop Christopher Toohey
Chairman, Bishops Commission for Justice and Service
Australian Catholic Bishops Conference

Introduction

When the nuclear genie came out of the bottle during the Second World War, the world changed forever. With the splitting of the atom came immense power for those who possessed it and potential destruction for those who did not. For the first time in history, human beings now had the ability to annihilate whole cities and states at the flick of a switch, without directly risking fatalities of their own. The bombings of Hiroshima and Nagasaki are stark reminders of the catastrophic repercussions of splitting the atom.

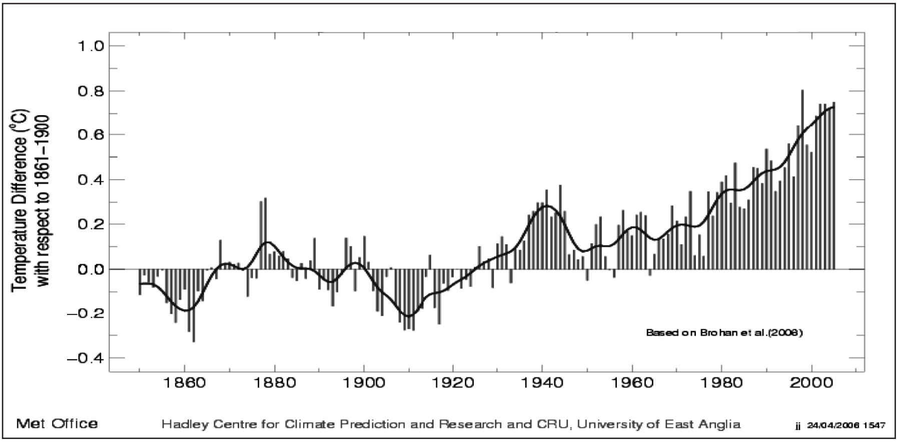
As nuclear weapons fast became the ultimate instrument of state power and various governments sought to acquire them, nuclear scientists quickly highlighted the peaceful potential of nuclear technology in providing an alternative source of energy. In 1946, the first nuclear power reactor was built at Sellafield in the United Kingdom. Since then, 30 countries have developed nuclear power programmes of their own, with 16% of global electricity production generated by nuclear reactors. The contribution nuclear power has made in providing an alternative energy source to fossil fuels has been profound. France, for instance, generates more than 70% of its electricity from nuclear power.

Since the development of nuclear power however, a plethora of fundamental concerns relating to radiation, safety and accidents, ongoing problems with storing nuclear waste, and the dangers associated with terrorism and the proliferation of nuclear weapons have plagued the industry. More than half a century after the first nuclear power station started operation, these issues are yet to be resolved.

During the 1980s and 1990s, the nuclear power industry experienced a severe downturn, with no new reactors built in the USA after the Three Mile Island accident in 1979. Since the turn of the century, however, the industry has enjoyed renewed interest, with supporters insisting that it contributes in two vital ways: by providing energy security and reducing greenhouse gas emissions. The world's main energy supplies are concentrated in small pockets around the globe, and as a result, many countries are extremely vulnerable to fluctuating energy supplies and energy price increases. Instability in regions rich in energy resources exacerbates price-hikes that can have severe repercussions on domestic economies elsewhere. In a bid to strengthen energy security by creating a viable indigenous supply, proponents of nuclear power insist it is the right option to decrease the dependence on foreign energy supply by generating energy independence.

The second and most important role nuclear power can fill, according to its supporters, relates to it allegedly representing a clean and green energy source. The realisation that burning fossil fuels is heating up our planet at an alarming rate has aroused public opinion to demand the replacement of traditional forms of energy production. Under the guise of combating climate change, the nuclear power industry has successfully relaunched a global campaign to increase its role as an energy-generating industry.[1] Global warming refers to the sustained increase in the average temperature of the earth's atmosphere; if it continues unabated, there will be dire consequences for our planet.[2] With excess heat in the atmosphere, over time a number of adverse consequences are becoming apparent, including rising sea levels and changing precipitation patterns affecting water supplies and threatening crop yields. According to the great majority of climate scientists, the impact of global warming is already plain to see, with the melting of polar icecaps and glaciers, Atlantic hurricane data and severe drought in Australia all providing powerful indicators supporting international consensus that climate change is a reality. With greenhouse gas emissions from burning fossil fuels widely recognised to be primarily responsible for global warming, most climate scientists agree that the international community needs to act now to avoid catastrophic climactic conditions.

Figure 1: Global Average Near-Surface Temperatures 1850-2005



Unfortunately, nuclear power does not promise an immediate or significant reduction in Australia's greenhouse emissions. The first reactor to begin operation in Australia is at least 15 years away. Considering the lengthy planning process, licensing, popular protest and approving reactor sites, to name but a few of the many obstacles that face new-build operations, it is more realistic to assume that the first reactor could start full-scale operations by around 2022. According to the International World Information Service on Energy, 2,000 new 1000MW (megawatts) nuclear power reactors are required to make a sizable dent in global greenhouse gas emissions.[3] Nevertheless, because uranium is a finite resource, the world supply of uranium would be exhausted relatively quickly.[4]

This report will examine if nuclear power represents a cost-effective, clean and safe form of energy generation. If nuclear power is the answer to climate change, it needs to address a number of fundamental issues. There remain legitimate concerns for public health, and its safety record needs close scrutiny. Fundamental problems with how to dispose of radioactive materials that remain hazardous for hundreds of thousands of years are still to be solved. Concerns about nuclear proliferation are also serious because ultimately the only difference between a civilian and military nuclear programme is one of intent. Moreover, the export of Australian uranium frees up indigenous supplies for the manufacture of atomic weapons. After more than 50 years of operation these issues have not gone away and remain at the centre of the debate on nuclear power.

References

1. Ian Lowe, 'If nuclear power is the answer, it must have been a pretty stupid question', in Jim Green (ed.), *Nuclear power: No solution to climate change*, Friends of the Earth, Melbourne, 2006, p. 12.
2. See Australian Commonwealth Scientific and Industrial Organisation, *Climate change in Australia: Impacts, adaptation and vulnerability*, Climate Adaptation Flagship, 2007.
3. A Makhijani, 'Nuclear power: No answer to global climate change,' *Nukewatch Pathfinder*, Autumn, 2002, p.6.
4. International Atomic Energy Agency, *Nuclear technology review*, Vienna, 2006, pp. 69-75.

Nuclear Power, Radiation and Safety

The term radiation refers to energy moving through space, in a spectrum including radiowaves, microwaves, lightwaves and ionizing radiation. Radiation can be harmful since it can affect the structure of some atoms, rendering them unstable where "electrically charged particles called ions are produced in the material it strikes."[5] Radiation can also damage humans by triggering mutations in the DNA found in the nucleus of cells. DNA molecules are the building blocks of life and DNA mutations lead to aberrant cell growth in exposed individuals.[6] Even more disturbing are the genetic effects which occur when the mutated DNA is passed on to future generations via reproductive cells, causing increased levels of cancers as well as gross deformities – as evidenced by the survivors of the atomic bombs on Nagasaki and Hiroshima, and the Chernobyl disaster.[7]

Are there safe doses of radiation?

As radiation is found naturally all around us in the sun, rocks and mountains, humans have always been exposed to it. Since the advent of nuclear technology however, people may now have increased exposure to ionizing radiation. As indicated by the World Health Organisation (WHO), "high levels of ionising radiation can have disastrous effects on health."[8]

The nuclear power industry has continually downplayed concern about the level of radiation produced by nuclear power reactors, insisting that it is at very low doses and therefore safe to the community. The 2007 Prime Minister's Uranium Mining, Processing and Nuclear Energy Review (UMPNER) report for the Australian government concludes that all industrial activities involve risks to human health and safety, and insists that nuclear power has lower risks than fossil fuel-based technology.[9] However, the lesser of two evils argument is not logically a good one for accepting nuclear power. Such logic is criticised in the submission by Doctors for the Environment Australia, who argue that "nuclear power at present provides only 16% of world energy generation, yet its existing health record is disturbing, and its predicted health implications appalling if the industry is expanded to a level necessary to provide a significant proportion of the world's energy."[10] The UMPNER report fails to acknowledge that many accidents do occur in the industry and human error will always be a possibility. Moreover, there is little mention of known health risks for those who work in the industry or recognition of increased clusters of childhood cancers around reactor sites.[11]

Despite the claims by the nuclear power industry, the more we learn about radiation, the more the safety threshold is lowered. The estimate of the acceptable level of radiation was 36 times lower in 1999 than it was in 1931.[12] Sir Richard Doll, a prominent British physiologist, writes that "whether there is a threshold below which no effect is produced is still open to doubt, but on present knowledge it seems unlikely that any such threshold exists. It must, therefore, be assumed that even very small doses produce some risk."[13] According to the National Radiological Protection Board in the United States in a statement issued in 1995, "there is no basis for the assumption that there is likely to be a dose threshold at which the risk of DNA damage would be zero."[14] Moreover, a panel from the US Academy of Sciences in a report regarding low-energy, low-dose ionizing radiation concluded "that it is unlikely that a threshold exists for the induction of cancer... furthermore, there is extensive data on radiation-induced transmissible mutations in mice and organisms. There is therefore no reason to believe that humans would be immune to this sort of harm."[15]

Despite evidence to the contrary, the nuclear power industry continues to claim emissions from nuclear power plants are safe, and that people should not be alarmed at the levels of radiation entering the atmosphere as a result of nuclear power.[16] Yet many scientists are in fact alarmed. Until the scientific community can give confident assurances regarding acceptable radiation levels, the nuclear power industry is potentially placing many thousands of people at risk of increased incidents of illness due to radiation exposure.

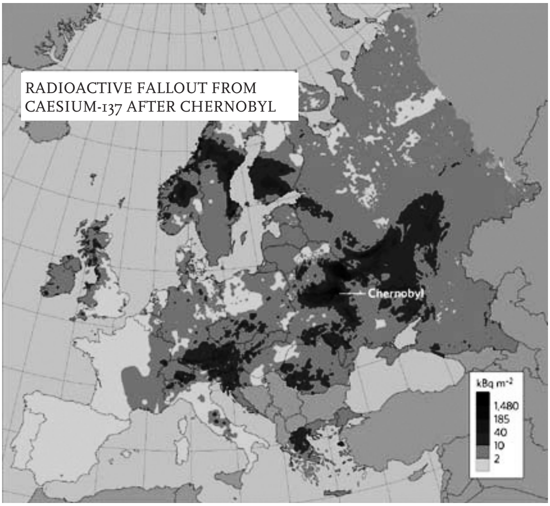
Nuclear Power Reactors and Accidents

The most commonly cited apprehension associated with nuclear power is the potential for catastrophic accidents to occur, such as the one at Chernobyl on 26 April 1986. Public alarm about the 1979 accident at the Three Mile Island (TMI) reactor is widely considered as the reason no new reactors have been built in the United States since. Nuclear advocates around the world are quick to point out that their safety record is second to none, with the industry subject to the strictest and most stringent regulations and guidelines. When compared with the safety statistics of traditional power generation sources, the number of immediate fatalities from nuclear power plants is lower than those in the coal and gas industries. Despite these impressive safety statistics however, nuclear power will never be completely safe from potential meltdown, and in the event of this occurring, the fallout will be profound for decades, perhaps even centuries to come. The risk of an accident may be slight but it is a real one and the consequences would be catastrophic.

Chernobyl

On the night of 25-26 April 1986, a reactor exploded at the Chernobyl nuclear power facility in the former USSR, signalling the biggest nuclear catastrophe witnessed since the Second World War. More than one-hundred times the amount of radiation created by the bombs dropped on Hiroshima and Nagasaki was released into the atmosphere, with shifting winds carrying radioactivity across 150,000 sq miles of Europe and beyond.[17] The International Atomic Energy Agency (IAEA) has indicated that only 32 people died as a direct result of the explosion, although these statistics trivialise the true gravity of the situation and are misleading at best. According to the President of Physicians of Chernobyl, Angelina Nyagu, "today more than seven million people are suffering due to the Chernobyl disaster. The effect of the radiation on millions of people is ethically unacceptable. There is no precedent in the history of mankind. It is thus the international community's duty to look after these people."[18]

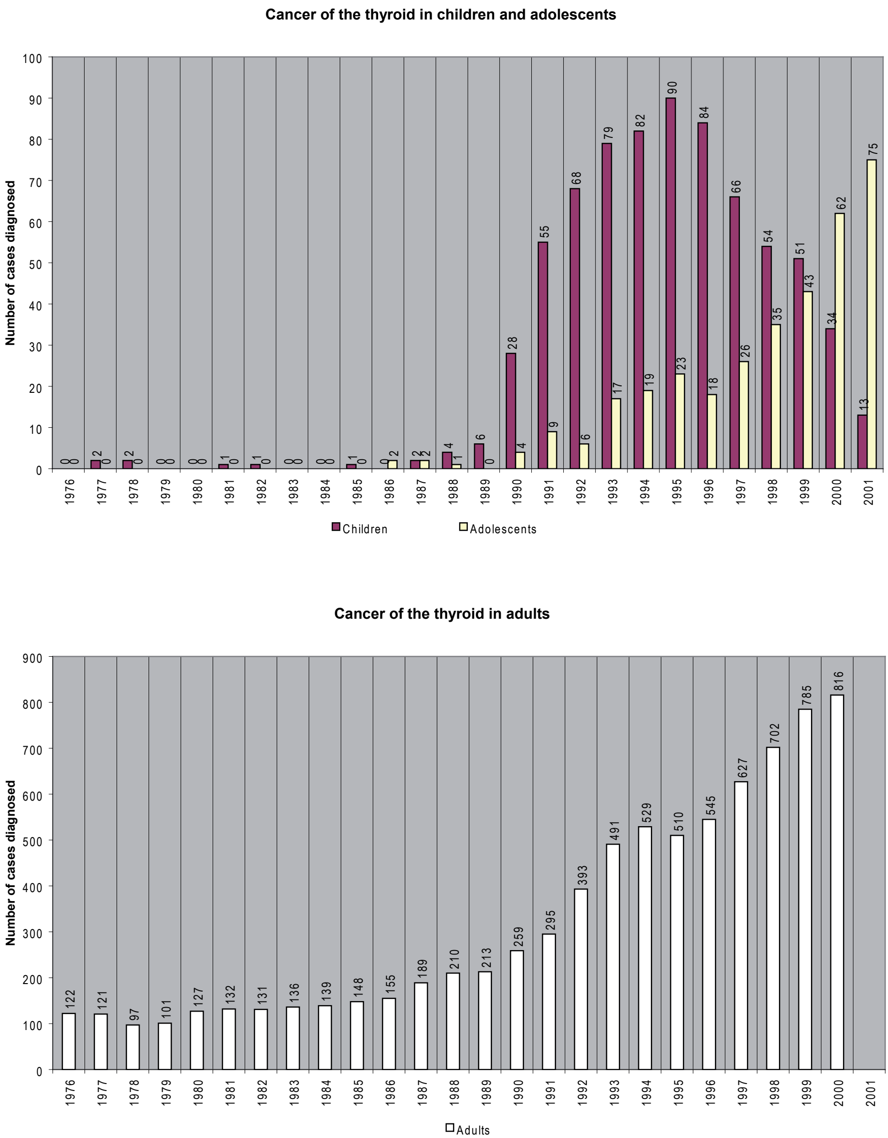
Figure 2: Diagram of the radioactive fallout after the Chernobyl disaster[19]



Nearly 600,000 people or "liquidators," which included firefighters, technicians and soldiers, were responsible for the clean-up of the site, and many were exposed to high levels of radiation. According to Dr Rosalie Bertell, who has worked at the Centre for Radiation Research outside Kiev, 13,000 of those have since died[20] and over 70,000 are permanently disabled because of radiation exposure, with few receiving adequate medical treatment.[21] Jim Green of Friends of the Earth stresses that "applying the standard risk estimate to the IAEA's estimate of human exposure to radiation from the Chernobyl disaster gives a figure of 24,000 fatal cancers."[22] Some 350,000 people had to be relocated, whilst 5.5 million people still live in contaminated areas.[23] A dramatic increase in rates of cancer of the thyroid in children, adolescents and adults is illustrated in Figure 3. To this day, wild game, mushrooms, berries and fish from as far away as Germany and Italy have levels of Caesium-137 well over a safe dose, and in Britain there are still restrictions on milk on 375 farms.[24]

Chernobyl serves as a powerful and sombre reminder to all policy-makers of the dangers of nuclear power from accidents, and perhaps now even more concerning, from terrorism or warfare.

Figure 3: Rates of cancer of the thyroid in children, adolescents and adults, 1976-2001[25]



Three Mile Island

On 28 March 1979, the Unit 2 reactor core at Three Mile Island (TMI) in the United States was destroyed when feedwater stopped flowing into the reactor, blocking its cooling mechanism.[26] Human error was to blame for the accident when a maintenance crew accidentally shut off water to the reactor and the valves in the emergency secondary system had been closed and not reopened two days earlier.[27] Although a few hours later the plant operators managed to restore the cooling-water supply, small amounts of radioactive gases were released into the atmosphere when storage tanks overflowed. Seventy percent of the reactor core was damaged in the incident.[28]

The TMI accident was attributed to a number of human errors, and although no fatalities occurred, there was a large release of the radioactive gases xenon-133 and iodine-131 into the atmosphere. The very fact that the reactor was only thirty minutes from a catastrophic meltdown, with over two million people living within a 90km radius of the plant, served to remind politicians and the public alike of the immense dangers of an accident at a nuclear power facility.[29] No matter how stringent regulations are, human error can never be completely eradicated. Despite the lack of recorded fatalities and assurances that the accident had no lasting effects on the region, twenty years after the accident a University of North Carolina study found that those living near the TMI nuclear power complex had cancer rates two-to-three times higher than the average.[30] In fact, the site is still so contaminated that not one person has set foot in the basement since March 1979.[31] No new nuclear power reactors have been built in the United States since.

Tokaimura

On 30 September 1999 radioactive gases escaped as a result of a mishap at a nuclear fuel facility in the village of Tokaimura, Japan – some 130kms northeast of Tokyo. The accident occurred when technicians mistakenly poured 16.6kgs instead of 2.4kgs of uranium into a solution of nitric acid during the conversion stage.[32] Unlike Chernobyl and TMI, the accident at Tokaimura generated a nuclear chain reaction in a nuclear fuel facility where no such thing should ever occur. The Japanese Atomic Energy Research Institute recorded radiation levels at 20,000 times more than found in the course of everyday life.[33] Two technicians died as a direct result, with 300,000 people told to stay indoors for more than a day. According to the Science and Technology Agency, four hundred people were exposed to high levels of radiation and the Agency later revoked the operating licence of the plant owner.[34]

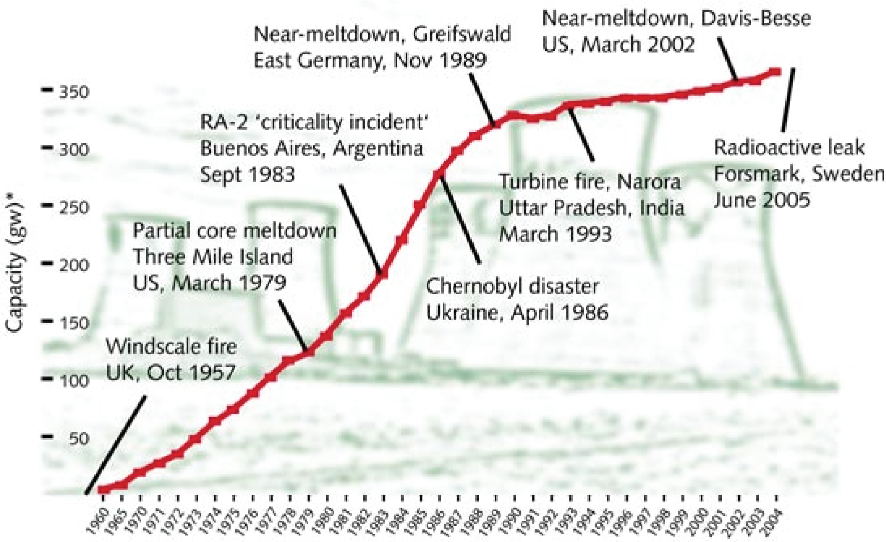
The Tokaimura accident was the third serious accident in Japan in just over four years. In 1996, a coolant leak and subsequent fire caused an emergency shutdown of the plutonium-fuelled reactor at Monju. The very next year, Tokaimura's reprocessing facility exposed thirty-five people to radiation as a result of a fire and explosion. By 2007, problems endemic within the Japanese nuclear power industry were compounded when an earthquake measuring 6.8 on the Richter scale caused radiation leaks into the ocean and atmosphere at the Kashiwazaki plant, the world's biggest nuclear power plant. The operating company, Tokyo Electric Power Co., reported

50 problems immediately following the earthquake and had to revise up the level of reported radiation leaks. Even more concerning was that according to the head of the IAEA, Mohamed ElBaradei, "it's clear that this earthquake... was stronger than what the reactor was designed for."[35] With Japan lying at the junction of four tectonic plates, it is hit by 20% of the world's most powerful earthquakes and there are grave concerns that Japan's nuclear power reactors are vulnerable to them.[36] The accidents at Tokaimura, Monju and Kashiwazaki highlight some of the serious deficiencies in the monitoring and administering of Japan's nuclear energy programme, and serve as a timely reminder that although the industry is relatively safe, it is by no means immune from nuclear accidents.[37]

Forsmark

Chernobyl, TMI and Tokaimura are three of the most publicised nuclear power accidents; however there have been many more around the globe which have received less attention from the world's media. In Sweden in 2006, its Forsmark reactor was shut down when it lost power following a power cut and its back-up generators failed to operate. Because the reactor core could not be cooled sufficiently, disaster was imminent. According to the head of the Swedish Nuclear Power Inspectorate, Bjorn Karlsson, this constituted "the worst incident in the history of Sweden's nuclear reactors."[38] By mid-2007, two of the three reactors at the Forsmark site had been shut down, with no reopening date set, and the Swedish government indicated that the nuclear power industry may indeed be phased out because of safety as well as economic and waste concerns.

Figure 4: Major nuclear accidents, 1957-2005



Summary

Proponents from the nuclear power industry insist that only three accidents in the past 50 years have resulted in immediate fatalities and the industry is learning from past mistakes by constantly updating its safety record, which according to David Mosey is nothing short of "outstanding."[39] Yet catastrophic reactor near-meltdowns, regular effluent releases and accidents outside of the reactor prove this is certainly not the case, and there remain many areas of concern for citizens living in close proximity to a nuclear power facility.[40] The dispersion of radioactive effluents in underground water from leaks remains a major problem. As stated by a World Health Organisation report, "there are no nuclear sites at which accidental spillage of contaminated water into the soil is impossible."[41] Moreover "at each stage of the nuclear fuel cycle, airborne or liquid effluents are generated, which contain radioactive materials that are released into the environment, thereby generating an exposure risk to the public."[42]

With a number of safety issues yet to be solved the nuclear power industry remains a dangerous and potentially life-threatening source of power generation. The accidents mentioned in this report are by no means exhaustive. There have been many others as indicated in the following diagram. Even if all the outstanding issues were resolved, the public is still at the mercy of human error, "because the health and life of everyone living near nuclear installations lie firmly in the hands of that curiously unreliable creature, the technician."[43]

References

5 Bill Williams, 'No safe dose', in Eve Vincent (ed.), *Yellow cake country?: Australia's Uranium Industry*, Beyond Nuclear Initiative Publication, 2006, p. 12.

6 Clive Gifford, *Essential chemistry*, London: Usborne, 1992, pp. 47-48

7 Margaret W. Thompson, Roderick R. McInnes and Huntington F. Willard, *Genetics in medicine*, London: W. B. Saunders, 1991, p. 379.

8 World Health Organisation, *Nuclear power and health: The implications for health and nuclear power production*, Regional Publications, Regional Series; no. 51, 1994, p. 15.

9 Commonwealth of Australia, 'Uranium Mining, Processing and Nuclear Energy Review', *Department of the Prime Minister and Cabinet*, January 2007.

10 David Shearman, Colin Butler, and William Castleden (eds.), *Submission to the Uranium Mining, Processing and Nuclear Energy Review*, Doctors for the Environment, Australia, Melbourne, 2006. Available at http://www.dea.org.au/node/139

11 See Brian McMahon, 'Leukemia clusters around nuclear facilities in Britain', *European Journal of Epidemiology*; 15, 9, October 1999, pp. 847-852.

12 Chris Busby, Martin Forwood and Lucinda Labes, 'Poisoning in the name of progress', *The Ecologist*; 29, 7, November, 1999, p. 398.

13 Quoted in Wade Allison, *The safety of nuclear radiation: A careful re-examination for a world facing climate change*, Department of Physics and Keble College, Oxford, 2007, p. 1. Available at http://www.physics.ox.ac.uk/nuclearsafety/ARTICLE.pdf

14 Busby *et al*, 'Poisoning in the name of progress', p. 399.

15 Cindy Folkers, 'US radiation panel: No radiation dose safe', *WISE/NIRS Nuclear Monitor*; 632, 15 July, 2005, pp.1-3.

16 World Nuclear Association, *Radiation and life*, July 2002, available at http://www.world-nuclear.org/education/ral.htm

17 Judith Condon, *Chernobyl and other nuclear accidents*, Hore, UK: Wayland, 1998, p. 3.

18 Angelina Nyagu, 'Statements', *Chernobyl.info*. Available at http://www.chernobyl.info/index.php?userhash=28314366&navID=191&ID=2&statementID=52

19 J. Smith and N.A. Beresford, *Chernobyl: Catastrophe and Consequences*, Praxis: Chichester, 2005. Image available online at http://www.answers.com/topic/radioactive-fallout-caesium137-after-chernobyl-jpg

20 Almost 20 per cent of those deaths were suicide.

21 Rosalie Bertell, Sarah Bell and David Edwards, 'Victims of the nuclear age', *The Ecologist*; 29. 7, November 1999, p. 408.

22 Jim Green, *Nuclear Power: No solution to climate change*, Friends of the Earth, 2006, p. 4.

23 Piers Paul Read, *Ablaze: The story of Chernobyl*, London: Seeker & Warbury, 1993, p. 14.

24 John Vidal, 'Hell on Earth', *The Guardian*, 26 April 2006. Available at http://society.guardian.co.uk/societyguardian/story/0,,1760930,00.html
25 'Overview of health consequences', *Chernobyl.info*, Image available at http://www.chernobyl.info/index.php?userhash=27340097&navID=21&lID=2.
26 David Mosey, *Reactor accidents: Nuclear safety and the role of institutional failure*, London: Nuclear Engineering International Special Publications, 1990, p. 69.
27 John Jagger, *The nuclear lion: What every citizen should know about nuclear power and nuclear war*, New York: Plenum Press, 1991, pp.113-114.
28 W. Booth, 'Postmortem on Three Mile Island', *Science*; 238, 1987, pp. 1342-1345.
29 Daniel F. Ford, *Three Mile Island: Thirty minutes to meltdown*, New York: Penguin, 1982, pp. 1-6.
30 Steven Wing, 'New study shows new cancer rate near Three Mile Island Nuclear Reactor Meltdown, *Environmental Helath Perspectives*, 24 February 1997.
31 Sharon Guynup, 'Safe or deadly?', *Science World*; 56, 9, February, 2000, p.14.
32 *ibid.*, p. 14.
33 *ibid.*, p. 13.
34 Edwin Lyman and Steven Dolley, 'Accident prone', *Bulletin of the Atomic Scientists*; 56, 2, March/April 2000, p. 45.
35 George Nishiyama, 'Japan quake shows nuclear findings', *The Age*, 17 July 2007.
36 'Fears of new leak at nuke plant', *The Australian*, July 18, 2007, p. 11.
37 Donald Macintyre, 'Unclear fallout', *Time Magazine*; 154, 15, October 18, 1999. [electronic version: http://www.web.archive.org/web/20000118171525].
38 'Nuclear meltdown narrowly averted', *The Ecologist*; 36, 9, November 2006, p. 9.
39 David Mosey, *Reactor accidents: Nuclear safety and the role of institutional failure*, p. 3.
40 Stephen Ansolabehere, *et al*, *The future of nuclear power: An interdisciplinary MIT Study*, 2003, pp. 47-52.
41 'Nuclear power and health: The implications for health of nuclear power production', *World Health Organisation*, p. 15.
42 *ibid.*, p.47
43 Zac Goldsmith, 'Nuclear havoc', *The Ecologist*; 29, 8, December 1999, p. 434.

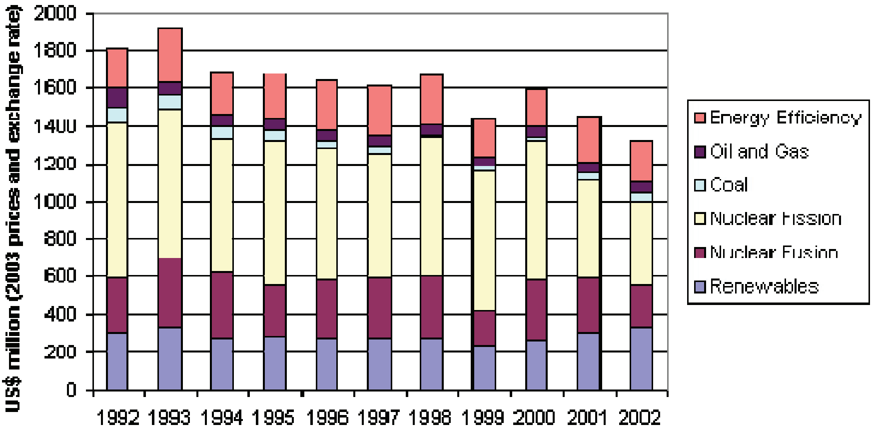
The Economics of Nuclear Power

Nuclear power has long been considered an expensive enterprise requiring favourable governmental policies and large subsidies to ensure its survival. In the past five years however, the nuclear power industry has seen a number of reports published indicating that it will become competitive with traditional fossil fuel electricity generators and much cheaper than renewable sources of energy in the near future. Proponents insist that with the likely adoption of carbon taxation or carbon-trading schemes to address climate change, nuclear power in some instances will even become the cheapest base-load electricity source available. Ian Hore-Lacy of the Uranium Information Centre, asserts that "nuclear ends up about half the real cost of gas."[44] He reaches such figures when high fossil fuel costs and a generous carbon-trading scheme are added, with nuclear power paying a low 5% interest rate on loans to build and run the facility. The World Nuclear Association stresses that except in locations where direct access to fossil fuel exists, "nuclear power is cost effective with other forms of electricity production."[45] Furthermore, according to a European study ExternE, when external costs of various fuel cycles are taken into account, nuclear power is claimed to incur a mere tenth of the costs of coal-fired electricity generation.[46]

Yet despite concerted efforts by the nuclear power industry to downplay its reputation as an extremely expensive source of energy production, the market itself is providing the most useful indication of its true financial costs. In 2006, the financial analyst Standard & Poor's issued a report stating that even the new incentives for the US nuclear industry would not be enough to entice new investors because of the extremely high capital, operating and decommissioning risks associated with nuclear power.[47] Amory Lovins, the CEO of the Rocky Mountain Institute, a Colorado-based energy analysis firm, says that the effects of even such huge subsidies will be the "same as defibrillating a corpse... it will jump, but it will not revive."[48]

The economics of nuclear power are varied and complex, rendering public perceptions confused and often misinformed as to the true costs of nuclear power. Experiences around the globe serve as precursors as to what might be expected in Australia should the government decide to develop an indigenous nuclear power supply. Government subsidies are usually provided to help new industries develop economies of scale. Despite nuclear power being in operation for more than half a century, governments continue to use taxpayers' money to help keep the nuclear power industry afloat. As the graph below illustrates, in Europe, although nuclear power is a mature actor within the energy sector, it continues to drain vast amounts of direct research and development resources and therefore has an unfair comparative advantage over other energy types, especially over less-developed renewable energy sources.[49] In an economic environment that religiously preaches the principles of free market economics, it seems inexplicable that this industry is continually being spoon-fed.

Figure 5: IEA-Europe States' Energy Research and Development Budgets 1992-2002[50]



The United States Energy Policy Act of 2005 included a number of nuclear specific provisions, that indicate nuclear power is far from being commercially viable on the open market. Nuclear specific provisions include tax production credits up to $7.3 billion, an increase in the Price-Anderson Nuclear Industries Indemnity Act through 2025 (which stipulates that the government will be responsible for any insurance claims over $10 billion), and the authorisation of cost-overrun support up to $2.6 billion for up to six new reactors. Overall, the nuclear industry is projected to gain $13 billion in subsidies and tax breaks.[51] Such huge subsidies have generated much criticism across the United States.[52] These subsidies are designed to attract a private sector that traditionally views the industry as extremely risky, especially given its poor track record when coming in at projected cost.

The decommissioning of the Yankee Rowe reactor in Massachusetts, USA began after it was shut down in 1992. Expected to cost $120 million, the site is not expected to be fully decommissioned until the end of 2007, with the final price now expected to top $450 million. The total cost of decommissioning all the 144 commercial, military and research reactors in the USA is now estimated at $33 billion.[53] The nuclear power facility at Watts Bar, Tennessee, is the USA's most recent reactor, and started operations in 1996; but it took 23 years to complete at a cost of $6.9 billion. A second reactor at the site started construction in 1973 but may never be completed. In New York, a nuclear power plant was built at Shoreham, but it had to be decommissioned in 1994 – 21 years after construction. It was never operational due to local opposition. The total costs rose from an original $70 million to $6 billion without a single watt of electricity produced.[54]

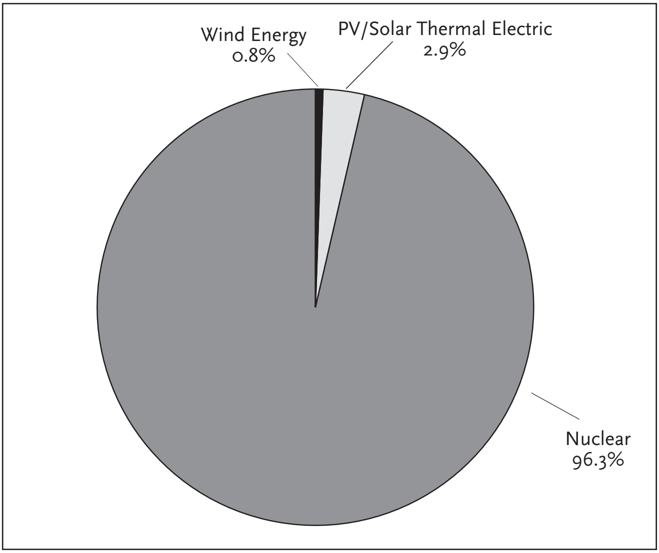
The Australian government's recent UMPNER report provides favourable economic forecasts for nuclear power, but it also recognises that "nuclear power is likely to be between 20-50% more costly to produce than power from a coal-fired plant."[55] With the implementation of carbon-trading schemes or carbon taxation, the report concedes that "even then, private investment in the first-built nuclear reactors may require some form of government support."[56] Following the release of the draft report, Australian Treasurer, Peter Costello, stated that it confirmed nuclear power was not feasible, as "the economics of nuclear power don't stand up."[57] Even he could not find an economic argument to support nuclear power, and in fact rejects it precisely on that premise.

There are a number of reasons why the economic side of nuclear power is so confusing to the public, and this helps the industry to hide the true costs. The fact is that until a modern reactor is actually built we will never know how much it will really cost. Of all the new reactor designs currently being considered in the West, only one plant (the European Pressurised Reactor at Olkiltuo, Finland) is currently under construction. However it is two years behind schedule and greatly over budget.[58] In the USA, no new type of reactor has been built since the Three Mile Island disaster in 1979; and in the UK, the last reactor built was the Sizewell B reactor in 1995. Therefore, the different costings to build and operate a nuclear power plant are pure speculation with respect to engineering costs, licensing, construction costs, raw material prices and interest and inflation rates. What's more, final waste disposal and decommissioning costs are even harder to predict.

When it comes to large construction projects of any kind, many exceed their cost estimates, and with the complex nature and extreme regulatory framework the nuclear power industry faces, it would be extremely optimistic to assume it will baulk the trend. According to a report in The New Scientist, "the energy from new reactors will cost almost three times industry predictions," and industry projections are gross underestimates with a very low chance of being realised.[59] The UMPNER report insists that Australia could establish a nuclear power industry within ten years. However, considering delays are almost guaranteed because of controversies over planning permissions, international authorisation and popular protests, this estimate is wildly optimistic. Long delays are not envisaged in nuclear power estimates; however, they are highly likely and can push the cost of projects above estimates by a substantial margin. The Dungeness B reactor in the UK is a prime example, completed some 18 years behind schedule and 400% above projected costs.[60]

Nuclear power advocates insist that since the renewable industry needs government subsidies, it is hypocritical to attack nuclear power for precisely the same reason. Examination of energy subsidies in the USA shows that the nuclear power industry has had far more help to mature from the federal government than has the renewable sector. Subsidies within the electricity generation sector are designed to help bring a technology to maturity, and after more than 50 years of operation, nuclear power is still not financially viable without substantial support. A 2000 report commissioned by the Renewable Energy Policy Project in the USA provides an historical account of federal government subsidies for nuclear, wind and solar technologies. The report concludes that between 1943 and 1999 the US federal government provided $151 billion worth of subsidies to electricity generation (excluding large-scale hydro). The nuclear power industry received $145.4 billion, or 96% of those subsidies (see Fig. X below). The differences are even more evident when an analysis of subsidies during the first 15 years of federal support for electricity generation technology is taken into account. Nuclear power between 1947 and 1961 received subsidies of $15.30 per kilowatt-hour (kWh), solar received $7.19/kWh and wind only 46 cents/kWh between 1975-1989.[61]

Figure 6: US Subsidies to Energy Sectors[62]



If nuclear power were as economically viable as the industry likes to assert, then it would be able to compete under market conditions without government support. The myriad overt and covert subsidies needed to keep the industry afloat prove that nuclear power is not competitive on the open market. Cost over-runs are commonplace with long delays plaguing the industry since its birth in the 1950s. Despite the nuclear power industry assuring the public that modern reactor designs are much cheaper than previous models, only one of these designs is currently under construction. The economics of nuclear power are complex and open to a number of interpretations. When it comes to assessing the economic viability of an industry, the market is the best mechanism to determine the answer, and the private sector has voted with its feet, showing its reluctance to invest in nuclear power unless the government provides the necessary incentives.

References

44 Ian Hore-Lacy, 'Nuclear energy: the world picture', *Issues*; 77, 2006.

45 44 World Nuclear Association, "The economics of nuclear power," London, 2007, http://www.world-nuclear.org/info/info02.html [accessed 8 February 2007].

46 European Commission: Directorate General XII Science, Research and Development, *External costs for electricity production in the EU (in Eur-Cent Per Kwh*, 1995. Available from http://www.externe.info/.

47 'Credit risk still high for nuclear plants: S&P report', *Nuclear Engineering International*, 11 January 2006. Available at http://www.neimagazine.com/story.asp?storyCode=2033547.

48 Michael Brooks, 'Is it all over for nuclear power?,' *New Scientist*; 190, 2548, 2006.

49 Philip Ward, 'Unfair aid: The subsidies keeping the nuclear industry afloat', *Nuclear Monitor*, 630 & 631, NIRS/WISE, Amsterdam, 24 June 2006, p. 8.

50 International Energy Agency 2004. European States are Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK

51 Helen Caldicott, *Nuclear power is not the answer to global warming or anything else*, p. 35.

52 Michael Grunwald and Juliet Eilperin, "Energy bill raises fears about pollution, fraud: Critics point to perks for industry," *Washington Post*, 2005.

53 Phillip Ward, *Nuclear power: No solution to climate change*.

54 'Nuclear energy coming back into vogue, despite problems', *The Economist*, 14 September 2007, Review p. 4.

55 Department of the Prime Minister and Cabinet, *Uranium Mining, Processing and Nuclear Energy: Opportunities for Australia*, Commonwealth of Australia, 2007.

56 *ibid.*

57 Katherine Murphy, 'Economics of nuclear power don't stack up: Costello,' *The Age*, 26 November 2006.

58 'Nuclear energy: The economics of atomic power,' *Australian Financial Review*, 14 September 2007, pp. 4-5.

59 'New UK reactor plants could prove costly,' *New Scientist*, 25 July 2005.

60 Andrew Simms, Petra Kjell, and David Woodward, *Mirage and oasis: Energy choices in an age of global warming*, New Economics Foundation, 2005.

61 Marshall Goldberg, *Federal energy subsidies: Not all technologies are created equal*, Report 11, Washington: Renewable Energy Policy Project, July 2000, pp. 3-7.

62 *ibid.*

Nuclear Power and International Security

Australia by mid-2006 was exporting 8000 tonnes of uranium to ten different countries around the world to be used as fuel in civilian reactors for the production of electricity.[63] Some Australian policy-makers seem to draw the conclusion that with the world's largest accessible uranium reserves, Australia could become the Saudi Arabia of uranium.[64] What the government fails to mention is that if Australia does become the Saudi Arabia of uranium, it would also become the principal supplier of the fuel needed to produce nuclear weapons. Although the Australian government insists that bilateral safeguards agreements ensure the peaceful uses of Australian uranium in nuclear power plants – an issue beyond the scope of this report - the fact remains that by exporting uranium for use in nuclear power programmes, you free up indigenous uranium supplies that could be diverted to atomic weapons manufacture. Moreover, according to Professor Ian Lowe of the Australian Conservation Foundation, "despite the hype, uranium accounts for about 1% of our mineral exports, ranking with such metals as tin and tantalum. The most optimistic forecast of the potential annual revenue from uranium sales to China by 2020 is about a third of our current income from exporting cheese."[65]

Nuclear Power and Nuclear Weapons Proliferation

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT), which came into effect in 1970, was designed to stop the increasing possibility of a nuclear arms race around the globe. The then existing nuclear weapons states – USA, Russia, UK, France and China – made a commitment to reduce their nuclear arsenals, in exchange for providing nuclear information and technology to those wanting to harness "peaceful" uses of nuclear technology – namely nuclear power. The IAEA is the agency responsible for overseeing the NPT's mandate and implementation of safeguards that ensure the treaty is adhered to, but it does not have any enforcement capabilities.[66] The agency is also charged with ensuring that nuclear weapons are not being covertly developed. Recognising the need to stop nuclear proliferation, the UN decided that no state outside the five declared nuclear weapons states was allowed legally to pursue a nuclear weapons programme. However under Article IV of the NPT, the UN also recognised the "inalienable right to the development, research, production and use of nuclear energy for peaceful purposes."[67]

In many respects, the NPT has helped to curb the number of states acquiring nuclear weapons, and the bombs the USA dropped on Nagasaki and Hiroshima in 1945 remain the only nuclear weapons used against a civilian population. The nuclear club has risen to ten however, with Israel, South Africa[68], India, Pakistan and North Korea all developing nuclear capabilities. There is also international concern that Iran is developing a nuclear weapons capability.

The problem with the NPT is that the only difference between a civilian and a military nuclear programme is one of intent.[69] Under the NPT, it is perfectly legal to develop techniques that separate plutonium from spent reactor fuel rods as well as the centrifuge enrichment of uranium, which can easily produce plutonium for nuclear weapons. As George Perkovich and Henry Sokolski illustrate, "a state could be fully compliant with the NPT so long as it declared all of its nuclear activities and avoided taking the final step," which could take as little as weeks to make a bomb.[70] Furthermore, NPT members can withdraw from the treaty when they wish, meaning that one could be part of the regime, and legally acquire all the relevant knowledge and technology to build a nuclear device, then withdraw from the treaty to make a bomb. North Korea reneged on the treaty in 2003; by 2006 they had declared they had become the world's eleventh nuclear power.

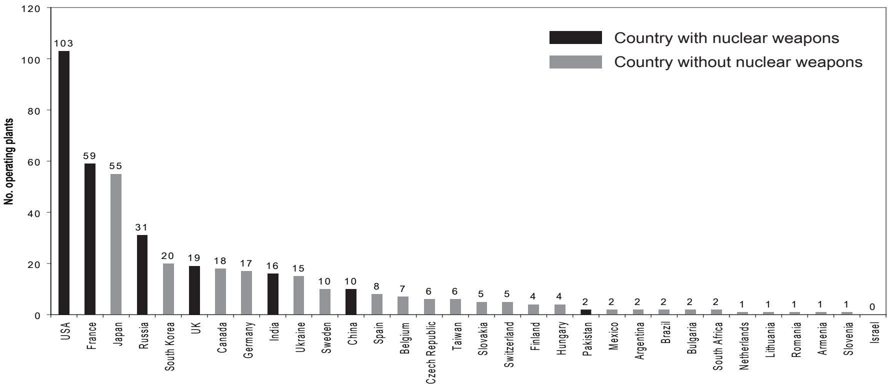
Iran is another nation many believe to be attempting to build an atomic bomb since it repeatedly hinders IAEA inspections. The governing body is powerless to ascertain how advanced the Iranian nuclear programme actually is, exacerbating its "toothless tiger" image. Iran has a uranium enrichment facility that could easily produce weapons-grade nuclear material. Under the NPT however, it is perfectly legal to build uranium enrichment facilities. Javad Zarif, Iran's permanent representative to the UN, issued the following statement which sums up dangerous inefficiencies of the NPT regime: "Iran has inalienable rights under the NPT and respect for these rights… is imperative for the authority and integrity of the treaty."[71] Both Lawrence Scheinman and William Porter highlight the danger posed by Iran which is "ominously using their NPT status to openly and legally acquire fuel cycle capabilities that could put them in a position to transition to nuclear weapon status, if they invoked the withdrawal clause of the NPT."[72] Then there are those which are not members of the NPT, with Israel, India and Pakistan building clandestine nuclear weapons programmes under the façade of research and power programmes.

The IAEA's effectiveness has been questioned by many analysts who cite their deficiencies in dealing with proliferation, because its mandate depends on the powers granted by the United Nations. Issues of enforcement and punishment for those who cheat the system are dependent on the international community, and therefore subject to the will of the international community at the time.[73] The IAEA's contradictory role in promoting nuclear energy while at the same time ensuring that nuclear weapons do not proliferate is clearly not working.[74] By aiding the spread of nuclear power, while at the same time preventing the spread of nuclear weapons, the IAEA is adopting a dangerous, complicated and contradictory approach.[75]

Samuel Bodman, the US Energy Secretary in a speech to the Nuclear Threat Initiative in Washington 2005, stated that the "information to make the most rudimentary nuclear weapon is widely available [with the] atomic genie out of the bottle."[76] Clearly the nuclear energy programme is increasing the likelihood of nuclear proliferation. Therefore for Australia to expand its uranium exports and develop a nuclear energy industry domestically would be fraught with danger. As a result of civil programmes around the world, the legacy of uranium enrichment and plutonium reprocessing is posing grave security concerns, with stockpiles of 1900 tonnes of highly enriched uranium in the possession of 46 nations and 1855 tonnes of plutonium stockpiled around the globe.[77]

The following graph shows a number of observations: four out of the six countries with the most nuclear power plants also have nuclear weapons; 55 per cent of all nuclear power plants are located in countries known to possess nuclear weapons; and the six countries with the most nuclear power plants own 97 per cent of nuclear weapons worldwide. Therefore it appears quite doubtful that using nuclear power for civil purposes is completely independent of military applications. The graph seems rather to indicate "the more nuclear power plants, the more likely nuclear weapons."[78]

Figure 7: Nuclear energy and nuclear proliferation



According to the IAEA, only 8kgs of plutonium are required to make a nuclear bomb; however a bomb the size of the one dropped on Hiroshima would only require 2-4kgs with a sophisticated bomb design.[79] For a nation or terrorist organisation in possession of highly enriched uranium, only 25kgs would be necessary to make a nuclear bomb that could completely destroy entire cities.[80] With such large stockpiles of nuclear weapons materials around the world, any increase in the number of reactors would see the exponential growth of proliferation risks also. Nuclear power is a profound international security risk, and therefore not worth pursuing if the world is to remain relatively safe from the possibility of nuclear warfare.

Terrorism

Since the turn of the century, international terrorist organisations have demonstrated their ability and desire to inflict catastrophic damage on both civilian populations and domestic infrastructures. Not surprisingly nuclear facilities have now become prime potential targets for terrorist attacks. Nuclear power facilities pose "attractive" targets for terrorists because of the importance of electricity supply to societies and because of the large radioactive inventories existing in many facilities.[81] Although the considerable strength of containment buildings and structures presents a major obstacle and hardened target, it is important to note that any evaluation of the safety of a nuclear reactor to a terrorist attack is speculation, because no previous experience of such an attack exists. Moreover, although the reactor itself may be able withstand an attack from a plane or missile, at many nuclear power facilities highly radioactive materials are stored outside of the protective shielding provided by the reactor. A further concern relates to the transportation of radioactive materials because when in transit their vulnerability to attack or theft increases markedly.

In 2004, a report commissioned by the Union of Concerned Scientists concluded that a major terrorist attack at the Indian Point nuclear power facility, situated 35 miles from New York City, would result in approximately 44,000 near-term deaths and up to 500,000 long-term deaths from cancer among those residing within 50 miles of the plant. Within 100 miles of the plant, the economic damages are estimated at up to $2.1 trillion. Millions of people would also require permanent relocation.[82] Not surprisingly, public protest against the Indian Point plant has intensified and is proving to be a real headache for policy makers in New York.

Terrorist attacks on nuclear power facilities are not the only safety concern. Since 1993, the IAEA's Illicit Trafficking Database recorded over 650 confirmed incidents of the trafficking in nuclear or radioactive materials since 1993.[83] The smuggling of nuclear and radioactive materials is of profound international concern because fissile material can be used to make nuclear weapons or "dirty bombs", with disastrous consequences.[84] In addition, crime syndicates are being investigated after allegations they are involved with the theft and sale of nuclear materials, and accused of dumping nuclear waste in developing countries or at sea, or burying it in Europe. Consider the implications of having hundreds of nuclear reactors across Asia, Africa and Latin America, in areas prone to conflict and war, or in earthquake zones. For instance, protests have been growing in Indonesia about plans to build four nuclear power plants at the foot of Mount Muria in Java, an area prone to earthquakes and volcanos. A nuclear disaster there could send dangerous contamination across South-East Asia and northern Australia. Moreover, it opens the way for a future regime to develop nuclear weapons.[85]

As nuclear power has faced safety concerns since its development, the immense danger posed by any release of radioactive effluents has forced many policy makers around the world to reassess security and safety provisions at nuclear power facilities in light of a terrorist attack. Since the attacks on the World Trade Centre on 11 September 2001, the international security landscape has changed markedly and nuclear power facilities now undoubtedly offer serious potential targets for terrorist organisations.

Missing Plutonium

Of further embarrassment to the IAEA and of profound concern to the international community is the issue of "missing" plutonium and uranium, with Japan and the UK alone admitting to having "lost" highly radioactive material which could easily be manufactured into weapons. In 2004, the UK publicly admitted to losing 30kgs of plutonium at its Sellafield reactor, with 19kgs missing in 2003. Japan has also admitted to being unable to account for 206kgs of reprocessed plutonium from its pilot plutonium reprocessing plant at Takaimura – enough to make up to 40 bombs.[86] At another plant, Japan reported to the IAEA that it was missing 70kgs of plutonium in 2005.[87] While the IAEA seems impotent in stopping "peaceful" uses of nuclear energy from being turned to military uses, it is also at a loss to account for every kilogram of highly enriched uranium or reprocessed plutonium. When we are dealing with such a dangerous material, it is an absolute imperative that every gram of it is accounted for. Therefore, any plans to develop nuclear power in Australia or to export more uranium would expose the international community to potentially devastating and unpredictable risks.

Summary

Nuclear power heightens serious concerns about the proliferation of nuclear weapons. In catering for the peaceful uses of atomic technology, while attempting to ensure proliferation does not occur, the International Atomic Energy Agency is fulfilling a contradictory role that diminishes international security. Under the United Nations Nuclear Non-Proliferation Treaty, it is perfectly legal for a state to acquire all the information and expertise necessary to come to within weeks of developing an atomic bomb.[88] Dominique Voyet, former French environment minister, echoes such sentiments, stating that "France must end its sales policy of nuclear materials and technology to whomever is willing to pay. This trade jeopardises world peace."[89] Moreover, with the information and technology of nuclear energy now readily available, there is also an increased possibility of terrorist or criminal organisations acquiring enough nuclear fuel to build their own radiological weapons. Australia has a choice to make; continue to export uranium, to suspend exports, or to limit its exports within the most stringent safeguards.

References

63 Jason Koutsoukis, 'Has anyone seen Australia's uranium?', *Australian Financial Review*, 9 November 2002, p.21.
64 John Howard, 'Let's not bury our heads in the sand on nuclear energy', *The Australian*, 18 July 2006.
65 Ian Lowe, 'Reaction time: Climate change and the nuclear option', *Quarterly Essay*; 27, 2007, p. 82.
66 See Marko Belijac *et al*, *An illusion of protection: The unavoidable limitations of safeguards on nuclear materials and the export of uranium to China*, Medical Association for the Prevention of War and The Australian Conservation Foundation, October 2006.
67 Quoted in James Traub, 'Why not build a bomb?', *New York Times Magazine*, 29 January 2006, p. 15. The NPT Treaty is available at http://www.un.org/events/npt2005/npttreaty.html.
68 South Africa was developing nuclear weapons from 1969. They officially abandoned this programme in 1991 when they signed the NPT.
69 'The long half life of nuclear disarmament', *The Economist*, London, 10 June 2006, p.24.
70 Henry Sokolski and George Perkovich, 'It's called nonproliferation', *Wall Street Journal (Eastern Edition)*, New York, 29 April 2005, p.16.
71 Malcolm Beith, 'The last word: Finding the missing link', *Newsweek (International Edition)*, New York, 24 April 2006.
72 Lawrence Scheinman and William Porter, 'The nuclear conundrum: Reconciling nuclear energy and nonproliferation, *Harvard International Review*; 26, 4, Winter 2005, p. 25.
73 'An award for the struggling nuclear detectives', *The Economist*, October 7, 2005, London, p.1.
74 Haider Rizui, 'Politics: Critics say UN can't push peace and nuclear power, Too', *Global Information Network*, New York, 20 April 2006, p.1.
75 Rob Edwards and David Lowry, 'Poacher or gamekeeper', *The Ecologist*; 29, 7, 29 November 1999, p.424.
76 Samuel Bodman, 'The nuclear threat: Preventing the proliferation of weapons of mass destruction', *Vital Speeches of the Day*, May 1, 2005, 71, p. 14.
77 Rob Edwards, '60 Years on is the world any safer?', *New Scientist*, 16-22 July 2005, London, p.8.
78 Carnegie Endowment for International Peace, *Nonproliferation: Nuclear numbers*, http://www.carnegieendowment.org/npp/numbers/default.cfm, 7 February 2007.
79 Henry Sokolski, 'After Iran: Back to basics on "peaceful" nuclear energy,' *Arms Control Today*; 35, 3, 1 April 2005.
80 'The long half life – Nuclear disarmament', *The Economist*, p.24.
81 Jim Green, *Nuclear Power: No solution to climate change*, p. 3.
82 Edwin S. Lyman, *Chernobyl on the Hudson?: The health and economic impacts of a terrorist Attack at the Indian Point nuclear plant*, Union of Concerned Scientists, September, 2004, www.ucsusa.org/global_security/nuclear_terrorism/impacts-of-a-terrorist-attack-at-indian-point-nuclear-power-plant.html.
83 International Atomic Energy Agency, *Illicit nuclear trafficking statistics: January 1993 – December 2003*, www.iaea.org/NewsCenter/Features/RadSources/Fact_Figures.html
84 Jim Green, *Nuclear power: No solution to climate change*, p.3.
85 Tom Hyland, 'Nuclear reactor plan on shaky ground', *The Age*, 14 October 2007, http://www.theage.com.au/news/climate-watch/nuclear-reactor-plan-on-shaky-ground/2007/10/13/1191696239293.html
86 *ibid*.
87 Henry Sokolski, 'After Iran: Back to basics on "peaceful" nuclear energy, p.21.
88 See Alison Broinowski, 'Nuclear politics: Taking the a train,' *New Matilda*, 1 October 2007.
89 Dominique Voyet, quoted in Haider Rizui, 'Politics: Critics say the UN can't push peace and nuclear power, too', *Global Information Network*, New York, April 12, 2006, p.1.

The Legacy of Nuclear Waste

One of the most contentious issues pertaining to nuclear power concerns the final disposal of high-level radioactive waste (HLW). After more than half a century of nuclear reactors operating around the globe, the problem of the permanent long-term storage of radioactive waste has still to be solved.

Storage of Nuclear Waste

Supporters of nuclear power insist that only very small quantities of HLW, less than 5% of total waste material, is actually created in the fuel cycle.[90] HLW from nuclear power plants includes the waste stream from reprocessing and surplus plutonium.[91] Various "solutions" to deal effectively with these waste materials have been posed, including positing it in deep-sea beds or blasting it into space. The most popular solution is to bury it in geological repositories, where giant storage facilities are built deep underground in stable rock formations and then sealed with concrete when they reach full capacity. This preferred method of HLW disposal has met with an array of social, political, scientific, administrative and economic problems, with no country, except possibly Finland, having a fully operational facility ready before 2017. With many nations seriously contemplating increasing or starting up new nuclear power programmes, it is imperative that the problem of storing the toxic waste it produces be resolved first. Unfortunately, this has not been done.

A major problem associated with the long-term storage of HLW is the staggering time-frames required for it to cease being hazardous. According to the World Information Service on Energy (WISE), although most radioactive waste decays over a short period, some of the most dangerous by-products can remain hazardous for thousands of years. The half-life of radioactive material is the time it takes its radioactivity to decrease by 50 per cent. Generally, ten-to-twenty half-lives are considered to be the hazardous lifespan of a radioactive substance. For example, while Plutonium-239 has a half-life of 24,000 years, it will actually remain hazardous for up to a quarter of a million years, or 12,000 generations. Even more troubling is that Uranium-235, which is generated during Plutonium-239's half-life, has a staggering half-life of 703,800 years.[92] Irradiated fuel rods, the most radioactive material on the planet, will continue to be hazardous for thousands of generations. Is this the legacy we want to leave for subsequent generations to deal with? Although HLW constitutes less than 5% of radioactive material produced by nuclear power reactors, only very small quantities are required to pose grave health risks.

Yucca Mountain, USA

There are 250,000 tonnes of HLW around the world left over from more than 50 years of military and civilian nuclear programmes. In the United States, some 54,000 metric tons of radioactive waste from 103 nuclear power reactors are currently stored in temporary facilities, awaiting transfer to a permanent home. In 1982, Congress passed the Nuclear Waste Policy Act, which stipulated that the Department of Energy had to find a permanent facility by 1998. In 1987, a repository at Yucca Mountain in the Nevada desert was the chosen site.[93] By the 1990s, audits found a number of problems with the site including the accuracy of simulating future geological events, especially given the immense time-frames required. Some 24 years and $9 billion later, only two tunnels have been built along with a temporary research facility. Facing strong opposition at state level, Yucca Mountain will not be fully operational until at least 2017, and many insist this new date for completion is grossly optimistic. Of further concern, millions of people will become exposed to the dangers of accidents as the radioactive waste is transported to the disposal site. Even more disturbing is that according to the President of the Nuclear Age Peace Foundation, David Krieger, "Yucca Mountain is directly above an active magma pocket and is the third most seismically active area in the United States... The most recent earthquake on July 14, 2002 had a magnitude of 4.4 on the Richter scale."[94]

United Kingdom

In the United Kingdom, some 80,000 cubic metres of radioactive waste are currently stored in temporary sites around the country. With the impending decommissioning of existing reactors, this amount will increase to 478,000 cubic metres needing to be stored safely by 2020.[95] A plethora of political and social obstacles has marred government attempts at building a deep geological facility at the Sellafield reactor in Yorkshire. Furthermore, the long-term waste management of HLW is exorbitantly expensive. According to Sussex Energy Corporation the costs of managing HLW in the last 50 years have risen above the original estimates of £65 billion to well over £90 billion, and are predicted to increase further when reactors are decommissioned.[96] A deep geological depository is expected to cost around £10 billion initially, but it is impossible to ascertain with any real conviction what the costs will be over the next hundred thousand or so years.[97] Furthermore, according to the Committee of Radioactive Waste Material in the UK, such a facility would take at least 20-30 years to build after finding a suitable site and generating public support.[98]

Japan

Japan is another country suffering from the problem of how to deal with its HLW. Its "closed" nuclear fuel cycle disposes of some 1000 tonnes of material annually, and Tokyo has expressed its desire to transform its waste into plutonium for reprocessing in its fast-breeder reactors. Following an accident at its Monju reactor in 1996, these plans have been shelved, and Japan has indicated that it will now have a fast-breeder programme operating by 2050, some 70 years behind schedule! In the meantime, Japan is shipping its HLW to a reprocessing plant at Rokkasho in northern Japan in one of the most expensive exercises of HLW management in the world.[99] Rokkasho has also caused international concern because it is the first large-scale industrial reprocessing plant in a country that does not have nuclear weapons, meaning it now has a very real potential for future weapons production. The Rokkasho plant is able to process eight metric tons of plutonium annually, enough to manufacture 1,000 bombs.[100]

Summary

The process of finding a suitable, geologically sound site for the storage of HLW is one that faces a multitude of problems from the outset. Huw Morris, editor of the United Kingdom journal Planning, insists that in setting up such a facility, "tortuous planning dispute(s)" are causing long delays, as the Sellafield site can attest.[101] Planning issues aside, numerous technical, political and social barriers render the permanent storage of HLW an arduously long and expensive undertaking. Major studies conducted by the IAEA indicate that 1,500 to 2,000 new atomic reactors are required to make a sizable dent in greenhouse gas emissions. This would create the need for a new Yucca Mountain-sized facility every three or four years. Because these types of facilities have so many problems attached to them, many countries are now showing a keen interest in developing reprocessing technology. As indicated in the previous chapter, because reprocessing is the only way of producing plutonium for use in military weapons, this new development poses grave proliferation risks.[102]

After more than half a century of nuclear power generation, the nuclear industry is still yet to resolve the problem of how safely and effectively to dispose of its HLW. Deep geological repositories have become the most popular way to deal with HLW. However a range of political, economic, technical and social concerns has placed proposed plans around the world decades behind schedule. As a result, various countries are now seriously considering developing their own reprocessing plants, posing serious proliferation risks. HLW has long been the bane of the nuclear power industry, and will continue to be so for a very, very long time.

References

90 'Nuclear power in the OECD' International Energy Agency report, 2001, p. 182.

91 *ibid.*, p.30.

92 Nuclear Monitor, 'Nuclear power: No solution to climate change', NIRS/WISE; 621, January/February 2005, p.15

93 Bret Schulte, 'Mired in Yucca much: Nuclear power is trendy again, but what about the waste?', *US News & World Report*, Washington, 30 October 2006.

94 David Krieger and Marissa Zubia, *Nuclear Age Peace Foundation's top ten reasons to oppose the DOE's Yucca mountain plan*, Nuclear Age Peace Foundation, August 23, 2002, [http://www.wagingpeace.org/articles/2002/08/23_kriger_yucca-top10.htm].

95 'Britain: The long view; Nuclear waste', *The Economist*; 380, vol. 8489, August , 2006, p. 29.

96 This figure also includes military waste. Junior Isles, 'What legacy will you Leave', *Power Engineering International*; 14, 7, August 2006, p. 3.

97 'Time Tight on Nuclear Waste', *Professional Engineering*; 19, 15, Bury St. Edmunds, 16 August 2006, p. 7.

98 Roger Milne, 'Nuclear waste bill £15 billion', *Utility Week*; 25, 10, 5 May 2006, p. 5.

99 William Walker, 'Destination unknown: Rokkasho and the international future of nuclear reprocessing,' *International Affairs'* 84, 4, July 2006, p. 751.

100 Carah Ong, *International concerns about reprocessing*, Nuclear Age Peace Foundation, May 2005, p. 2, http://www.wagingpeace.org/articles/2005/05/00_ong_international-concerns-about-reprocessing.pdf].

1010 Huw Morris, 'Nuclear waste issue refuses to disappear', *Planning*, Issue 1667, London, p.11.

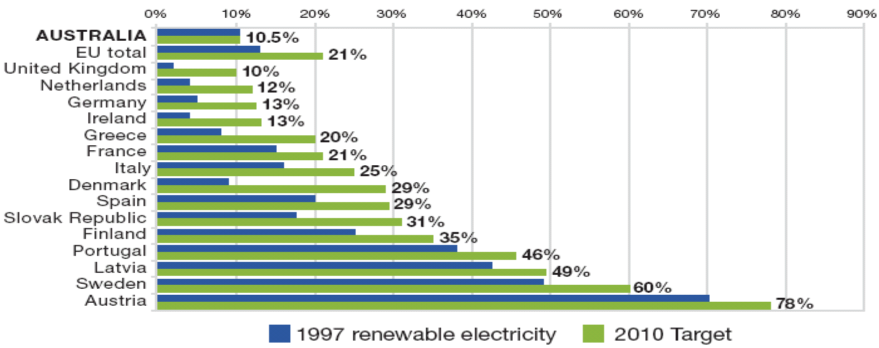
102 Carah Ong, *Reprocessing and proliferation dangers*, p. 1.

The Case for Renewables

Renewable energy is created using abundant resources such as sunlight and the wind. In harnessing the power generated by the wind, sun, water, geothermal heat and biomass, renewable energy sources are currently catering for 18% or nearly one fifth of the world's total energy production.[103] In 2004, renewables helped stop 0.9 billion tones of CO2 being released into the atmosphere and displaced some 3% of global power generation that would otherwise have been generated by fossil fuel sources.[104] With respect to their development, most renewable energy sources are in their infancy and with the renewable energy industry growing exponentially, there is great scope for future growth.

Unlike nuclear power, very few greenhouse emissions are created throughout the life cycle of a renewable power plant. As a result, the increased role of renewable energy sources in our energy mix, coupled with favourable government policies to facilitate their growth, are vital in curbing climate change. Unfortunately, Australian renewable energy targets lag behind many industrialised nations, yet the scope to expand energy generation from renewables in Australia is vast.

Figure 8: Renewable electricity in selected countries: 1997 generation and 2010 targets



Wind Power

Wind power involves the use of giant turbines that harness the wind's energy by driving generators to create electricity. Large utility-scale turbines generally have 80m high towers with 40m long blades attached. Each one has the capacity to power 600 homes, supplying over 1.8 MWe of power and costing around A$1.5 million each.[105] Smaller wind turbines are generally used to power farms or very small communities and cost much less, generally standing at 35m in height with 15m blades. These are traditionally used to power small rural communities without access to electricity grids. Wind power has an added bonus of creating the dual use of land, proving to be a godsend to many small-scale farmers with the wind industry paying reasonable sums for the use of their land.

Currently, less than 1% of the world's energy supply is generated from wind power. However by 2020, conservative estimates see wind power catering for between 6-to-12% of global electricity production, and up to 22% by 2040.[106] In 2004, wind power outpaced nuclear power sixfold in annual capacity, and threefold in annual output additions. It is also proving to be the first renewable source of power, apart from large-scale hydro, entering mainstream energy markets, with the global power industry already adding more wind capacity each year relative to nuclear power, and producing almost as much as hydro power.[107] The growth in wind power energy is quite remarkable, highlighting the enormous potential it has as a viable and dependable source of energy supply devoid of carbon emissions. In the US states of Texas, Minnesota and Alaska – remote areas with high wind velocities – the growth of the wind industry is prodigious. In 1981, all three states produced a meagre 10 megawatt hours of electricity by wind power. By 2006 that number had increased to 9,149-megawatt hours of power, with projections seeing that number doubling by 2010.[108]

In terms of cost, wind power is currently as cheap as coal to produce[109] in many parts of the world, and production costs are projected to drop even further with the advent of new, more cost-efficient technologies. Global markets are realising the enormous potential of wind power, especially considering its strong growth and low risks which are ideal for investors. Between 2000 and 2004, grid-connected wind power worldwide increased by 28%, compared with a 1.6% annual increase for nuclear power.[110] As the Democrat director of the Senate Energy and Natural Resources Committee in the USA stated, the "smart money is placing multibillion-dollar bets on ethanol, wind power, and solar, it's not throwing buckets of cash at nukes."[111]

Wind power's most active markets in Spain, Germany, the USA and Denmark all point to the positive economic and environmental impact wind power is having. Moreover, due to its relatively cheap operational costs, developing countries are eager to set up wind farms to deal with increasing energy demands, with India comprising the world's fifth largest capacity, and China's Centre for Renewable Energy Development reporting targets of 20,000 megawatts supplied by wind power by 2020.[112] According to Eric Marinott, wind power should grow at 15-30% annually until 2020, and if offshore wind farming develops and becomes economically viable, then it is possible that wind power could contribute up to 12% of global energy supply by 2020.

Solar Power

Solar energy comes directly from the powerful rays of the sun, and can be used directly to provide light and heating to homes, and to generate electricity for water heating, solar cooling and a wide range of industrial and commercial uses. On average, Australia receives more solar radiation per square kilometre than any other continent.[113] The energy generated by the sun can be harnessed in a number of ways, and various technologies are being developed to maximise effectiveness and reduce costs.

The main uses of solar power currently are:

Photovoltaics (PV) – the oldest and most common technology currently used, converting sunlight directly into electricity using semi-conductor materials or solar panels.

Solar Heating – solar collectors absorb energy to provide low-temperature heating used directly for hot water or space heating for residential or commercial buildings.

Concentrating Solar Power – an effective mechanism using reflective material that concentrates the sun's heat energy to drive a generator that produces electricity.[114]

Figure 9: One of the three new solar power stations in the Northern Territory utilising solar power technology. Built at a cost of $A7 million, they supply power to several thousand people.[115]

Solar power, like wind power, currently generates less than 1% of global energy supplies. However in recent years it has also seen remarkable growth. New more advanced and cost-effective technologies, coupled with favourable government policies in many countries around the world, have facilitated this growth. According to Martin Green of the ARC Photovoltaics Centre for Excellence at the University of New South Wales, the foundations have been laid for global solar productivity to double every two years, with annual additions to solar photovoltaic capacity predicted to overtake nuclear additions by 2007. Revenues from solar technology are destined to hit $A25 billion in 2006, with estimates of a $A100 billion windfall in 2010.[116]

Although solar power remains one of the most expensive sources of renewable energy, its costs are falling rapidly with the advent of new technologies. Germany is a good example of how government policies can effectively encourage the growth of the solar industry, by "guaranteeing the price of each unit of electricity produced over the first twenty years of the life of new photovoltaic systems."[117] Japan and several states in the US have adopted similar strategies that are reaping a number of rewards, such as the creation of extra jobs as well as feeding additional electricity back into their grids. Dutch engineer Sven Teske from Greepeace has indicated that solar power is about to enter mainstream markets, citing its sustained growth rate of almost 40% over the past decade.[118]

The economic benefits are plain to see. On current growth rates it is estimated that more than 3.2 million people will gain employment as a result of the solar power industry worldwide by 2020. Greenpeace's 2005 forecasts of 838 MW of solar power generation fell short of the actual figure that climbed to 1,387 MW. Following Germany's lead, industry regulation illustrates just what contribution solar power can make both economically and environmentally, while at the same time providing a great source of energy completely free of CO_2 emissions.

Hydroelectric

Hydroelectric power stations produce electricity by harnessing the energy of falling water, through dams, turbines and generators. Some 16% of the world's total electricity production in 2003 was generated by hydroelectric schemes – the same percentage as nuclear power.[119] However, while hydroelectric power stations produce extremely small quantities of CO_2 emissions, many still have adverse environmental and social impacts, especially when large areas of land are flooded, displacing people, as well as destroying vast and complex ecosystems. Huge dam projects such as China's Three Gorge's project and India's Namada Dam have displaced millions of people and have had a profoundly negative impact on local ecosystems and populations.[120] However, small-scale hydroelectric projects are proving to be environmentally acceptable and a dramatic increase in capacity and production is occurring around the world, providing rural communities with adequate sources of environmentally sound power.

In Australia, the most famous instance of the social and environmental impact that large-scale hydroelectric projects can have was the Franklin River Dam project in Tasmania in the early 1980s. Since then, there have been concerted efforts to pursue more environmentally friendly hydroelectric schemes. According to the National Greenpower Accreditation Programme, hydro projects that were shown to be environmentally acceptable saw 17,032 new MWh added in the April – June quarter to an existing 89,891 MWh, for a total of 106,923 MWh of green generation added to Australia's energy supply.[121]

Biomass

Biomass and waste products can produce electricity when biomass-fired generators create methane – generated by the decomposition of waste products in landfill sites and sewage treatment plants. Waste from agricultural products such as forestry, sugar cane, cotton and winery production are other resources that can harness electricity when fed into these generators. There are also a wide array of crops – known as "energy crops" – that can be specifically grown for energy production, such as timbers, natural oils and complex sugars. Such energy crops have the added bonus of giving farmers the option of a greater diversification of crops that can be used in crop rotations, decreasing their vulnerability to crop failure.[122]

Biomass saw 157,085 MWh added in the second quarter of 2006, to make a total of 246,558 MHh, a result of the Green Accreditation Program. The dramatic increase in MWh added to Australian energy production is likely to continue with the government approval of four new biomass generators in Victoria, NSW and Tasmania commissioned between March and June 2007. The merits of biomass forms of electricity generation are numerous because they help to curb CO_2 emissions, increase energy security, provide a more diversified renewable energy industry, reduce import dependence and utilise the potential of agricultural sectors.[123]

Geothermal

Geothermal energy is heat derived from the earth. It is the thermal energy contained in the rock and fluid that fills the fractures and pores within the rock in the earth's crust and is able to produce base-load electricity.

Geothermal energy currently finds itself in third place among renewables, following hydroelectricity and biomass, and ahead of solar and wind. Despite these impressive statistics, the current level of geothermal use pales in comparison to its potential.[124] Currently in Australia no electricity is produced from geothermal technology, although efforts are under way to explore the benefits of a "hot rock" power station in South Australia. Increased public awareness and government support is paramount in ensuring that the geothermal production of electricity becomes a viable and efficient source of electricity. The benefits are plain to see. Once a geothermal power station is built, it is extremely cheap to run, and as it only takes up a small area of land, is not aesthetically displeasing.[125] Europe and New Zealand have been reaping the rewards of geothermal electricity for the last decade, and it would help to diversify Australia's energy supply, thus further reducing the need to use traditional forms of energy production.

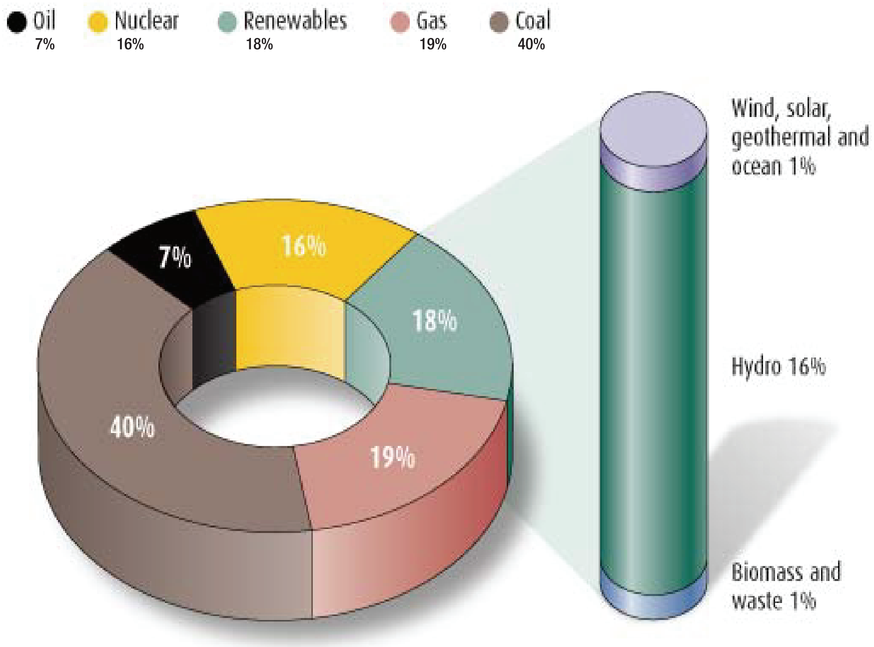
Summary

Climate change is an issue that is quickly generating profound concern internationally, and has provided a key set of arguments used by nuclear power advocates. Advocates of nuclear power claim it can play a critical role in combating climate change, alleging that it produces no greenhouse gas emissions and hence is a clean, safe and green energy source. According to US President George W. Bush, "the one hundred and three nuclear power plants in America produce 20% of the nation's electricity without producing a single pound of air pollution or greenhouse gases."[126] Such statements are misleading at best, because during the nuclear fuel cycle significant emissions are created, from the mining of uranium, to transportation, to building nuclear reactors and their decommissioning using robots via remote control, and storing radioactive waste for hundreds of thousands of years. Moreover, as we have seen, the potential for nuclear accidents threatens the earth with a far more dangerous and potential catastrophe – that of radioactive materials entering the ecosystem, as the residents of Chernobyl and surrounding areas can attest. Uranium is also a finite resource, and therefore is a stopgap solution that will eventually have to be replaced with other energy sources.

Conversely, renewable sources of energy such as wind, solar, hydroelectric, biomass and geothermal are abundant, producing small quantities of CO_2 emissions when their complete production cycles are taken into account. Moreover, in the event of an accident occurring from a renewable energy source, the ramifications would be far more localised, with no chance of deadly materials entering into the atmosphere. Excluding large hydroelectric power stations, renewables currently account for two per cent of the world's electricity production. Extraordinary growth rates however, particularly in the wind, biomass and solar sectors, coupled with the enormous potential shown by geothermal energy sources, have many conservative estimates insisting there is a distinct possibility renewables could contribute 40-50 per cent of the world's primary energy supply.[127]

With concerted efforts by policy-makers around the world actively to encourage the growth of renewables, such targets can be reached. In the USA, $13 billion has been allocated to the nuclear power industry as set out in the 2005 US Energy Bill.[128] That money would be far better invested in renewables, and not with an outdated and financially risky industry. Even with new incentives for the nuclear industry, investors in international financial markets are not being persuaded to invest. Nuclear energy represents a high-risk investment due to the many unforeseen variables that can incur exorbitant costs in the future. Government subsidies do not deal with capital, operating and decommissioning risks, which are proving to be of high concern to the markets.[129]

Figure 10: Energy Breakdown – Renewables accounted for nearly one-fifth of the world's total electricity production in 2003



Renewable sources of energy are also attractive options for developing countries to pursue, where the quest for industrialisation legitimately requires cheap energy sources. Wind power and biomass are just as cheap to produce as coal, and with technological advances increasing cost-efficiency in the future, are likely to become an even more attractive option. Although solar power is expensive to produce in most cases, in isolated rural areas solar power is in fact proving to be the only economically viable source of energy generation. In April 2006, the Nigerian Commissioner for

Science and Technology, Kadri Hamzat, announced that over twenty remote villages, which had never before had access to electricity, now had power thanks to solar power. "It costs about 150 million naira (around $1.2 million) to connect each village to the national grid, while the solar energy projects cost only about 10 million (around $83,000) per village."[130] In China and India, massive projects are under way in the renewables sector, with both nations seeing them as particularly valuable in regions not connected to national power grids. By 2010, China has set a policy target of 10% of total energy capacity sourced from renewables.[131] India aims at 10% by 2012 and Thailand has set a policy target for renewables making up 8% of their primary energy by 2011. In all, thirteen developing countries have made official policy targets for renewables.[132] Renewable sources of energy are not just for Western nations who can afford to encourage them; rather in many instances they are the only economically and technically viable option available.

The nuclear power industry is in a transition phase worldwide, with existing nuclear reactors either in a decommissioning stage, or fast approaching it. New generation reactors will not be operational until at least 2015, and will only be able to provide for 18% of global energy supplies. Australia is therefore in a prime position to lead the way and reap the economic, social and environmental rewards that renewable sources of energy have to offer. As Greg Bourne of the World Wildlife Foundation states, "Australia has more renewable resources per person than any other nation on earth – we do not need nuclear power plants in this country."[133]

References

103 Michael Brooks, 'The march of renewable energy', *The Age*, 1 May 2006, p.13.
104 Eric Martinot, 'Renewable energy gains momentum: Global markets and policies in the spotlight', *Environment*; 48, 6, July/August, 2006, p.28.
105 American Wind Energy Association, *Wind power today*, 2007. Available at www.awea.org/pubs/factsheets/WindPowerToday_2007.pdf
106 World Watch Institute, *Renewable energy enters boom period: Renewable energy continues rapid growth worldwide*, Washington, 10 July 2003.
107 Caldicott, *Nuclear power is not the answer to global warming of anything else*, pp.167-68.
108 Don Comis, 'A renewable energy update: Wind, sun and farm-based energy sources', *Agricultural Research*, Vol. 54, Washington, August 2006, p.4.
109 Due to Australia having such abundant coal reserves, wind power is currently not as cheap as coal-fired generated power.
110 Martinot, 'Renewable energy gains momentum: Global markets and policies in the spotlight', pp.30-31.
111 Ashton, Carey and Morrison, *op cit*, p.34.
112 Howard W. French, 'In search of a new energy source: China rides the wind,' *New York Times*, 22 June 2005.
113 Carina Denis, 'Solar energy: radiation Nation', *Nature*, 7 September 2006. Available at www.nature.com/nature/journal/v443/n7107/full/443023a.html
114 National Renewable Energy Laboratory, *Solar energy basics*, www.nrel.gov/learning/re_solar.html, and the US Department of Energy Efficiency and Renewable Energy, www.eere_energy.gov/solar. [accessed 22 September 2006].
115 http://www.kalbould.wa.gov.au/Shared/Images/General/WebPages/Solar%20Cities%20-%20photo.jpg.
116 Martin Greene, 'By following Germany's lead, Australia could enhance its strong position in solar power research', *Australian Policy Online*, 7 August 2006.
117 *ibid*.
118 *ibid*.
119 Rob Edwards, '60 years on is the world any safer?', p. 27.
120 For further information on the social and environmental consequences of India's Narmada Dam, see Maggie Black, 'The day of judgment', *New Internationalist*, no. 336, July 2001, pp.9-12.
121 'Greenpower', *Quarterly Status Report – 1 April-30 June 2006*, National Greenpower Accreditation Program, p.2. [available at www.greenpower.gov.au].
122 *ibid*., p.30.
123 'Promoting biofuels in Europe: Securing a clearer future for transport', *Director-General for Energy and Transport*, European Commission, 2004, p.8.
124 Geothermal Resources Council, http://www.geothermal.org.
125 Energy Australia, http://www.energy.com.au/energy/ea.nsf/Content/Kids+Geothermal.
126 George W Bush, speech at Calvert Cliffs reactor, www.whitehouse.gov/news/releases/2005/06/20050622.html, June 22, 2005.
127 Martinot, 'Renewable energy gains momentum: Global markets and policies in the spotlight', p.40.
128 Caldicott, *Nuclear Power is not the Answer to Global Warming of Anything Else*, p.xiv.
129 Brooks, 'The march of renewable energy', p.13
130 Toye Olori, 'Nigeria: Solar power goes where rickety power grids can't, *Global Information Network*, New York, August 7, 2006, p.1.
131 This target does not include large hydro-electric projects.
132 Eric Martinot, 'Renewable energy gains momentum: Global markets and policies in the spotlight', p.34.
133 AAP General News Wire, *Energy debate needs to be on renewables*, Sydney, May 4, 2006, p.4.

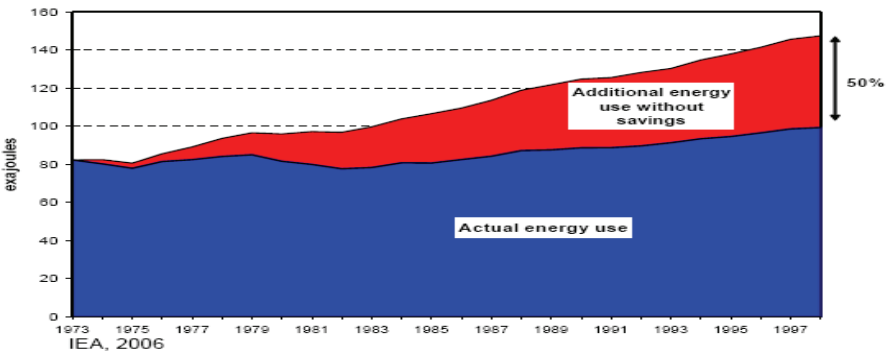
Energy Efficiency

Energy efficiency refers to "gaining the same or a higher level of useful output, using less energy input", and can be considered, with renewable forms of energy, as vital in reducing global greenhouse gas emissions and increasing energy security.[134] Around the globe, in residential, commercial, industrial and transport sectors, too much energy is being wasted. Standby power alone consumes 11% of residential and commercial energy usage. According to the International Energy Agency (IEA), with environmental and energy security benefits aside, energy efficiency measures "can reduce the need for investment in energy infrastructure, cut fuel costs, increase competitiveness and improve consumer welfare."[135] Aside from reducing greenhouse gas emissions, energy efficiency can deliver massive cuts to energy bills. Policy makers need to do much more to educate and promote more effective ways of using energy.

A recent study conducted by the McKinsey Global Institute estimated that the rate of global energy consumption could be reduced by more than 50% of current levels in the next fifteen years through aggressive energy efficiency in homes, offices and industry. What's more, the study concludes that the technology to bring about such dramatic cuts in energy consumption is currently available and affordable. Good savings, both in energy and financial terms, can be realised by efforts that include the use of compact fluorescent light bulbs, improved insulation in buildings, reducing standby power requirements, increasing efficiency standards for appliances and the use of solar-powered water heaters.[136] By implementing such simple measures on a global scale, the study indicates that electricity growth would decrease from the IEA's projected 2.2% to 0.6% annually. Energy efficiency can be applied to every sector of society that contributes to climate change, since the potential to reduce CO2 emissions is considerable. Amory Lovins from the Rocky Mountain Institute insists that, "saving electricity needs around 1,000 times less capital and repays it about ten times faster than supplying more electricity."[137]

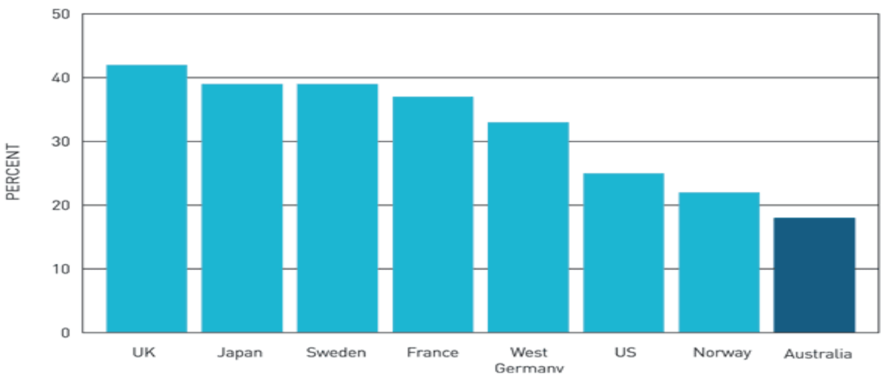
The figure below demonstrates the enormous benefits already derived from energy efficiency between 1973 and 1997. These savings are without the aggressive energy-saving techniques that can be implemented today.[138]

Figure 11:Energy Savings due to energy efficiency since 1973



In order to realise the immense monetary and environmental benefits that derive from energy efficiency, a number of obstacles need to be overcome and they are not expensive or difficult to implement. There are three major impediments to realising optimal energy efficiency in Australia. First, current price signals and market arrangements do not fully value the benefits from energy efficiency, either as a mechanism for addressing greenhouse gas emissions or reducing energy demand in response to higher prices. Secondly, energy users in Australia have had little incentive to manage their energy use effectively. Finally, a lack of information about opportunities to enhance energy efficiency and cultural barriers within the industrial, commercial, transportation and residential sectors results in decision-makers being unaware of the potential economic and environmental opportunities on offer. According to the federal government, "energy efficiency has constantly proved the most cost-effective of Australia's responses to greenhouse emissions."[139] Despite this, the IEA has found Australia's energy efficiency improvements have progressed by less than half other industrialised nations since 1973, as supported by the graph below, a situation that needs to be rectified quickly.[140] Low energy prices here in Australia have been a major factor in the lethargic uptake of energy efficiency measures and commercial incentives are essential to change this trend.

Figure 12: How various countries have improved the energy efficiency of their manufacturing industries, 1973-95[141]



There have been positive signs in recent years that industry in particular is warming to the benefits of energy efficiency. The National Framework for Energy Efficiency (NFEE), set up in November 2002 and developed cooperatively with the involvement of all government jurisdictions and key stakeholders, has helped to stimulate efficiency measures in a number of areas.[142] By implementing all available energy efficiency technologies, the NFEE estimates that residential energy use can be cut by 13%, commercial energy use by 10.4% and industrial energy use by 6.2%.[143]

Table 1: The potential for savings from energy efficiency in Australia

Sector	Total Energy Use	Percentage of energy use (%)	Potential to Improve Energy Efficiency (%)
Manufacturing and mining	1250.0	67	51
Commercial	224.0	12	15
Residential	399.5	21	34
Total	1873.5	100	100

Source: Based on ABARE (2003) and unpublished ABS data, NFEE (2004)

At the Amcor Botany Mill, with a $A250,000 investment, "projected energy savings of approximately $A1.65 million and greenhouse gas emission reductions of more than 20,000 tonnes were achieved in just one section of the plant by concentrating on improvements to the boiler plant and steam distribution system alone."[144] Australia Post has made a saving of $A500,000 by using more fuel-efficient vehicles, replacing single trailers with double trailers, and using larger but fewer trucks. The Normandy Mine in Queensland has also realised huge energy and financial savings by reducing the energy used per tonne of ore by 25%.[145] These three examples show how energy efficiency techniques can bring about substantial financial and environmental rewards. However, there is still a long way to go before the full potential of energy efficiency is realised. The transport sector, which accounts for 41% of final energy use in Australia, is still highly inefficient and aggressive energy techniques could make significant impacts.

The way we use energy needs to be seriously overhauled. The use of energy from fossil fuels is contributing to climate change, and our consumption mentality needs to give way to one of sustainability. Currently, too much energy in all its forms is needlessly wasted, yet with available technology we can use less energy without compromising productivity or comfort. With concerted efforts by policy-makers to increase energy efficiency in all sectors of society, Australia can do much to combat climate change. By implementing some simple measures, we can all minimise our ecological footprint, in turn empowering ourselves and our communities, saving money and helping to preserve this wonderful planet for future generations.

References

134 Commonwealth of Australia, 'Securing Australia's Energy Future', *Department of the Prime Minister and Cabinet*, June 2004, p. 107. Available at www.pmc.gov.au/energy_future

135 International Energy Agency, *Energy efficiency*, www.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID4122

136 Steve Lohr, 'Energy use can be cut by efficiency, survey says', *New York Times*, 24 November, 2006, p. 26.

137 Amory Lovins, *Nuclear is uneconomical*, Rocky Mountain Institute, April 2007. Available at http://www.mothersalert.org/lovins.html

138 International Energy Agency, 2006.

139 Commonwealth of Australia, 'Securing Australia's Energy Future', *Department of the Prime Minister and Cabinet*, 2004, p. 62.

140 International Energy Agency, 2001b.

141 International Energy Agency, 'Energy use in Australia in an international perspective', 2001.

142 National Framework for Energy Efficiency, *What is the national framework for energy efficiency?*, http://www.nfee.gov.au/about_nfee.jsp?xcid=62, [11 February, 2007].

143 Commonwealth of Australia, 'Securing Australia's Energy Future', p. 63.

144 Commonwealth of Australia, ''Case study: Amcor achieves impressive results', *Department of Industry, Tourism and Resources*, ITR/2003, November 2000, p. 1.

145 Commonwealth of Australia, 'Securing Australia's Energy Future', p. 63.

Conclusion

Nuclear power offers no solution to climate change, and remains a very dangerous and expensive form of energy production. Even if nuclear power doubled its global output by 2050, only a 5% reduction in greenhouse gas emissions would result when replacing coal.[146] Yet nuclear power is by no means free of carbon emissions, as fossil fuels are required throughout the nuclear fuel cycle, from the exploration and mining of uranium, building the reactor, decommissioning the facility, to final waste disposal. Moreover, as high-grade uranium reserves are increasingly depleted, the recovery of low-grade uranium in the future will increase its energy intensity and therefore its greenhouse gas emissions.

A number of serious problems have plagued the nuclear power industry from the start. There are grave concerns about radiation and safety, from major accidents at Chernobyl and Three Mile Island, to repeated effluent emissions from leaks and decommissioning which place the public at increased risk of exposure to ionising radiation. The safety threshold of radioactivity has been repeatedly lowered, with the present threshold some thirty-six times lower than it was in 1931.[147] The scientific community has acknowledged that the effects of low doses of radiation are still not entirely known, and that no dose of radiation may in fact be entirely safe.[148]

The issue of high-level nuclear waste has proven yet another negative consequence of nuclear power, and no country in the world has built an operational long-term storage facility. Nuclear power poses intergenerational concerns as the disposal of high-level radioactive waste involves time scales of more than a quarter of a million years before ceasing to be hazardous. Difficulties with the proposed deep geological facility to store radioactive waste at Yucca Mountain, Nevada, USA, indicate clearly that we do not know how safely to store such waste. Running 24 years behind schedule, political, technical, economic and social considerations have many questioning whether Yucca Mountain will in fact ever become operational. Similar problems of where and how to store radioactive waste have been commonplace around the world, with the United Kingdom, Japan, Sweden, the Czech Republic and France among others trying to find a solution to a problem that has plagued the industry since the beginning.

Nuclear power also heightens serious concerns about the proliferation of nuclear weapons. In catering for the peaceful uses of atomic technology, while attempting to ensure proliferation does not occur, the International Atomic Energy Agency is fulfilling a contradictory role that diminishes international security. Under the United Nations Nuclear Non-Proliferation Treaty, it is perfectly legal for a state to acquire all the information and expertise necessary to come to within weeks of developing an atomic bomb. But the withdrawal clause within the NPT makes it possible for any state wishing to renege from the treaty to do so, after obtaining all the relevant knowledge required to start a nuclear weapons programme. Israel, India, South Africa, Pakistan and North Korea have all developed nuclear weapons since the NPT came into effect. The international community has closely monitored events in Iran, fearful that it will become the world's eleventh declared nuclear power. Undeniably, nuclear power has helped various nations develop the technology needed to establish a clandestine nuclear weapons programme, gravely undermining international security. According to Ian Lowe, "one concerning factor is that acceptance of nuclear power implicitly presumes eternal peace."[149] Moreover, with the information and technology of nuclear energy now readily available, there is also an increased possibility of terrorist or criminal organisations acquiring enough nuclear fuel to build their own radiological weapons.

The potential of renewable sources of energy is growing by the day as technological advancements increase their efficiency and reduce their costs. Wind, solar, geothermal, biomass and environmentally friendly hydroelectric energy production are the cleanest forms of electricity generation and do not incur the grave dangers associated with nuclear power. Conservative estimates see wind power alone catering for up to 22% of the global electricity supply by 2040.[150] By taking up renewable sources of energy, governments will have highly diversified and environmentally sound energy sources that will help to decentralise energy grids and increase self-sufficiency around the globe, thereby increasing energy security. Instead of pouring vast sums of money into nuclear power to help make it economically viable for plant operators, it would be far better to encourage renewable sources of energy which are proven clean, green, safe, and most of all, provide unlimited sources of energy generation.

Decisive action on climate change needs to be taken now. Waiting at least 15 years for the relatively small, expensive and dangerous contributions nuclear power can hope to make in Australia would be too little and too late in reducing greenhouse gas emissions. Establishing a nuclear power industry would divert Australia away from an excellent opportunity to develop alternative energy sources and to transfer this knowledge to the rest of the world.

The twin challenges of increasing energy security and decreasing greenhouse gas emissions are among the most important challenges ever faced by the international community. Nuclear power advocates have used these challenges in an attempt to revitalise a flagging industry that has been in a downturn since the 1970s. The UK's Sustainable Development Commission issued a report on the role of nuclear power in a low-carbon economy and found that the UK could meet its CO2 reduction targets and energy needs "without nuclear power, using a combination of demand reduction, renewables and more efficient use of fossil fuels."[151]

Nuclear power in Australia offers no cure for climate change. If the international community is to act swiftly to avoid climate change, policy-makers around the world need to:

- reduce demand for energy
- divert the enormous sums of money subsidising the nuclear power industry into promoting renewable forms of energy
- increase energy efficiency and
- promote the cleaner use of fossil fuels.

In doing so, it is possible that by 2050 greenhouse gas emissions could be cut by up to 60%, the level required to stabilise the atmospheric concentration of greenhouse gases.[152]

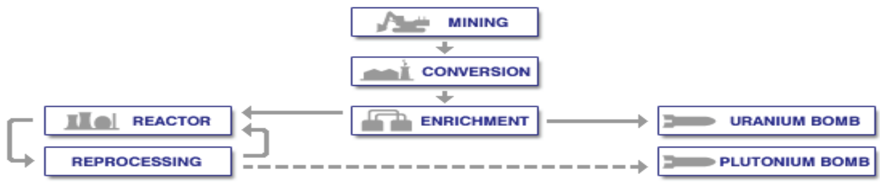
References

146 Phillip Ward, 'Nuclear power: No solution to climate change', p. 3.
147 Chris Busby, Martin Forwood and Lucinda Labes, 'Poisoning in the name of progress', p. 398.
148 Cindy Folkers, 'US radiation panel: No radiation dose safe', pp.1-3.
149 Ian Lowe, 'Reaction time: climate change and nuclear option,' p. 71.
150 World Watch Institute, *Renewable energy enters boom period: Renewable energy continues rapid growth worldwide*, Washington, 10 July 2003.
151 Sustainable Development Commission, *The role of nuclear power in a low carbon economy*, London: Position Papers, March 2006, p. 19. Available online at http://www.sd-commission.org.uk/publications/downloads/SDC-NuclearPosition-2006.pdf.
152 Saddler, Diesendorf and Deniss, *A clean energy future for Australia*, A study by Energy Strategies for the Clean Energy Group, WWF Australia, March 2004.

Appendix: The Nuclear Fuel Cycle

The process which transforms uranium into nuclear fuel is varied and complex depending on the type of reactor and sophistication of the technology used. This process is referred to by the nuclear power industry as the nuclear fuel cycle. This is somewhat of a misrepresentation and common misconception. The so-called "nuclear fuel cycle" is not really a cycle at all, because it is a cycle with a great number of open ends. In reality, the nuclear fuel cycle is nothing more than the route the uranium follows from the mine, past various stages to the reactor, and ending in its final disposal. Unfortunately, safe and secure forms of disposal do not exist yet.[152]

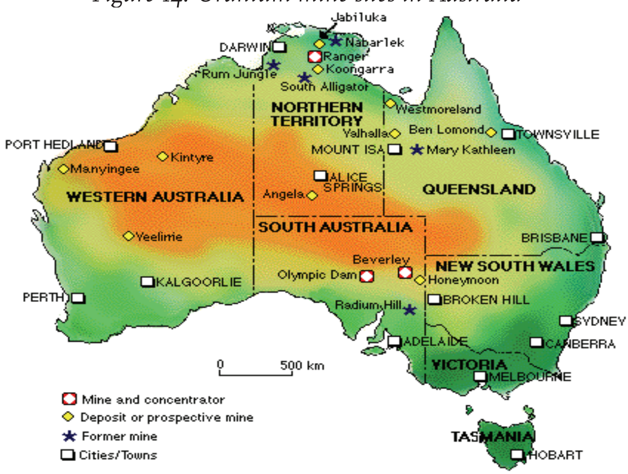
Figure 13: Diagram of the Nuclear Fuel Cycle from the BBC



Mining

Depending on the depth and concentration in which the ore body is found, uranium is mined using surface, underground or sulphuric acid in situ[153] techniques. Australia in late 2007 has three commercial mine sites. The Ranger site in the Northern Territory is an open-cut mine, Olympic Dam in South Australia is underground, and Beverley in South Australia uses in situ techniques. A fourth mine at the Honeymoon site in South Australia is currently being developed, which will also use in situ leaching techniques.

Figure 14: Uranium mine sites in Australia[154]



Although uranium is found everywhere on earth, deposits are found in concentrations of only 0.02 – 0.01 per cent, meaning on average, a standard 100mw/eh (megawatt electrical hours) reactor requires approximately 160 tonnes of uranium fuel annually, which is processed from 16 million tonnes of rock.[155] Most uranium ore grades are very low. Generally, much less than one percent of the rock is actually uranium. Therefore, for every tonne of uranium produced, thousands of tonnes of finely powdered radioactive rock are left over. The leftover waste rock is referred to as "tailings." According to Monash University's Dr Gavin Mudd, by mid-2006 there were 135 million tonnes of radioactive tailings across Australia, with no plans of substance to deal with the long-term waste storage currently in place.[156] This waste, which contains quantities of the carcinogenic alpha emitters, is left at the mine sites for future generations to deal with. Contrary to industry claims, uranium mining poses grave environmental, social and health risks, and is responsible for large amounts of greenhouse gas emissions into the atmosphere throughout its lifecycle. According to Dr Mudd, the Olympic Dam mine alone "is responsible for the emission of over one million tonnes of greenhouse gases per year and this could increase to four million tonnes if the mine is expanded."[157] Moreover, as ore grades diminish in the future, the greenhouse gas emissions generated will increase dramatically since it becomes more energy intensive to extract from the ground, proving that nuclear energy is neither clean nor green. The rehabilitation of mine sites is yet another serious problem associated with uranium mining, with the Federal Government allocating $A7.3 million in its 2006 budget over four years to clean up abandoned mines in Kakadu National Park alone.[158]

In response to numerous spills and leaks at Australia's uranium mine sites, a comprehensive 2003 Senate enquiry into uranium mining found "a pattern of non-compliance at mine sites in Australia," and concluded that "changes were necessary in order to protect the environment and its inhabitants from serious and irreversible damage."[159] Uranium mining has similar hazards to coal mining, with an added hazard of radioactive tailings leaving groundwater susceptible to contamination.[160] In March 2004, 150 workers at the Ranger mine became "exposed to drinking water containing uranium levels 400 times greater than the Australian safety standard."[161] The contamination of groundwater at the Beverly mine was also discovered in July 2006. These are only two examples among many.

Along with the negative health and environmental impacts of uranium mining come the severe social implications uranium mining can have on local indigenous populations. In Australia, Aboriginal communities have been fighting to keep their land free of uranium mine sites for decades. Uranium mines are invariably located on Aboriginal land, and many indigenous people have suffered as a result. They often have little involvement in mine operations and must depend on government or on statutory bodies for safeguards and royalties from uranium mining.[162] Such dependence is neither helpful nor beneficial to the indigenous population.

Figure 15: Recoverable International Uranium Reserves[163]

Milling

The next stage of the nuclear fuel-cycle sees uranium ore, a mixture of valuable minerals and waste, sent to a mill where huge diesel machines crush and grind it into a fine slurry, which is leached in sulphuric acid to allow the separation of uranium from the waste rock.[164] It is then recovered from the solution and precipitated as uranium oxide (U308) concentrate, often referred to as "yellowcake". The leaching process also extracts molybdenum, vanadium, selenium, iron, lead and arsenic from the rock.[165]

Conversion

Because uranium needs to be in the form of a gas before it is enriched, the U308 is converted into the gas uranium hexafluoride (UF6) at conversion plants in Europe, Russia or North America.[166]

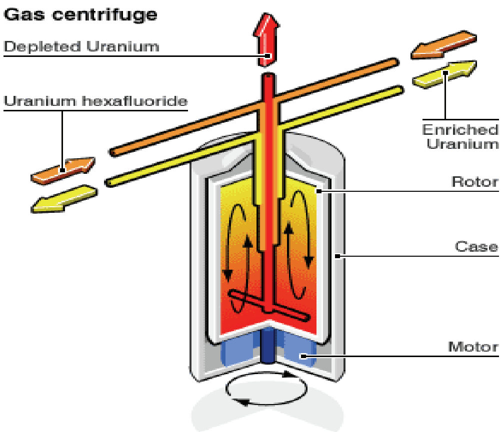
Refining and Enrichment

The vast majority of all nuclear power reactors require enriched uranium fuel where the proportion of the U-235 isotope is raised from the natural level of 0.7% to 3-5%. There are two commercial methods of enrichment available – gas diffusion and the use of centrifuges.[167] The enrichment process removes about 85% of the U-238 by separating gaseous UF6 into two streams: one stream is enriched to the required level and then passes to the next stage of the fuel cycle; the other stream is depleted U-235, commonly called "tails", which need to be disposed of.[168]

Because less than 0.25% U-235 remains in the tails it is of no further use for energy. However, since it is 1.7 times denser than lead, depleted uranium is used in metal form in yacht keels, as counterweights, in radiation shielding, and by the United States military in artillery shells and bullets.[169]

Once enriched, the uranium gains further military value. Depending on the level of enrichment (theoretically anything above 6%), the uranium can then be used as fuel for power, research, medical purposes or nuclear weapons.[170]

Figure 16: A typical gas centrifuge used to enrich uranium



Fuel fabrication

Enriched UF6 is then transported to a fuel fabrication plant to be converted into uranium dioxide powder (UO2) and pressed into small pellets. These pellets are placed into thin tubes to form fuel rods that are sealed and assembled in clusters to form fuel assemblies for use in the core of the nuclear reactor.[171]

The Nuclear Reactor

Several hundred fuel assemblies make up the reactor core. For a reactor with an output of 1000 MWe, the core would contain about 75 tonnes of low-enriched uranium. In the reactor core the U-235 isotope fissions or splits, producing heat in a continuous process called a chain reaction. Some of the U-238 in the reactor core is turned into plutonium and about half of this is also fissioned, providing about a third of the reactor's energy output. As in fossil fuel electricity plants, heat is generated to produce steam in order drive a turbine and an electric generator.[172] A nuclear reactor is thus an extremely complicated way of boiling water. To maintain efficient reactor performance, about a third of the spent fuel is removed every year or 18 months and replaced with fresh fuel.

The process requires massive amounts of water to keep the reactor operating at safe temperatures. According to Craig Nesbit, a spokesman at Exekon which operates the largest group of nuclear power plants in the USA, finding enough water "is front and centre of everything we will do in the future."[173] Moreover, David Lochbaum from the Union of Concerned Scientists, has insisted that we need to solve climate change before we can even contemplate building a nuclear power industry because as the climate warms up, water supplies are becoming severely depleted, meaning nuclear power plants are less able to deliver.[174] During the heat wave in Europe in 2003, 17 reactors in France had to be either shut down or their capacity reduced when ground water supplies dried up in many parts of the country. As a result, electricity had to be purchased from neighbouring countries on the open market, where the extra demand drove electricity prices up markedly. Germany and Spain also shut down some of their reactors for the same reasons. In Australia, reactors will not be built inland as it is the most arid continent on earth. Reactors, therefore, would have to be built on the coast, close to electricity grids and dense population centres, especially on the eastern seaboard.

Spent Fuel Storage

Spent fuel assemblies taken from the reactor core are highly radioactive and produce great amounts of heat. In most cases, used fuel rods are stored in ponds at the nuclear facility, which is designed to reduce their heat and contain their radioactivity. The water in the ponds serves the dual purpose of acting as a barrier against radiation and dispersing the heat from the spent fuel.[175] These ponds were only designed as temporary however, and do little to decrease the immense radiation given off by high-level radioactive materials. Spent fuel has been stored in these ponds for long periods without too much concern, though in recent years their vulnerability to terrorist attack has raised apprehensions. Spent fuel assemblies can also be dry-stored in engineered facilities cooled by air. Both kinds of storage are intended only as an interim step before the spent fuel is either reprocessed or sent to final disposal.

According to the World Nuclear Organisation there are two alternatives for spent fuel:

- Reprocessing to recover the usable portion of it – an extremely expensive option which also poses serious proliferation risks; or
- Long-term storage and final disposal without reprocessing. This has not been developed anywhere in the world yet, with the first facility not expected to open until 2017 in Finland, although more delays are expected.[176]

Reprocessing

Reprocessing refers to the chemical operation which separates the useful fuel for recycling from waste. Spent fuel still contains approximately 96% of its original uranium, of which the fissionable U-235 content has been reduced to less than 1%. About 3% of spent fuel comprises high-level radioactive waste products and the remaining 1% is plutonium, produced while the fuel was in the reactor and not “burned” then.[177]

Reprocessing separates uranium and plutonium from waste products by chopping up the fuel rods and dissolving them in acid to separate the various materials. Recovered uranium can be returned to the conversion plant for conversion to UF6 and subsequent re-enrichment. The reactor-grade plutonium can be blended with enriched uranium to produce a mixed oxide fuel, in a fuel fabrication plant. The remaining 3% of high-level radioactive wastes can be stored in liquid form and subsequently solidified.[178]

Reprocessing of spent fuel occurs at facilities in Europe, Japan and Russia, with a capacity of over 5000 tonnes per year. Reprocessing facilities are also considered to enhance prospects of proliferation because reprocessing is the only way of separating plutonium for use in military weapons.[179]

Vitrification

After reprocessing, the liquid high-level waste can be heated to produce a dry powder, which is incorporated into borosilicate glass to immobilise the waste. The glass is then poured into stainless steel canisters, each holding 400kg of glass. A year's waste from a 1000 MWe reactor is contained in 5 tonnes of such glass, or about 12 canisters 1.3 metres high and 0.4 metres in diameter. These can be readily transported and stored, with appropriate shielding.[180]

It is important to note that one of the most hazardous operations of the nuclear fuel chain is moving spent fuel from one location to another. Most commonly, fuel is moved out of interim storage by road or rail to a reprocessing plant and is thus at its most vulnerable to accidents or terrorist attacks.

This is as far as the nuclear fuel cycle has gone. The final disposal of vitrified high-level wastes, or the final disposal of spent fuel that has not been reprocessed, has not occurred after more than 50 years of nuclear power.

Final disposal

The waste forms envisaged for disposal are vitrified high-level wastes sealed into stainless steel canisters, or spent fuel rods encapsulated in corrosion-resistant metals such as copper or stainless steel.[181] The most widely accepted plans are for these to be buried in stable rock structures deep underground. Extremely long delays have plagued every country around the world in setting up permanent waste disposal sites, with Finland intending to introduce a final disposal site by 2017 at the earliest, while the USA is planning to finalise its Yucca Mountain project by 2021-23. The rest of the world is mired in administrative, economic, political, social and technical problems for the long-term disposal of radioactive waste. As a result, the actual dates for completion are impossible to ascertain.

References

152 Peter Bossew, 'The true price of nuclear power: The economic, environmental and social impacts of the nuclear fuel cycle', speech given at The World Uranium Hearing, Salzburg, 1992. Available at www.ratical.org/radiation/WorldUraniumHearing/PeterBossew.html, [accessed 17 September 2007].
153 In situ mining refers to pumping hundreds of tonnes of sulpheric acid, nitric acid, ammonia and other chemicals into the rock. This is then pumped out again after 5-to-25 years to separate the uranium from the rock strata. This is the preferred mining technique of the industry because it is the cheapest.
154 World Nuclear Organisation, 'Australia's Uranium', available at http://www.world-nuclear.org/education/ozuran.htm.
155 Jon Hughes, 'Nuclear power dossier: Uranium mining and milling', *The Ecologist Online*, http://www.theecologist.org/archive_detail.asp?content_id=627, [accessed 12 May 2007].
156 Australian Wilderness Society, *Nuclear Wilderness: Uranium Mining*, http://www.nuclear-wilderness.org.au, [accessed 25 February 2007].
157 Monash University, 'Digging deep: Uncovering the true costs of uranium', *Monash Memo*, http://www.monash.edu.au/news/monashmemo/stories/20070314/uranium.html, 14 March 2007, [accessed 15 May 2007].
158 Australian Wilderness Society, *Nuclear wilderness: Uranium mining*.
159 Commonwealth of Australia, 'Regulating the Ranger, Jabiluka,Beverley and Honeymoon Uranium Mines', *Environment, Communications, Information Technology and the Arts References Committee*, The Senate, October 2003, p. 9.
160 Union of Concerned Scientists, *How Nuclear Power Works,* 8 December 2005, http://www.ucsusa.org/clean_energy/nuclear_safety/offmen-how-nuclear-power-works.html. [accessed 12 May 2007.
161 Australian Wilderness Society, *Nuclear Wilderness: Uranium Mining*.
162 Vincent Forrester, 'Uranium Mining and Aboriginal People', *The Sustainable Development and Anti-Uranium Service*, 1984, available at http://www.sea-us.org.au/blackuranium.html.
163 Based on Identified Resources which consist of Reasonably Assured Resources and Inferred Resources at costs less than $80 (US) per kilogram U as at January 1, 2005. Chart is available at http://www.nea.fr/html/general/press/2006/redbook/redbook.pdf
164 Most uranium ore grades are very low – generally, much less than one percent of the rock is actually uranium. Therefore, for every tonne of uranium produced, thousands of tonnes of finely powdered radioactive rock are left over. This waste, which contains huge quantities of the carcinogenic alpha emitters, is left at the mine sites for future generations to deal with.
165 Jon Hughes, 'Nuclear power dossier: Uranium mining and milling'.
166 World Nuclear Organisation, *The nuclear fuel cycle*, http://www.world-nuclear.org/education/nfc.htm.
167 For more information on the two forms of enrichment see IAEA, 'Nuclear Technology Review 2006', Vienna, pp. 78-80.
168 Figures in this diagram assume enrichment to 3.5% U-235 and a tails assay of 0.25%.
169 For information on the grave health problems encountered by soldiers and civilians in Iraq because of depleted uranium littering battlefields, see James Denver, 'Horror of USA's depleted uranium in Iraq threatens world', *Vive le Canada*, 29 April 2005. Available at http://www.vivelecanada.ca/article.php/20050429121615724.
170 Zia Mian, A.H. Nayyar, R. Rajaraman, and M.V. Ramana, *Fissile materials in South Asia: The implications of the U.S.-India nuclear deal*, Research report of the International Panel on Fissile Materials, Princeton, USA, September 2006.
171 World Nuclear Organisation, *The Nuclear Fuel Cycle*.
172 *ibid*.
173 James Kanter, 'Climate change puts nuclear energy into hot water', *International Herald Tribune*, 20 May 2007, available at www.iht.com/articles/2007/05/20/africa/nuke.php.
174 *ibid*.
175 World Nuclear Organisation, *The Nuclear Fuel Cycle*.
176 *ibid*.
177 *ibid*.
178 *ibid*.
179 Carah Ong, *Reprocessing and proliferation dangers*, Nuclear Age Peace Foundation, 2005 [accessed 23 October 2006]); available from http://www.wagingpeace.org/articles/2005/05/00_ong_reprocessing-proliferation-dangers.pdf.
180 World Nuclear Organisation, *The Nuclear Fuel Cycle*.
181 World Nuclear Organisation, *The Nuclear Fuel Cycle*.

Bibliography

AAP General News Wire, *Energy debate needs to be on renewables*, Sydney, May 4, 2006, p.4.

Allison, Wade. *The safety of nuclear radiation: A careful re-examination for a world facing climate change*, Department of Physics and Keble College, Oxford, 2007, http://www.physics.ox.ac.uk/nuclearsafety/ARTICLE.pdf

American Wind Energy Association, *Wind power today*, 2007. Available at www.awea.org/pubs/factsheets/WindPowerToday_2007.pdf.

'An award for the struggling nuclear detectives', *The Economist*, October 7, 2005, London, p.1.

Ansolabehere, Stephen *et al. The future of nuclear power: An interdisciplinary MIT study*, 2003.

Australian Commonwealth Scientific and Industrial Organisation, *Climate change in Australia: Impacts, adaptation and Vulnerability*, Climate Adaptation Flagship, 2007.

Australian Wilderness Society. *Nuclear wilderness: Uranium mining*, http://www.nuclear-wilderness.org.au

Beith, Malcolm. 'The last word: Finding the missing link', *Newsweek (International Edition)*, New York, 24 April 2006.

Belijac Marko, *et al. An illusion of protection: The unavoidable limitations of safeguards on nuclear materials and the export of uranium to China*, Medical Association for the Prevention of War and The Australian Conservation Foundation, October 2006.

Beresford, N. A and J. Smith. *Chernobyl: Catastrophe and Consequences*, Praxis: Chichester, UK, 2005.

Bertell, Rosalie, Sarah Bell and David Edwards. 'Victims of the nuclear age', *The Ecologist*; 29. 7 November 1999, pp. 408-411.

Black, Maggie. 'The day of judgement', *New Internationalist*, no. 336, July 2001, pp.9-12.

Bodman, Samuel. 'The nuclear threat: Preventing the proliferation of weapons of mass destruction', *Vital Speeches of the Day*, May 1, 2005, 71, p. 14.

Booth, W. 'Postmortem on Three Mile Island', *Science*; 238, 1987, pp. 1342-1345

Bossew, Peter. 'The true price of nuclear power: The economic, environmental and social impacts of the nuclear fuel cycle', speech given at The World Uranium Hearing, Salzburg, 1992. Available at www.ratical.org/radiation/WorldUraniumHearing/PeterBossew.html

Broinowski, Alison. 'Nuclear politics: Taking the A train,' *New Matilda*, 1 October 2007.

'Britain: The long view; nuclear waste', *The Economist*; 380, vol. 8489, August, 2006, p. 29.

Brooks, Michael. 'The march of renewable energy', *The Age*, 1 May 2006, p.13.

Busby, Chris, Martin Forwood and Lucinda Labes. 'Poisoning in the name of progress', *The Ecologist*; 29, 7, November, 1999, pp. 395-402.

Bush, George W. Speech at Calvert Cliffs reactor, www.whitehouse.gov/news/releases/2005/06/20050622.html, 22 June 2005.

Caldicott, Helen. *Nuclear power is not the answer to climate change or anything else*, Melbourne: Melbourne University Press, 2006.

Carnegie Endowment for International Peace, *Nonproliferation: Nuclear numbers*, http://www.carnegieendowment.org/npp/numbers/default.cfm, 7 February 2007.

Comis, Don. 'A renewable energy update: Wind, sun and farm-based energy sources', *Agricultural Research*, Vol. 54, Washington, August 2006, p. 4-7.

Commonwealth of Australia, 'Case study: Amcor achieves impressive results', *Department of Industry, Tourism and Resources*, ITR/2003, November 2000.

Commonwealth of Australia, 'Regulating the Ranger, Jabiluka, Beverley and Honeymoon uranium mines', *The Senate*, Environment, Communications, Information Technology and the Arts References Committee, October 2003.

Commonwealth of Australia, 'Securing Australia's energy future', *Department of the Prime Minister and Cabinet*, 2004.

Commonwealth of Australia. 'Uranium mining, processing and nuclear energy review: Opportunities for Australia', *Department of the Prime Minister and Cabinet*, January 2007.

Condon, Judith. *Chernobyl and other nuclear accidents*, Hore, UK: Wayland, 1998.

'Credit risk still high for nuclear plants: S&P report', *Nuclear Engineering International*, 11 January 2006. Available at http://www.neimagazine.com/story.asp?storyCode=2033547

Denis, Carina. 'Solar energy: Radiation nation', Nature, 7 September 2006. Available at www.nature.com/nature/journal/v443/n7107/full/443023a.html

Denver, James. 'Horror of USA's depleted uranium in Iraq threatens world', *Vive le Canada*, 29 April 2005.

Diesendorf, Mark. *Towards Victoria's clean energy future: A plan to cut Victoria's greenhouse gas emissions from electricity by 2010*, WWF Australia, January 2005.

Edwards Rob, and David Lowry. 'Poacher or gamekeeper', *The Ecologist*; 29, 7, November 1999, 424-425.

Edwards, Rob. '60 years on is the world any safer?', *New Scientist*, London, 16-22 July 2005, pp. 6-9.

European Commission: Directorate General XII Science, Research and Development, *External costs for electricity production in the EU (in Eur-Cent Per Kwh)*, 1995, available from http://www.externe.info/.

European Commission: Directorate General for Energy and Transport, *Promoting biofuels in Europe: Securing a clearer future for transport*, 2004.

'Fears of new leak at nuke plant', *The Australian*, 18 July 2007, p. 11.

Folkers, Cindy. 'US radiation panel: No radiation dose safe', *WISE/NIRS Nuclear Monitor*; 632, 15 July, 2005.

Ford, Daniel F. *Three Mile Island: Thirty minutes to meltdown*, New York: Penguin, 1982.

Forrester, Vincent. 'Uranium mining and Aboriginal people', *The Sustainable Development and Anti-Uranium Service*, 1984, available at http://www.sea-us.org.au/blackuranium.html

French, Howard W. 'In search of a new energy source: China rides the wind,' *New York Times*, 22 June 2005.

Gifford, Clive. *Essential chemistry*, London: Usborne, 1992.

Goldberg, Marshall. *Federal energy subsidies: Not all technologies are created equal*, Report 11, Washington: Renewable Energy Policy Project, July 2000.

Goldsmith, Zac. 'Nuclear havoc', *The Ecologist*; 29, 8, December 1999.

Green, Jim (ed.). *Nuclear power: No solution to climate change*, Friends of the Earth, 2006.

Greene, Martin. 'By following Germany's lead, Australia could Enhance its strong position in solar power research', *Australian Policy Online*, 7 August 2006.

Grunwald, Michael and Juliet Eilperin. 'Energy bill raises fears about pollution, fraud: Critics point to perks for industry,' *Washington Post*, 2005.

Guynup, Sharon. 'Safe of deadly?', *Science World*; 56, 9, February, 2000.

Hore-Lacy, Ian. 'Nuclear energy: The world picture,' *Issues*; 77, 2006, pp. 18-21.

Howard, John. 'Let's not bury our heads in the sand on nuclear energy', *The Australian*, 18 July 2006.

Hughes, Jon. 'Nuclear power dossier: Uranium mining and milling', *The Ecologist Online*, http://www.theecologist.org/archive_detail.asp?content_id=627

Hyland, Tom. 'Nuclear reactor plan on shaky ground', *The Age*, 14 October 2007, http://www.theage.com.au/news/climate-watch/nuclear-reactor-plan-on-shaky-ground/2007/10/13/1191696239293.html

International Atomic Energy Agency, *Nuclear technology review*, Vienna, 2006.

International Energy Agency, *Energy efficiency*, www.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID4122.

Isles, Junior. 'What legacy will you leave', *Power Engineering International*; 14, 7, August 2006, p.3.

Jagger, John. *The nuclear lion: What every citizen should know about nuclear power and nuclear war*, New York: Plenum Press, 1991.

Kanter, James. 'Climate change puts nuclear energy into hot water', *International Herald Tribune*, 20 May 2007, available at www.iht.com/articles/2007/05/20/africa/nuke.php

Koutsoukis, Jason. 'Has anyone seen Australia's uranium?', *Australian Financial Review*, 9 November 2002, p.21.

Krieger, David and Marissa Zubia. *Nuclear Age Peace Foundation's top ten reasons to oppose the DOE's Yucca mountain plan*, Nuclear Age Peace Foundation, August 23, 2002, http://www.wagingpeace.org/articles/2002/08/23_kriger_yucca-top10.htm.

Lohr, Steve. 'Energy use can be cut by efficiency, survey says', *New York Times*, 24 November, 2006, p. 26.

Lovins, Amory. *Nuclear is uneconomical*, Rocky Mountain Institute, April 2007. Available at http://www.mothersalert.org/lovins.html

Lowe, Ian. 'Reaction time: Climate change and the nuclear option', *Quarterly Essay*; 27, 2007.

Lyman Edwin, and Steven Dolley. 'Accident prone', *Bulletin of the Atomic Scientists*; 56, 2, March/April 2000, pp. 42-46.

Lyman, Edwin S. *Chernobyl on the Hudson?: The health and economic impacts of a terrorist attack at the Indian Point nuclear plant*, Union of Concerned Scientists, September, 2004, www.ucsusa.org/global_security/nuclear_terrorism/impacts-of-a-terrorist-attack-at-indian-point-nuclear-power-plant.html.

Macintyre, Donald. 'Unclear fallout', *Time Magazine*; 154, 15, 18 October 1999 available at http://www.web.archive.org/web/20000118171525.

Makhijani, A. 'Nuclear power: No answer to global climate change,' *Nukewatch Pathfinder*, Autumn, 2002.

Martinot, Eric. 'Renewable energy gains momentum: Global markets and policies in the spotlight', *Environment*; 48, 6, July/August, 2006, pp. 26-44.

Mian, Zia, A.H. Nayyar, R. Rajaraman, and M.V. Ramana. *Fissile materials in South Asia: The implications of the U.S.-India nuclear deal*, Research report of the International Panel on Fissile Materials, Princeton, USA, September 2006.

Milne, Roger. 'Nuclear waste pit bill £15 billion', *Utility Week*; 25, 10, 5 May 2006, p. 5.

Monash University, 'Digging deep: Uncovering the true costs of uranium', *Monash Memo*, http://www.monash.edu.au/news/monash-memo/stories/20070314/uranium.html, 14 March 2007.

Morris, Huw. 'Nuclear waste issue refuses to disappear', *Planning*, Issue 1667, London, 5 May 2006, p. 11.

Mosey, David. *Reactor accidents: Nuclear safety and the role of institutional failure*, London: Nuclear Engineering International Special Publications, 1990.

Murphy, Katherine. 'Economics of nuclear power don't stack up: Costello,' *The Age*, 26 November 2006.

National Framework for Energy Efficiency, *What is the National Framework for Energy Efficiency?* http://www.nfee.gov.au/about_nfee.jsp?xcid=62

National Greenpower Accreditation Program. *Greenpower*, Quarterly Status Report – 1 April-30 June 2006, www.greenpower.gov.au.

National Renewable Energy Laboratory, *Solar energy basics*, www.nrel.gov/learning/re_solar.html.

'New UK reactor plants could prove costly', *New Scientist*, 25 July 2005.

Nishiyama, George. 'Japan quake shows nuclear findings', *The Age*, 17 July 2007.

'Nuclear energy coming back into vogue, despite problems', *The Economist*, 14 September 2007, Review, pp. 4-5.

'Nuclear meltdown narrowly averted', *The Ecologist*; 36, 9, November 2006, p. 9.

Nuclear Monitor, 'Nuclear power: No solution to climate change', NIRS/WISE; 621, January/February 2005.

'Nuclear power in the OECD' International Energy Agency report, 2001.

'Nuclear power industry – Dangerous to taxpayers', *National Catholic Reporter*; 1 June 2001, p. 28.

Olori, Toye. 'Nigeria: Solar power goes where rickety power grid can't, *Global Information Network*, New York, August 7, 2006, p.1

Ong, Carah. *International concerns about reprocessing*, Nuclear Age Peace Foundation, May 2005, http://www.wagingpeace.org/articles/2005/05/00_ong_international-concerns-about-reprocessing.pdf

Ong, Carah. *Reprocessing and proliferation dangers*, Nuclear Age Peace Foundation, 2005 [accessed 23 October 2006]), http://www.wagingpeace.org/articles/2005/05/00_ong_reprocessing-proliferation-dangers.pdf.

Read, Piers Paul. *Ablaze: The story of Chernobyl*, London: Seeker & Warbury, 1993.

Rizui, Haider. 'Politics: Critics say UN can't push peace and nuclear power, too', *Global Information Network*, New York, 20 April 2006, p. 1.

Saddler, Diesendorf and Deniss, *A clean energy future for Australia*, A study by Energy Strategies for the Clean Energy Group, WWF Australia, March 2004.

Scheinman, Lawrence and William Porter. 'The nuclear conundrum: Reconciling nuclear energy and nonproliferation,' *Harvard International Review*; 26, 4, Winter 2005, pp. 24-27.
Schulte, Bret. 'Mired in Yucca much: Nuclear power is trendy again, but what about the waste?', *US News & World Report*, Washington, 30 October 2006.
Shearman, David, Colin Butler, and William Castleden (eds.). *Submission to the Uranium Mining, Processing and Nuclear Energy Review*, Doctors for the Environement Australia, Melbourne, 2006.
Simms, Andrew and Petra Kjell, and David Woodward, *Mirage and oasis: Energy choices in an age of global warming*, New Economics Foundation, 2005.
Sokolski, Henry. 'After Iran: Back to basics on 'peaceful' nuclear energy,' *Arms Control Today*; 35, 3, April 2005, pp. 20-25.
Sokolski, Henry and George Perkovich. 'It's called nonproliferation', *Wall Street Journal (Eastern Edition)*, New York, 29 April 2005, p. A 16.
Sustainable Development Commission, *The role of nuclear power in a low carbon economy*, London: Position Papers, March 2006, p. 19. Available online at http://www.sd-commission.org.uk/publications/downloads/SDC-NuclearPosition-2006.pdf.
Traub, James. 'Why not build a bomb?', *New York Times Magazine*, 29 January 2006, pp. 15-16.
'The long half life of nuclear disarmament', *The Economist*, London, 10 June 2006, p.24.
'Time tight on nuclear waste', *Professional Engineering*; 19, 15, Bury St. Edmunds, 16 August 2006, p. 7.
Thompson, Margaret W., Roderick R. McInnes and Huntington F. Willard, *Genetics in medicine*, London: W. B. Saunders, 1991.
Union of Concerned Scientists, '*How nuclear power works*', 8 December 2005, http://www.ucsusa.org/clean_energy/nuclear_safety/offmen-how-nuclear-power-works.html
United States Department of Energy Efficiency and Renewable Energy, *Solar power*, www.eere_energy.gov/solar.
John Vidal. 'Hell on Earth', *The Guardian*, 26 April 2006. Available at http://society.guardian.co.uk/societyguardian/story/0,,1760930,00.html
Vincent, Eve (ed.). *Yellow cake country?: Australia's uranium industry*, Beyond Nuclear Initiative Publication, 2006
William Walker, 'Destination unknown: Rokkasho and the international future of nuclear reprocessing,' *International Affairs*, 84, 4 July 2006, pp. 743-761.
Ward, Phillip. 'Nuclear power: No solution to climate change', *NIRS/WISE*, Amsterdam: Publication #621 & #622, February 2005.
Ward, Philip. 'Unfair aid: The subsidies keeping the nuclear industry afloat', *Nuclear Monitor*, 630 & 631, NIRS/WISE, Amsterdam, 24 June 2006, pp. 8-9.
World Health Organisation, *Nuclear power and health: The implications for health of nuclear power production*, Regional Publications, Regional Series; no. 51, 1994.
World Nuclear Organisation, *The nuclear fuel cycle*, http://www.world-nuclear.org/education/nfc.htm
World Nuclear Association, *Radiation and Life*, July 2002, available at http://www.world-nuclear.org/education/ral.htm
World Nuclear Association, *The economics of nuclear power*, London, 2007, http://www.world-nuclear.org/info/inf02.html
World Watch Institute, *Renewable energy enters boom period: Renewable energy continues rapid growth worldwide*, Washington, 10 July 2003.

Nuclear power poses excruciating moral dilemmas. Its advocates claim we need to multiply nuclear power plants greatly to reduce greenhouse gas emissions when generating electricity.

Critics of nuclear power argue that the risks are too great. Building thousands of nuclear reactors around the world would enormously increase risks from terrorism, war or accidents that could contaminate large regions for many thousands of years. Will expanding electricity production from nuclear power result in the further proliferation of nuclear weapons? And how will we and future generations manage the huge quantities of radioactive waste?

Ultimately these questions are profoundly moral ones. *Nuclear Power: Cure or Curse?* examines the alleged benefits of expanded nuclear power against the risks to future generations.

The decision about expanding nuclear power may well be one of the most significant decisions human beings have ever made.

A discussion paper of Catholic Social Services Victoria and the
Melbourne Catholic Commission for Justice, Development and Peace, in collaboration with the
Social Questions Commission of the Victorian Council of Churches.