

More nuclear? What international experts say about our energy future

Nuclear and Energy Questions and Answers

19 November 2006

The investment in new nuclear power plants in Europe have been described by the consultancy UBS as “a potentially courageous 60-year bet on fuel prices, discount rates and promised efficiency gains.” ...Even if they [financial lenders] would lend money, the interest rate might be so high (to reflect the risk) as to make nuclear power hopelessly uneconomic.

Professor Steve Thomas

... we're seeing from most nuclear proponents their old five P playbook – pushed power plants; postponed problems. Nuclear power's asserted comeback in the US rests not on newfound competitiveness in power plant construction, but on an old formula: subsidy, licensing shortcuts, risks borne by customers and taxpayers, political muscle, ballyhoo and pointing to other countries (once the Soviet Union, now China) to indicate that the US is “falling behind”. Climate change has replaced oil dependence as the bogeyman from which only nuclear power assertedly can save us.

Peter Bradford

The intergenerational aspects of nuclear waste storage or disposal raise a number of important questions. Given that some waste needs to be isolated from the environment for hundreds of thousands of years, it is difficult to know what guarantees could or should be given.

Antony Froggatt

It is hard to conceive that the Australian industry as a total newcomer to nuclear power would do better than the largest and most experienced builders in the world, and these builders struggle getting one large project off the ground.

Mycle Schneider

...a study by the Australian Greenhouse Office has suggested that the electricity network could easily accommodate 8000 MW of wind and there is almost certainly potential for more.

David Milborrow

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Introduction

An independent international expert panel on nuclear and energy issues answered questions ahead of the release of the Prime Minister's Nuclear Taskforce Draft Report on Tuesday 21 November. This paper is a compilation of the questions and answers.

The questions covered such topics as:

- The role of nuclear power in reducing CO₂ emissions in an attempt to address climate change;
- The global subsidies given to energy and nuclear power;
- How renewable energy can deliver reliably;
- The potential for wind power;
- Future designs of nuclear reactors;
- The economics of nuclear power;
- Safeguarding nuclear material; and
- Management of radioactive waste

Context

For the first time in decades all nuclear activities – with the exception of nuclear weapons – are on the negotiating table for Australia including:

- more uranium mining;
- building domestic nuclear power plants;
- supporting nuclear power development in India, China and Indonesia
- enriching uranium in Australia;
- reprocessing nuclear materials;
- becoming part of a global or regional nuclear fuel leasing consortium; and
- hosting an international nuclear waste dump.

Australian Prime Minister John Howard announced his Prime Ministerial Taskforce – the Uranium Mining, Processing and Nuclear Energy Review on 6 June 2006. Its purpose is to: “undertake an objective, scientific and comprehensive review into uranium mining, processing and the contribution of nuclear energy in Australia in the longer term”.

The Taskforce will launch its draft report on 21 November 2006 at the National Press Club. Comments on the draft report are due by 12 December 2006; subsequently the Taskforce will present a Final report to the Government before Christmas. To date the Government has not stated or signalled a timetable for responding to the report.

The draft report is expected to present its already-leaked conclusion that nuclear power could be viable in 10-15 years in Australia and that nuclear should be part of the ‘energy mix’ to reduce greenhouse emissions.

Although the Prime Minister called for a full-blooded debate the process has been flawed from the beginning.

The terms of reference are narrow and cover a small range of issues – mostly economic. The Taskforce membership is very pro-nuclear and the Taskforce Chair Dr Ziggy Switkowski pre-empted the outcomes within weeks of his appointment saying the Taskforce was “very much around establishing the facts, laying out scenarios, framing the debate”.

While the Taskforce has been presented as looking at the role of nuclear power in addressing climate change it has always had a strong focus on Australia's uranium interests and the potential implications of the United States Global Nuclear partnership (GNEP) for Australia. It is unclear what the Government's real agenda is.

The Taskforce seems destined to recommend further Australian engagement in the nuclear industry at the expense of consideration of clean and sustainable solutions to climate change.

Methodology

The independent international expert panel was created at the request of Greenpeace as a counter to the approach of the Prime Minister's taskforce. However, the panel members in answering these questions do not represent the views of Greenpeace but their own expertise.

The panel ran for three days from 15-17 November. Questions from journalists, Federal politicians and in response to media commentary were sent to the panel members around 7pm each night and the panellists provided answers by 7am the next morning.

The broad range of questions were answered as accurately and concisely as possible given the limited time available and give an insight into often very complex problems on which much debate has and continues to take place. These questions and their answers do not cover all of the issues surrounding consideration of Australia's current or future involvement in the nuclear fuel cycle.

This document is a collated version of the questions and answers with duplicate or similar questions deleted.

The panel will provide initial commentary on the draft Nuclear Taskforce Report on Wednesday 22 November and may provide more detailed consideration before 12 December 2006.

Panel Chair

Antony Froggatt, international energy and nuclear policy consultant, United Kingdom

Antony Froggatt advises Members of European Parliament on energy issues via written reports, drafting amendments and providing briefings. He has given evidence to the Austrian, German and European Parliaments. He also provides analysis on energy policy to non-government organisations and the energy industry. Since 1997 Mr Froggatt has produced over 30 publications on energy-related topics.

Panel Members:

Peter Bradford, former member, Nuclear Regulatory Commission, United States

Peter Bradford is a former member of the United States Nuclear Regulatory Commission, and former chair, New York and Maine utility regulatory commissions. Mr Bradford has taught at the Yale School of Forestry and Environmental Studies. With 37 years of expertise in the field of energy law and policy, he is the author of many articles and one book. He is a member of the Policy Advisory Council of the China Sustainable Energy Project. He served on a panel advising how best to replace the remaining Chernobyl nuclear plants in Ukraine and also on an expert panel on the opening of the Mochovce nuclear power plant in Slovakia. Mr. Bradford is Vice-Chair of the Union of Concerned Scientists.

David Milborrow, renewable energy studies consultant, United Kingdom

David Milborrow is an independent consultant who has been associated with renewable energy for 27 years. He specialises in studies of generation costs and wind integration issues. He lectures on this and other topics at several universities, writes for *Windpower Monthly* and is Technical Adviser to the British Wind Energy Association and other bodies.

Mycle Schneider, international consultant on energy and nuclear policy, France

Mycle Schneider was the Executive Director of the World Information Service on Energy-Paris for 20 years. He now works as an independent consultant on energy and nuclear policy. He has been advising the offices of the French Minister of the Environment and of the Belgian Secretary of State for Energy (1998-2003). He was also a member of the International Chokei Review Commission that analysed Japan's long-term nuclear energy plan (2005). In 1997 he was honoured with the Right Livelihood Award for his work, with Jinzaburo Takagi, "...serving to alert the world to the unparalleled dangers of plutonium to human life". He has written many papers and articles on energy and environmental issues.

Stephen Thomas, Professor of Energy Policy, Public Services International Research Unit, Business School, University of Greenwich, United Kingdom

Stephen Thomas is a researcher at the Public Services International Research Unit (PSIRU) in the UK. He specialises in the energy sector, particularly in energy restructuring, privatisation and regulation; nuclear energy; and environmental issues. He is currently writing a book on the UK and Brazilian experiences with electricity privatisation. Before joining PSIRU he worked for 22 years at the Science Policy Research Unit at Sussex University, where he carried out many international energy projects.

Nuclear Economics

Will the nuclear industry be viable for Australia in 10-15 years?

Professor Steve Thomas: It is not clear what exactly the Taskforce may mean by 'commercially viable'. Does it mean a comprehensive nuclear industry including equipment supply or simply that nuclear power becomes competitive? From the point of view of reactor supply, if, for example, Australia was to adopt a rather ambitious target of ordering five large nuclear reactors by 2020, this would be unlikely to justify the setting up of local equipment suppliers for nuclear specific equipment. Suppliers of major pieces of equipment must go through a rigorous certification process and for the volume of orders required, it would be unlikely that these costs would be justified. New Australian suppliers would find it difficult to compete in international markets with existing suppliers with proven skills and a long track-record. Until nuclear power is established as a commercially competitive technology in Australia, it would make more sense for Australia to buy any plants from the international market.

For fuel cycle activities, such as enrichment and fuel manufacture, there are obvious values to Australia 'adding value' to the uranium mined in Australia. However, Australia would need to be similarly cautious in entering these markets. There are a number of highly experienced and skilled companies, for example, in USA, UK, France and Russia, often with facilities that are already paid for, that would be hard to compete against. Particularly in the early stages of any programme, scarce nuclear skills would need to be concentrated in areas, such as regulation, operation and maintenance where using the international market was not such an easy option.

If by 'commercially viable', the Taskforce means that nuclear power could compete, without subsidies or guarantees with other forms of electricity generation, this is difficult to predict. Clearly one element is the fossil fuel price, which is the main part of the cost of nuclear's main competitor. In today's political climate, a forecast of a high fossil fuel price seems reasonable, but the likelihood is that, while the fossil fuel price is likely to continue to be higher than it was, say, five years ago, it is likely to be volatile, present prices are probably not sustainable and there are likely to be periods when it would be relatively low. It is worth remembering that the British nuclear generation company, British Energy, was bankrupted in 2002 by, amongst other things, low fossil fuel prices. It was rescued at huge public cost (ca £10bn).

The nuclear specific elements, such as construction cost, operating cost, reliability etc have been notoriously difficult to predict throughout the history of nuclear power and until current designs are proven, the uncertainty will remain high. Of the likely technology choices, only one has been ordered, the EPR and this is at the highly problematic Olkiluoto site in Finland [see page 7 and 31 for more on this reactor].

Until there is actual experience with current designs, their economics will be highly uncertain.

Another uncertainty is the extent to which the electricity industry will run on competitive principles. This will affect how far building a new power station of any type is seen by financiers as economically risky and hence will determine the cost of borrowing. Nuclear power, because of its high construction cost can only be competitive with low interest rates.

When the electricity industry was a monopoly business, the risk of power station construction fell wholly (unreasonably) on consumers. Introducing competition means that this risk is transferred, at least in part, to plant owners and financiers. It is worth recalling that in the UK in 2002, 40% of its generating capacity (less than half owned by British Energy) was owned by effectively bankrupt companies, so the risk is real and large. Unless Australia reverts to a fully monopoly-based electricity system, the cost of borrowing for new nuclear plants will be high.

To summarise, it would be highly risky for Australia to build up a nuclear industry in areas such as equipment supply and fuel cycle services until nuclear power was well established in Australia. Whether it will be competitive is highly uncertain. World fossil fuel prices are unlikely to be predictable or stable, so while nuclear might be competitive in some years when prices are very high, it might be uncompetitive in others when the price is lower (likely to force a costly taxpayer rescue). There are also question marks about current designs because of the lack of experience with them, while the changes in the cost of borrowing that apply to nuclear orders because of liberalisation of the electricity industry seriously damage the economics of nuclear power.

Has the nuclear industry only survived due to Government subsidies, will this change in the future?

Professor Steve Thomas: Yes. Some of the subsidies are clear, such as funding for prototypes and demonstration plants, consumer subsidies and capital write-offs, assuming responsibility for decommissioning and waste disposal costs, restrictions on the extent of liability of plant owners in the event of an accident.

For the future, while most countries intending to expand nuclear power overtly say this will be on the basis that the nuclear industry meets its full costs, it is far from clear that this will be achievable and all experience suggests that when things do go wrong, it is the taxpayer that has to foot the bill.

It is clear that any future construction programme will require Government assistance. The 2006 World Energy Outlook clearly stated that: “Nuclear power will only become more important if the governments of countries where nuclear power is acceptable play a stronger role in facilitating private investment, especially in liberalised markets”.¹

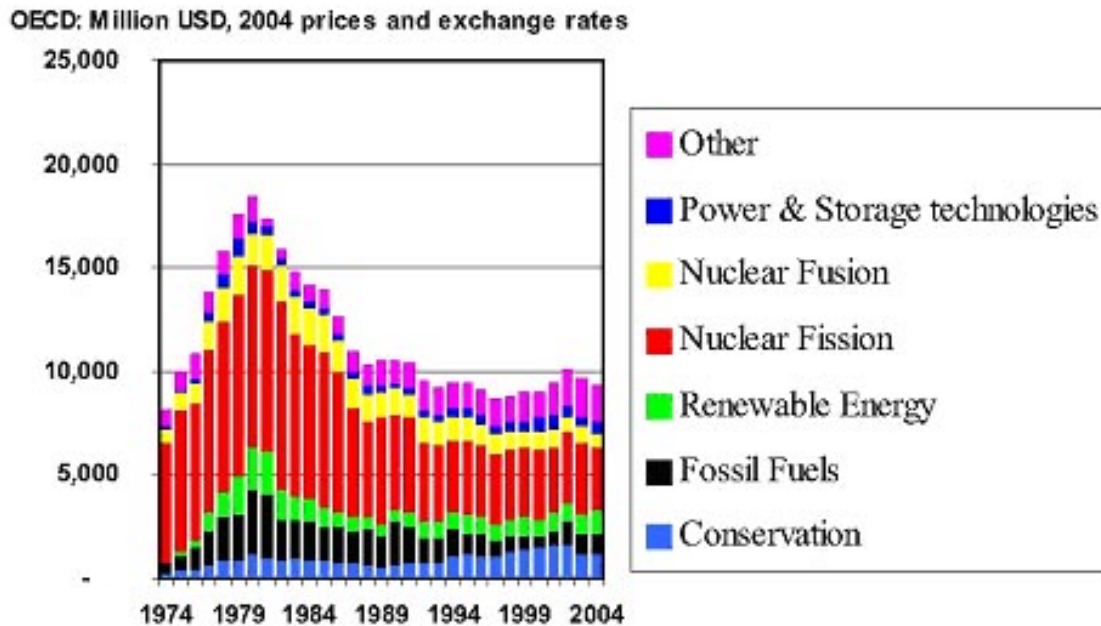
What is the global contribution from governments to the nuclear power industry?

Antony Froggatt: It is impossible to say what the total global support to nuclear power is as it comes through a variety of different sources. However, there are some important indicators for the scale of funds involved.

Firstly, government research and development (R&D) expenditure: This gives an indication of the historic and current direct government expenditure between different energy technologies. The International Energy Agency keeps a database of Government R&D expenditure. The summary of this can be seen in the chart below, which shows that nuclear research – fission and fusion – has received more funding than all other energy sources combined.²

¹ World Energy Outlook 2006, International Energy Agency, <http://www.iea.org/>

² <http://www.iea.org/Textbase/stats/rd.asp>



International Energy Agency

OECD Expenditure on Energy

It is also clear that any future construction programme will require Government assistance. A clear example of this is in the United States where the Government has announced a subsidy programme in an attempt to restart nuclear construction, which hasn't seen a reactor ordered and completed for over 30 years. This package includes:

- a tax credit of 1.8 cents/kWh for the first eight years of generation for the first six units;
- a federal loan guarantee of up to 80% of the cost of innovative technologies;
- a support framework against regulatory or judicial delays, worth up to \$500 million for the first two reactors and \$250 million for the next four; and
- further research and development funding worth \$850 million;
- plus assistance with historic decommissioning costs (up to \$1.3 billion).³

It is thought that the total cost of this nuclear support programme is around \$12 billion for six to eight reactors.

What is the cost of nuclear energy, including building, mining, transport, safety, enrichment, storage of waste, remediation and decommissioning?

Professor Steve Thomas: This is a difficult question to answer as it requires a large number of assumptions to be made, which in the past have proved difficult, and forecasts have often been very inaccurate, almost invariably far too optimistic.

The main cost of a kWh of nuclear electricity is the fixed cost associated with building the plant (usually about two thirds). This has three main components: the construction cost, the cost of borrowing and the reliability. The first, construction cost is widely discussed and the 'nuclear revival' is based on the premise that the cost of new designs will be much lower and more predictable than in the past. However, this is a claim that the nuclear industry has been

³ 2005 Energy Bill: The Impacts on Nuclear Power, ICF Consulting.

making for more than 30 years and so far it has not been fulfilled. The real cost of building nuclear plants has gone up, not down and still construction programmes are going off-track. The Olkiluoto order in Finland, widely touted as the project that would demonstrate the ability of the nuclear industry to build to time and (low) cost is already going seriously wrong and little more than a year into construction, it is a year behind schedule and well over budget.

The second element, much less discussed is the cost of borrowing. Reforms of electricity industries worldwide have tried to introduce competition into the electricity generation business and, if this works well, this will mean that if things go wrong in a nuclear project, it will be the plant owners that pay, not the consumers as was the case in the past. This increased risk on plant owners is reflected in much higher costs of borrowing because the threat that plant owners could go bankrupt is demonstrably real and banks risk losing their money.

The third element, again little discussed, is plant reliability. The more output a plant can produce, the more thinly the fixed costs can be spread. The nuclear industry has always predicted very high reliability for nuclear plants, typically 90%, but this has seldom been realised and, 15 years ago, the average reliability worldwide was about 70%. Improvements have been made and now the worldwide average is greater than 80% but still, even new designs are having reliability problems. The predecessor to the Areva EPR (the design used at Olkiluoto) was the N4 and in the first four years of operation of the four units of that design built, the reliability was only 45%.

The operating cost (operation, fuel and maintenance) is also little discussed and while generally lower than for fossil fuel stations should not be discounted. Fuel is a small element of this and mining is a small element of the fuel cost so if the uranium price were to stay high, it would not make a big difference. Of course there may be other impacts, for example, if high prices encouraged the mining of low grade uranium ore, the environmental impact of mining would be much higher. Enrichment costs have also proved relatively stable because of large enrichment capacities.

Non-fuel operating costs per kWh are much higher than expected and, of course, this is influenced by any need for safety upgrades and to deal with equipment failures.

If waste disposal and decommissioning costs are on the scale forecast by the industry and if the cost of electricity includes an element to pay for this which is kept separate from company accounts so it will not be lost if the company fails, these costs are also not a major element of the kWh cost of electricity. However, there is minimal experience of decommissioning of large commercial nuclear plants that have operated for a prolonged period (the materials have been heavily exposed to radiation) and there is little if any experience of disposing of waste, especially the longest lived and most dangerous wastes. So these estimates must be seen as little more than guesses and, if the history of the nuclear industry is a good guide, could be well below real costs. Even before there is actual experience of these operations, estimates are going up rapidly and, for example, the estimated cost decommissioning Britain's oldest reactors has gone up by a factor of about six in only 15 years. This could create huge problems for a plant owner that has taken money from consumers to pay for these operations, only to find half way through the life of the plant that the cost is dramatically higher than predicted. Companies would have to significantly increase their prices to pay these extra costs (increasing price might not be possible in a competitive market). This will be seen as a major risk by financiers, again reflected in the cost of borrowing.

What are the costs to the consumer of nuclear energy?

Professor Steve Thomas: Governments typically claim to follow the ‘polluter pays’ principle, which would imply that consumers of nuclear electricity should pay all the costs listed above. In practice, when things go wrong with nuclear power, costs are passed on to taxpayers (the Government has to pay costs that the companies can’t meet) or, worse still, costs are passed on to future taxpayers. For example, the cost of decommissioning existing nuclear facilities in the United Kingdom will fall on the taxpayers of the day, when the costs are incurred. On current plans, this could mean taxpayers 100 years or more in the future will be paying to decommission today’s nuclear facilities: clearly a morally indefensible position.

Are marketplace lenders shunning nuclear energy?

Professor Steve Thomas: Perhaps it would be more accurate to say marketplace lenders are shunning nuclear because of the risk to their investment that these concerns bring. As argued above, in the past a company lending money to build a nuclear power plant faced a low risk, because if anything went wrong, the consumer would pay. The risks are the same as they have always been but now a company owning a nuclear plant could go bankrupt and financiers would lose their money. This was very clearly expressed by the Thomas Capps, Chief Executive Officer of Dominion, a company widely reported as being likely to order a new nuclear plant soon. He said in 2005: “We aren’t going to build a nuclear plant anytime soon. Standard & Poor’s and Moody’s would have a heart attack. And my chief financial officer would, too.” The investment in new nuclear power plants in Europe have been described by the consultancy UBS as “a potentially courageous 60-year bet on fuel prices, discount rates and promised efficiency gains.”⁴

Even if they would lend money, the interest rate might be so high (to reflect the risk) as to make nuclear power hopelessly uneconomic.

⁴ UBS 2005

Renewable Energy

How much public money has been committed towards renewable energy?

David Milborrow: According to the International Energy Agency, average spending on renewable energy research development and demonstration in Australia between 1990 and 2003 was about \$US 0.4 per capita. Assuming that level has been maintained, this equates to about \$US 8 million per year. In 2002 the United States committed \$US 250 million and the European Union around \$US 390 million.⁵

Do we need to have centralised power stations?

David Milborrow: Yes. Integrated electricity networks into which such stations feed are very efficient at smoothing the fluctuations in consumer demand and smoothing the output of thermal power stations. Centralised power stations are also more efficient than smaller ones. It must be remembered that thermal plants are not 100% reliable; sometimes they are off-line for unscheduled maintenance and sometimes they instantaneously 'trip' for various reasons such as faulty instrumentation and mechanical or electrical failure. The value of an integrated network is that such 'trips' cause no problems since reserves are available to ensure continuity of supply.

Is the need for big base load power a myth?

Mykle Schneider: An electricity supply system should be designed according to energy service needs. Those are essentially light, heat, cold, mobility, communication and motor force. Usually, nobody can be interested in a large difference between base and peak load, neither during the day nor seasonal. A balanced load curve leads to lower reserve capacity needs and therefore to higher productivity of the overall system. The orientation at the service needs allows influencing the load curve through demand side management. In other words, rather than building a new plant, saving the need for it away. Lighting is a typical example because it's a daily peak load use. In many occasions utilities would make much more money simply giving away energy efficient light bulbs to curve down the consumption rather than building a new plant.

Unfortunately, the dynamic of existing capacity indeed often stimulates use, rather than the other way round. The larger the units, the bigger the probability that base load overcapacities come up. France is the ultimate example. While it has built up a huge base load nuclear overcapacity it struggles to cover seasonal peak load that exploded due to the massive introduction of electric space heating and domestic water heaters. Instead of consequently attacking peak load, the French utility has done the opposite: try to fill up the summer valley through the promotion of air conditioning.

System dynamics and second effects are vastly underestimated in energy policy.

What is the potential of wind power?

David Milborrow: Enormous. In the short term, a study by the Australian Greenhouse Office has suggested that the electricity network could easily accommodate 8000 MW of wind and there is almost certainly potential for more. It does not need 1000 windmills to produce a megawatt of power. A single 2.3 MW machine will produce, on average, nearly

⁵ EUREC Agency

1 MW. They operate for about 75-85% of the time, and their average output – depending on location – is between 30% and 45% of their ‘nameplate’ output. Reliability is now extremely high and ‘downtime’ for maintenance is typically 2%, or less.

Can wind power deliver reliable energy supply?

David Milborrow: Although numerous studies in Europe and United States have established that wind energy can replace base load power stations (roughly speaking, 1000 MW of wind plant will replace around 300 MW of thermal plant), less work has been carried out in Australia on this topic and so it is difficult to be precise. However, that is not a key issue. Even if wind cannot displace any thermal plant it still has significant monetary and environmental value in terms of its ability to save fossil fuels and so avoid CO₂ emissions. The additional value attached to displacing thermal plant is quite modest.

Is wind a significant part of energy supply anywhere?

David Milborrow: Yes. Around 20% of the annual electricity consumption in Denmark comes from wind energy. Although Denmark has links with Germany, Sweden and Norway, the system operator has recently published a paper examining the issues surrounding a penetration level of 70%. The analysis ignored the presence of these links and demonstrated that the additional cost to the consumer, with 50% wind, would be about €/MWh – about 5% extra on a domestic bill.

Will we need a landscape of windmills if wind is a significant part of the energy mix?

David Milborrow: No. To produce the same amount of electricity as a 1000 MW coal-fired power station, it is true that about 1000 2.3 MW wind turbines would be required. Denmark (much smaller than Australia) has at least three times that number of wind turbines. Assuming many of Australia’s coal-fired power stations are remote from built up areas and so there are transmission links that could be utilised to avoid building wind turbines too near built-up areas.

I note that the nuclear industry claims costs will fall. So will those of wind energy.

What is the cost comparison between a solar generator on every house in Sydney and a nuclear power plant?

David Milborrow: You would need an awful lot of solar panels to match the output of a 1000 MW nuclear power station. Taking an optimistic figure for PV output, and a pessimistic figure for nuclear output, you would need about 5000 MW of PV panels. PV panels are currently more expensive, per kilowatt, than nuclear power stations, so even if the costs fall to an equivalent level, PV will be more expensive by a factor of at least five.

PV is not yet viable for large-scale electricity generation, but has numerous uses in off-grid applications in the developed and the developing world, where the economic yardstick is not the price of centralised generation.

Have specific studies been done on non-nuclear soft energy paths for India and China?

David Milborrow and Mycle Schneider: Both China and India are pursuing ambitious renewable energy policies that acknowledge their diverse needs.

More Nuclear? What international experts say about our energy future

In India, for example, the Ministry of New and Renewable Energy suggests the wind, small hydro, and biomass potential for electricity generation totals around 80,000 MW. In addition, they are encouraging the uptake of solar water heating, biogas for heat and improved methods for cooking in locations that do not have grid access. In the shorter term, they aim to double the installed capacity of renewable sources to 13,500 MW by 2012.⁶

The picture in China is similar. There are huge resources of renewable energy, particularly hydro power and development is proceeding rapidly. By 2020, hydropower capacity is expected to reach 300,000 MW and wind capacity 30,000 MW. Renewable energy is expected to account for 16% of total energy supply (not just electricity).⁷ The principal policy tools in both China and India are 'feed in tariffs' which provide renewable energy developers with fixed prices for their electricity. This is the mechanism that proved so successful in Germany, but whereas early experience was that many of these tariffs were over-generous, that is no longer the case. Both countries come near the top of the Ernst and Young's *Renewable energy country attractiveness indices* which assesses a range of issues likely to foster investment.

⁶ Ministry of New and Renewable Energy, India, Wind Power Monthly, November 2005 p 64 and September 2006, p 60.

⁷ Source: Worldwatch Institute.

Safeguards of nuclear materials

Can IAEA inspections guarantee that nuclear material is not diverted from civilian nuclear power to weapons programs?

Mykle Schneider: No. IAEA inspections are not designed to prevent the diversion of nuclear material. They can lower the probability for a diversion from undeclared purposes to go undetected.

The Government says Australia's safeguards are among the best in the world? Is this true?⁸

Mykle Schneider: If the Australian government has made that statement, it is a surprising if not somewhat strange statement. Under the headline 'what are safeguards?' the IAEA defines: "By definition, the safeguards system comprises an extensive set of technical measures by which the IAEA Secretariat independently verifies the correctness and the completeness of the declarations made by States about their nuclear material and activities."

In other words, safeguards are carried out on a worldwide scale by the IAEA (in the EU by the European Commission) on the implementation of obligation by member states. Australia does not carry out safeguards but physical protection and verification under a state system of accountancy and control. In addition, the government has a political obligation to make sure that international treaties are respected. It has set up the Australian Safeguards and Non-Proliferation Office (ASNO) as a Division within the Department of Foreign Affairs and Trade. According to its own presentation:

"ASNO ensures that Australia's international obligations are met under the Nuclear Non-Proliferation Treaty (NPT), Australia's NPT safeguards agreement with the International Atomic Energy Agency (IAEA), the Convention on the Physical Protection of Nuclear Material (CPPNM) and Australia's various bilateral safeguards agreements (of which there are currently 20)."

"ASNO has four main areas of responsibility in the nuclear area: the application of safeguards in Australia; the physical protection and security of nuclear items in Australia; the operation of Australia's bilateral safeguards agreements; and contribution to the operation and development of IAEA safeguards and the strengthening of the international nuclear non-proliferation regime."⁹

As of the middle of 2006 ASNO had a total staff of only thirteen, including seven executive officials. Considering the list of responsibilities, one wonders how this tiny office should be up to guarantee the respect of Australia's national and international obligations on technologies of weapons of mass destruction.

⁸ Alexander Downer: "Mr Beazley says we should have the toughest nuclear safeguard arrangements in the world. Well, we already have those and they have been in place since the 1970's", Doorstop interview, Adelaide, 25 July 2006, http://www.foreignminister.gov.au/transcripts/2006/060725_ds.html

⁹ http://www.asno.dfat.gov.au/about_us.html

Table 11: ASNO Staff at 30 June 2006

	Male	Female	Total (Approved)
SES B2	1	0	1 (1)
SES B1	1	0	1 (1)
Executive Level 2	3	2	5 (5)
Executive Level 1	1	1	2 (3)
APS Level 6	1	1	2 (2)
APS Level 5	1	1	2 (2)
APS Level 4	0	0	0 (0)
TOTAL	8	5	13 (14)

*Australian Safeguards and Non-Proliferation Office (ASNO) staffing levels*¹⁰

Beyond the vast nuclear responsibilities, ASNO promises more:

“ASNO ensures that Australia’s international obligations under the Chemical Weapons Convention (CWC) are met while at the same time ensuring that the rights of relevant areas of the chemical industry are protected. ASNO also promotes effective international implementation of the CWC, particularly in Australia’s immediate region. A further activity is to contribute to activities to strengthen the Biological Weapons Convention (BWC). ASNO co-ordinates work in Australia developing the verification system for the Comprehensive Nuclear-Test-Ban Treaty (CTBT), including the establishment and/or upgrading of Treaty monitoring facilities. ASNO also contributes to the technical work of the CTBTO Preparatory Commission developing procedures for the conduct of CTBT verification activities.”

The division must be made up of quite unusual human beings.

Could anyone develop nuclear weapons from Australian uranium within the current safeguards regime?

It is quite simple to use Australian uranium under current safeguards agreements. In fact, it is quite likely that it happened in the past. Here is one – not the only – possible pathway how it could happen.

Australian uranium concentrate (U308) enters the French territory. From then on, the equivalent quantity of material carries a peaceful end-use obligation. However, it can be mixed with non-obligation uranium at various stages. The Australian origin uranium is converted in France to UF6. In the conversion process, it is mixed up with other uranium with no peaceful end-use obligation. The Australian origin UF6 is mixed with UF6 carrying no peaceful end-use obligation and enriched in the EURODIF plant.

In the past, low enriched UF6 has been used as feed material for the enrichment to high levels for use in research reactors, nuclear submarines and nuclear weapons.

¹⁰ ASNO Annual Report 2006

While France currently does not enrich uranium beyond low levels for reactor use, there is no legal obligation that would prevent it from doing so again in the future.

The Australian government has always known that France has never committed to keep Australian uranium physically from military use but only to keep an equivalent quantity of material under peaceful end-use obligation. The French government has explicitly confirmed recently that nothing has changed: “In fact, France is a civil and military nuclear power and does not have two separate cycles”.¹¹

Charles Millon, then French Minister of Defence, commented this way on Australian protests over French nuclear testing in 1995:

*“First, I would like to make an observation: Tahiti is France, Mururoa is France, it’s a French territory, and I think that many people forget that France is not only the metropolitan territory. That is my first remark. My second remark is that I am listening carefully to our Australian friends and they forget one single thing that is that it is them who sell us uranium. And there they do not have any problems with their conscience when they sell us the uranium, which they put on their ships and they send in fact their uranium ships to France to be able to operate our nuclear industry, whether it is civil or military.”*¹²

Isn’t selling uranium to China, or even France, as bad as selling uranium to India, regardless of the NPT?

Mycle Schneider: China and France are ‘official’ nuclear weapons states in the terms of the NPT. India is an ‘unofficial’ nuclear weapon state but that has carried out nuclear tests and is therefore a ‘confirmed’ nuclear weapons state. India has in the past deliberately used facilities and materials that were under bilateral peaceful end-use obligation for military purposes. France and China have supported the Pakistani nuclear program that has equally been abused for military purposes. Assuming that the term ‘bad’ suggests ‘not proliferation proof’, neither of these countries have provided sufficient guarantees for the peaceful end-use of materials and facilities. In this sense one is as ‘bad’ as the other.

Peter Bradford: Selling uranium to a country that uses its civilian reactors to produce fuel for bombs (as India does) definitely contributes to weapons proliferation. India is short on fuel of its own and can use more of its own fuel to make weapons material in the unsafeguarded reactors if it can buy fuel from Australia for some of its power plants.

Would the sale of Australian uranium to India weaken the NPT?

Mycle Schneider: The sale of Australian uranium to a non-NPT country with a negative proliferation record would further erode the credibility of non-proliferation efforts trying to limit international nuclear trade to stringent conditions.

Peter Bradford: Yes, because it will weaken the incentives for other countries to remain within the NPT framework. If India, a country that has not signed the NPT and has abused

¹¹ BSCMNS, *Rapport sur l’application des dispositions des articles L.1333-1 et suivants sur la protection et le contrôle des matières nucléaires*, Rapport d’activités 2005, undated

¹² Charles MILLON, French Minister of Defence, TV Magazine *TRANSIT*, Arte, 13 September 1995, see Mycle Schneider, Mathieu Pavageau, *Australian Uranium and the French Nuclear Weapons Program*, WISE-Paris, December 1996

nuclear exports under peaceful use assurances from the US and Canada to make its first nuclear weapon, can participate in international nuclear commerce, then other countries – especially Pakistan and Iran – will wonder why they should accept the NPT framework.

Does Australia have a significant influence in non-proliferation affairs?

Mykle Schneider: It is difficult to substantiate Australia's 'significant influence in non-proliferation affair'. Australia's long-standing opposition of nuclear testing has certainly had an influence on the international treaty negotiations. However, besides the specific issue of nuclear testing, much of the past influence seemed to have been linked rather to individuals than to national policy. For example, I have a vivid memory of former Australian UN Ambassador Richard Butler¹³ at the 1985 Non-Proliferation Treaty Review Conference, who had a physically visible influence on the negotiations over a final document that was achieved in extremis on the last day after a whole night of negotiations at 6h00 in the morning. Butler has still practised in recent years unusually frank and clear language on proliferation issues.¹⁴

Is it possible to control the nuclear fuel supply process so that countries can't divert nuclear fuel to make nuclear weapons?

Professor Steve Thomas: The non-proliferation regime is necessary and important but there can be no guarantees it will be infallible. Countries such as Israel, South Africa, North Korea, Pakistan and India have all acquired nuclear weapons under the cover of civil nuclear programmes.

Mykle Schneider: The technical capabilities to control nuclear facilities and nuclear materials have been increasing steadily. However, the IAEA's and EURATOM's Nuclear Safeguards systems have never been designed to prevent diversion for military purposes but rather to make the detection of a diversion sufficiently probable to deter any diversion in the first place. The national authorities of the countries that sign a verification agreement with the IAEA are responsible for the physical protection of materials and facilities covered by the agreement as well as for the accountancy and control.

The safeguards system can only detect something that has already taken place. There is no feasible technical possibility to gain a 100% detection capability. The probability to go undetected, if difficult to put a figure to, is in fact relatively high. Confidential IAEA Safeguards Implementation Reports have been full of technical problems reaching from blank films in surveillance cameras to operator inspection refusals because of insurance issues. History has shown that the IAEA has missed substantial developments in member states signatory to the NPT. For example, up to the first Gulf war, Iraq (an NPT signatory) developed the first steps towards a substantial uranium enrichment project on two large sites that were unknown to the IAEA.

The most frightening developments stem from the Khan network. The former head of the Pakistani nuclear program admitted transmission of highly sensitive information to various countries including Libya (an NPT signatory) and North Korea (then also an NPT signatory who quit the NPT in 2003).

History has also shown that several countries, including Pakistan, India and Israel, have diverted materials and facilities that were earmarked as civil. The idea to export nuclear

¹³ In the heated negotiations between the US, Iran and Iraq, Butler first quit his jacket and then his tie...

¹⁴ see Richard Butler, *Why Nuclear is Not the Answer*, The Age, 17 March 2002

materials to a country like Indonesia that has a broad terrorism problem seems to be particularly adventurous.

The proliferation proof nuclear fuel system is not realistic. New concepts like fuel leasing – for example the Russian sponsored concept of leasing compact fuel elements for the entire life of a reactor and taking it back after – do not change the principles of the problem. Limited technical capacities are only one side of the issue. The political will of the IAEA member states, of the states that export nuclear materials and equipments and of the states that are on the receiving ends is crucial.

In the past the practice has shown that exporting states, including Australia, has willingly accepted a system that is all but a guarantee to exclude that physically Australian uranium gets mixed up in the French nuclear fuel system that does not distinguish between civil and military uses. The 1978 trilateral Agreement between France, EURATOM and the IAEA only stipulates that an equivalent quantity of material remains under safeguards and clearly favours the conditions of the nuclear weapon state France. Australia has never insisted on anything else but the assurance that an equivalent quantity of Australian uranium remains under peaceful end-use conditions.

The NPT member states generally have shown a certain hypocrisy in the past by not giving the IAEA urgently needed additional funds to carry out more effective verification activities – the IAEA had many years of zero budget growth prior to 11 September 2001 – and complaining of the lack of efficiency after.

Has there been any assessment of the extent of undetected illicit trafficking of radioactive materials?

Mykle Schneider: Intelligence services have assessed the extent of previously undetected smuggling of nuclear materials. The US National Intelligence Council, for example, stated in its 2004 Annual Report to Congress on the Safety and Security of Russian Nuclear Facilities and Military Forces: “We find it highly unlikely that Russian authorities would have been able to recover all the material reportedly stolen. We assess that undetected smuggling has occurred, and we are concerned about the total amount of material that could have been diverted or stolen in the last 13 years.”

Porter Goss, Director of the CIA until May 2006, during a Congressional hearing in February 2005 on ‘Current and Projected National Security Threats to the US’, replies to a related question from a Congressman, with specific reference to Russia: “There is sufficient material unaccounted for, so that it would be possible for those with know-how to construct a nuclear weapon. I hope that’s sufficiently clear.”

Do we know how much nuclear material is unaccounted for?

Mykle Schneider: Precise figures on the amounts of materials involved have not been published.

The term ‘material unaccounted for’ (MUF) is a slightly misleading term because it is a technical safeguards term that is used to describe the uncertainty margin of the quantification of nuclear materials in a given material balance zone. The main problem with large-scale bulk-handling facilities, in particular for plutonium facilities like reprocessing and plutonium fuel fabrication plants, is that the technical capabilities are very limited. This means in practice that several bombs worth of material can be unaccounted for because operators and

More Nuclear? What international experts say about our energy future

inspectors are technically unable to measure more precisely. This material can be stuck to the inner walls of pipes, containers and glove boxes in large quantities. In the case of the Japanese small reprocessing plant at Tokai-mura the quantity was estimated to over 70 kg of plutonium.

Greenhouse implications of the nuclear industry

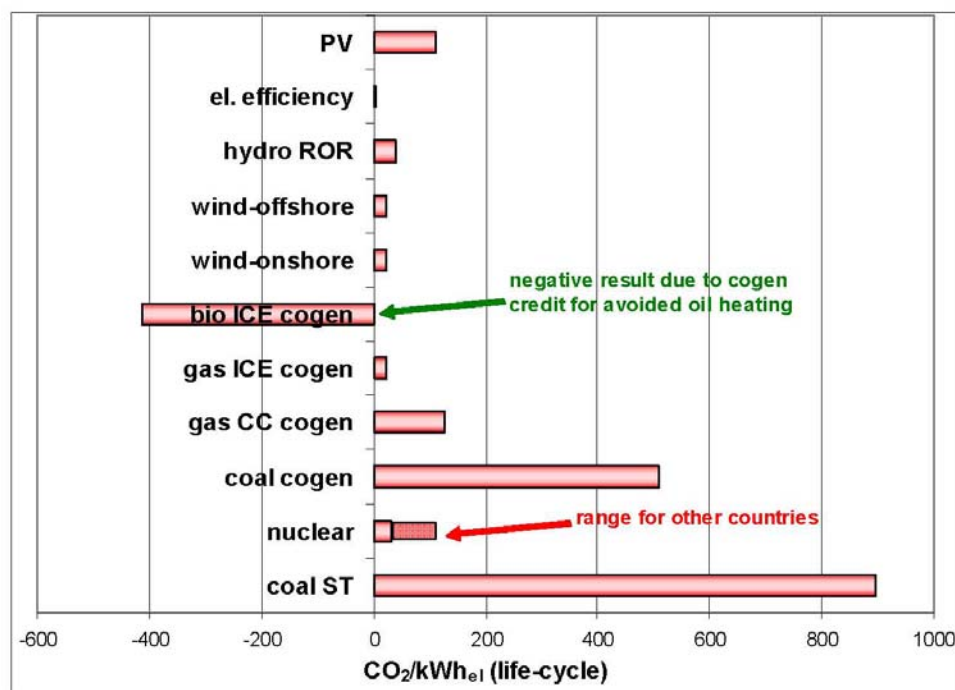
Are there agreed comparisons of greenhouse gas emissions/financial costs/public subsidies for the whole of life cycles of each current energy source, including geothermal generated electricity?

Antony Froggatt: There is a range of estimates for the greenhouse gases from the whole of the fuel cycle. This will vary considerably on the technology deployed, the concentration of the ore mined, the transportation distances necessary and the efficiency of the whole system.

A report published earlier this year by the Öko-Institut in Germany suggested that the nuclear power plants in Germany produced 33g CO₂ (equivalent)/kWh (electrical). However, they also cited other papers that give larger ranges, 30-60g from the IEA and up to 120g/kWh by Van Leeuwen/Smith.¹⁵

Given the lack of agreement on CO₂ emissions from nuclear power plants, due to the significant technological and policy variations, there is no agreed comparison. However, below is a graphic, from the Öko-Institut, which gives one particular view.

Figure 3 Life-Cycle CO₂ Emissions from Electricity Generation (GEMIS data)



Source: own calculation with GEMIS 4.3

Life-cycle CO₂ emissions from electricity generation

¹⁵ Comparison of Greenhouse-Gas Emissions and Abatement Cost of Nuclear and Alternative Energy Options from a Life-Cycle Perspective, Öko-Institut January 2006

Globally, can significant cuts in greenhouse gas emissions be achieved without nuclear power?

Peter Bradford: Nuclear power cannot be a magic bullet answer to climate change. Even if it is scaled up much faster than anything now in prospect, it cannot provide more than 10-15% of the greenhouse gas displacement that is likely to be needed by mid-century.

Those who tell you things like: ‘It could save the earth’¹⁶ or ‘Clean, green atomic energy can stop global warming’¹⁷ or ‘Nuclear energy just may be the energy source that can save our planet from catastrophic climate change’¹⁸ are inviting you into a dangerous la-la land in which nuclear power will be over-subsidized and under-scrutinized while other more promising and more rapid responses to climate change are neglected and the greenhouse gases that they could have averted continue to pollute the skies at dangerous rates.

Not only can nuclear power not ‘stop global warming’, it is probably not even an essential part of the solution to global warming. A widely noted paper by Princeton professors Stephen Pacala and Robert Socolow introduces the useful concept of a ‘wedge’, defined as any measure that would, over the next 50 years, lead to a global reduction of 25 billion tons of carbon dioxide emissions relative to business as usual. The number of wedges that will be required to avoid dangerous climate change will depend on many factors. Under optimistic assumptions, some seven wedges will be needed; this number could increase significantly under less optimistic assumptions.

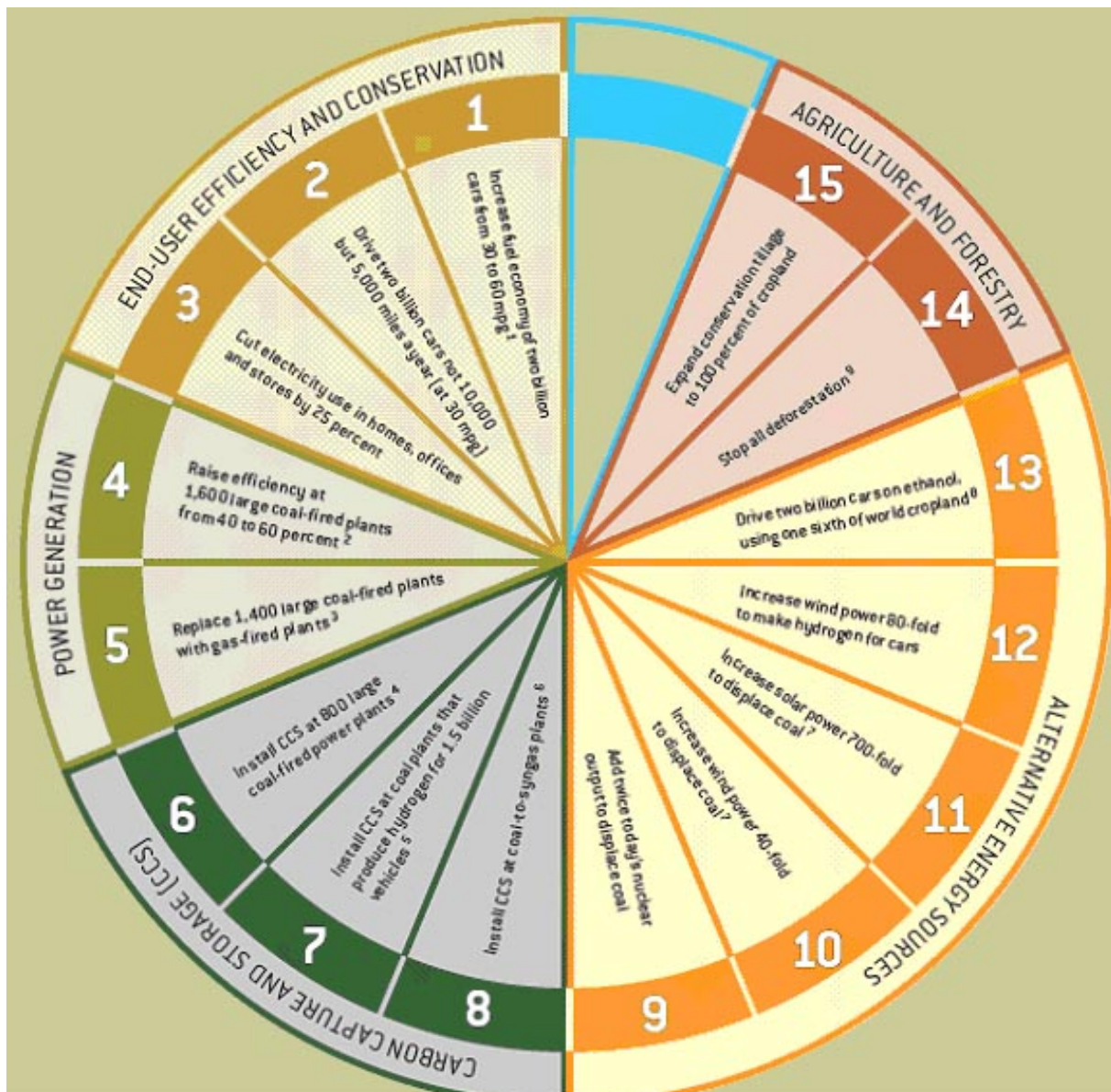
The study provides a list of fifteen measures from technologies to public policy initiatives that exist today and could be scaled up to become one or more wedges. In brief, energy efficiency and conservation comprise three wedges, alternatives to business-as-usual gasoline-powered transportation accounts for another four, and increasing natural sinks provides two wedges. Generating electricity in less carbon intensive ways contributes four wedges. Of the latter, at most one wedge would be contributed by a world-wide tripling of nuclear power”.¹⁹

¹⁶ National Geographic, April, 2006

¹⁷ Wired Magazine, February, 2005

¹⁸ Patrick Moore, Washington Post, April 16, 2006

¹⁹ From Peter Bradford and Kurt Gottfried, <http://www.commondreams.org/views06/0915-28.htm>



A 'wedge' is defined as any measure that would, over the next 50 years, lead to a global reduction of 25 billion tons of carbon dioxide emissions relative to business as usual²⁰

To constitute even one wedge, nuclear power must triple world wide over the next fifty years, if the new plants replace only coal and old nuclear units. To the extent that the new units replace natural gas or hydroelectricity, even more are needed.

Tripling nuclear power worldwide over the next 50 years will require a massive scaling up of nuclear construction. As the wedge chart shows, nothing resembling such a nuclear renaissance is now underway. Indeed, when retirements are netted against nuclear capacity additions, the worldwide annual growth rate is about 5%, far under the 15% that a wedge will require (and this shortfall will increase as the rate of nuclear power plant retirement inevitably increases).

²⁰ Pacala and Socolow, "A Plan to Keep Carbon in Check", Scientific American, September 2006, p. 54

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Country	Nuclear capacity GW (plants)	Percent of electric production	Plants under construction
United States	99.2 (104)	20	0
France	63.4 (59)	79	0
Great Britain	11.9 (23)	22	0
Japan	47.8 (55)	34	1
Russia	22 (31)	14	4
Canada	12.6 (18)	13	0
Germany	20.3 (17)	29	0
South Korea	16.9 (20)	40	3
India	3.9(16)	03	7
Ukraine	13.5 (15)	48	2
China	6.7 (10)	02	4
World total	370 (442)	16	28

Nuclear power capacity²¹

However, nuclear power is considerably more expensive and controversial both than other ways of generating electricity and than other ways of curbing CO₂ emissions, so this trebling can only be done by providing direct subsidies and other governmental assistance to nuclear power. The subsidies enacted by the US Congress in 2005 are substantial, but they are limited to a few plants. They may produce a limited number of plant orders, though they have yet to do so. But this will prove only that governments can build nuclear plants by putting taxpayers and customers (instead of investors) at risk for financial disappointment. China and Russia already teach us that.

²¹ Taken from John Deutch and Ernest Moniz cochairs, *The Future of Nuclear Power*, (MIT, 2003), <http://web.mit.edu/nuclearpower/>, p. 41

Table 5.1 Costs of Electric Generation Alternatives			
Real Levelized Cents/kWe-hr (85% capacity factor)			
<i>Base Case</i>	25-YEAR	40-YEAR	
Nuclear	7.0	6.7	
Coal	4.4	4.2	
Gas (low)	3.8	3.8	
Gas (moderate)	4.1	4.1	
Gas (high)	5.3	5.6	
Gas (high) Advanced	4.9	5.1	
<i>Reduce Nuclear Costs Cases</i>			
Reduce construction costs (25%).	5.8	5.5	
Reduce construction time by 12 months	5.6	5.3	
Reduce cost of capital to be equivalent to coal and gas	4.7	4.4	
<i>Carbon Tax Cases (25/40 year)</i>			
	\$50/tC	\$100/tC	\$200/tC
Coal	5.6/5.4	6.8/6.6	9.2/9.0
Gas (low)	4.3/4.3	4.9/4.8	5.9/5.9
Gas (moderate)	4.6/4.7	5.1/5.2	6.2/6.2
Gas (high)	5.8/6.1	6.4/6.7	7.4/7.7
Gas (high) advanced	5.3/5.6	5.8/6.0	6.7/7.0

Costs of electric generation alternatives

The power plants aren't the whole story. A nuclear wedge requires fuel enrichment (perhaps an additional 15 plants), waste repositories (perhaps the equivalent of 14 Yucca Mountains) and perhaps reprocessing plants. The only effort to model the cost of this undertaking that I have seen comes from the Natural Resources Defense Council and puts the total bill between two and three trillion dollars.

A sensible approach to climate change would start with a trading regime or a carbon tax that would put a significant price on fuels according to their carbon content. It would offer non-discriminatory governmental support to technologies in accordance with their ability to achieve the needed reductions rapidly, inexpensively and in a manner acceptable to the public. It might well mimic the California approach to new electric facilities, in which all practical efficiency and renewable options are deployed before a new central station power plant is considered. Because the spread of nuclear weapons is a menace at least comparable to

climate change, it would insist that nuclear power's growth occur in ways that diminish rather than enhance the association between nuclear power and the spread of nuclear weapons.

Nuclear proponents should welcome such an approach. If theirs is truly the most economic technology, it will prevail in competition with the other wedges. If it is even minimally competitive, enough plants will be built to enable nuclear power to maintain its current worldwide share of electric energy production.

But instead we're seeing from most nuclear proponents their old five P playbook – pushed power plants; postponed problems. Nuclear power's asserted comeback in the US rests not on newfound competitiveness in power plant construction, but on an old formula: subsidy, licensing shortcuts, risks borne by customers and taxpayers, political muscle, ballyhoo and pointing to other countries (once the Soviet Union, now China) to indicate that the US is 'falling behind'. Climate change has replaced oil dependence as the bogeyman from which only nuclear power assertedly can save us.

Asserting that nuclear power answers climate change is like asserting that the Iraq invasion answers September 11. This is policy making built on distraction, bolstered by deception, burdened by debt and bound for disillusion. No wonder it's in vogue in today's Washington.

Where nations with liberalised economies are developing new nuclear power plants, has reducing greenhouse gas emissions been an important consideration?

Professor Steve Thomas: The only Western country to place a new order for a nuclear plant in the past 15 years is Finland. The Finnish electricity supply industry had been trying to get permission to build this plant since the late 1980s, long before global warming was a widely accepted phenomenon.

Of the countries considering nuclear power, the UK is the one that has most explicitly linked the decision with greenhouse gas emissions. However, the UK timetable does not foresee a unit being completed before 2021 (ordered in 2015) so there is considerable scope for these plans to be de-railed.

The US government is pushing hard to revive nuclear ordering but not for reasons to do with global warming. For other countries considering orders, the motivation appears to be a mix of desire to diversify out of fossil fuels, desire to decrease import dependence on fossil fuels (nuclear power is seen as an indigenous source whether or not the uranium is imported) and concern about greenhouse gases. There remain major political and economic obstacles to ordering and a realistic timescale for orders in any of these countries would be similar to that of the UK.

There are frequent claims that the latest nuclear power reactor designs, such as the Westinghouse AP1000 which the Australian Government seems to be considering, are safer than earlier models.

What are the greenhouse emissions and financial costs of reprocessing spent fuel rods?

Mykle Schneider: The reprocessing of spent nuclear fuel does not directly emit traditional greenhouse gases. However, there remains great scientific uncertainty to what extent the massive release of krypton-85 (half-life 10.7 years) through reprocessing – basically the only

source for krypton-85 – has an influence on climate change. Krypton-85 “increases conductivity of lower atmosphere, with possible implications for earth’s electric field and precipitation from convective clouds”.²²

Reprocessing consumes also considerable amounts of electricity. The respective greenhouse gas emissions depend on the fuel mix of the given country.

The costs of reprocessing are complex to evaluate. Reprocessing consists of the separation of uranium and plutonium from (other) radioactive waste. It basically splits up one single waste stream into a number of different waste streams. A significant share of the waste volume is released into the environment in the form of gases and liquids during the reprocessing operations. Reprocessing in France and the UK contributes by far the largest share to the collective dose from nuclear power in Europe (>80%)²³. In fact, it is important to compare the two spent fuel management options: direct disposal as waste and reprocessing. Even without taking into account the potential substantial external costs like environmental pollution and health effects, reprocessing is much more expensive than the “once through” option. As Harvard’s eminent nuclear expert Matthew Bunn pointed out during recent congressional hearings:

“In a recent Harvard study, we concluded that reprocessing would increase spent fuel management costs by roughly 80%, compared to once-through approaches, even making a number of assumptions that were quite favourable to reprocessing. A wide range of other studies, including government studies in both France and Japan, have reached similar conclusions.”²⁴

What sort of greenhouse emissions/financial costs/safety issues are incurred by the mining/milling/processing of lower-grade uranium?

Mycle Schneider: The elaboration of an appropriate response to this question would go beyond the scope of the exercise. However, it is perfectly clear that the exploitation of lower-grade uranium resources as well as of the large uranium resources in sea water would consume significantly larger quantities of energy. The impact in terms of greenhouse gas emissions and costs would be highly dependent on the energy mix in the network, the fissile uranium content and the ore access path.

How much water is needed to ensure safety for the whole uranium energy cycle, from mining to storage of waste?

Antony Froggatt: The panel does not contain a specific expert on uranium. There are a number of experts that might be able to help further with this, both in Australia and other parts of the world. Two are listed below, one from an environmental NGO the other from an industry lobby/information group, these are: the Wise Uranium Project (<http://www.wise-uranium.org>) and the World Nuclear Association – formally the Uranium Institute (<http://www.world-nuclear.org/>)

²² http://stephenschneider.stanford.edu/Climate/Climate_Science/PrincipalHumanActivities.html

²³ for details see Mycle Schneider et al. *Possible Toxic Effects from the Nuclear Reprocessing Plants at Sellafield (UK) and Cap de la Hague (France)*, Final Report for the Scientific and Technological Options Assessment (STOA) Program, Directorate General for Research, European Parliament, Luxemburg, November 2001

²⁴ see http://bcsia.ksg.harvard.edu/BCSIA_content/documents/bunn_gnep_testimony.pdf

Radioactive Waste

For how long do the various forms of nuclear waste remain dangerously radioactive?

Mycle Schneider: There are radioactive isotopes or radio-nuclides of half-lives varying from hours to millions of years. During a half-life the radioactivity naturally decays by half of the original value. Depending on their respective radiotoxicity, radionuclides can represent a significant health risk for many times their half-life. The impact of radioactivity on health and the environment depends on the physical and chemical form and the type of radiation, its radioisotopic composition of radioactive substance as well as on the way it is integrated into the human body or the environment. For example, plutonium particles inhaled can cause lung cancer in quantities of a few millionth of a gram while its penetrating radiation is low and can be shielded relatively easily. Plutonium is also a highly strategic heavy metal that is very dense. The 6 kg that were contained in the Nagasaki bomb would fit into a coke can.

Significant radionuclides in nuclear wastes include the radioactive form of hydrogen tritium with a half-life of 12.3 years. Tritium behaves like water, including in the human body, and is extremely difficult to contain. The radiological half life of plutonium is about 24,000 years and the biological half life is about 20 years for liver and 50 years for skeleton. Plutonium represents about 1% of spent nuclear fuel. A standard light water reactor produces about 250 kg of plutonium per year. A large scale reprocessing plant separates several metric tons of plutonium per year.

Other significant radionuclides contained in nuclear waste include iodine-129 with a half-life of 16 million years that is released into the air and the sea in vast quantities by reprocessing plants or remains contained in spent fuel. Iodine fixes on the thyroid and the short-lived isotope iodine-131 released from Chernobyl has generated hundreds of cancer cases in children and adults. Technetium-99 (half-life 214,000 years) discharges from the UK Sellafield plant have led to particular concern.

Technetium concentrations in crustacean – particularly in lobster – reached 13 times the European Council Food Intervention Level (CFIL) in the vicinity of Sellafield, travelled by sea as far as Norway and has concentrated there in fish, shellfish, sediments and aquatic plants, sometimes exceeding CFILs several times.

Will the proposed geologic waste repository at Yucca Mountain in the US leak. Is there any guarantee that it would not leak?

Mycle Schneider: There are indeed numerous scientific flaws in the safety assessment of the proposed Yucca Mountain final nuclear waste repository. One of the key problems consisted in the fact that the project's promoters could not provide the necessary guarantees that dose limits would be respected over time periods under consideration.

On 9 July 2004, the US Court of Appeals for the District of Columbia decided that the '10,000 year rule' was not consistent with the findings of the US National Academy of Sciences that had recommended that a standard be developed that would provide protection when radiation doses reach their peak within the limits imposed by long-term stability of the geologic environment, which turned out to be well after the 10,000 years originally envisaged. In fact, peak doses could be reached several hundred thousand years from now.

The imagination to provide a 'sure guarantee' over those time frames seems to stem from the arrogance unfortunately widespread in the nuclear community.

For how many years can spent fuel be reprocessed to produce weapons grade plutonium or uranium?

Mykle Schneider: There is no specific time limit for the separation of plutonium and uranium from spent nuclear fuel as it can be stored for decades. However, depending on the degradation of certain types of fuels (e.g. metallic fuels) under certain storage conditions (e.g. in water), the fuel rods might get damaged and the reprocessing could become significantly more complex. In fact, weapons grade plutonium is often generated in dedicated production reactors that use metallic fuels (e.g. gas-cooled, graphite-moderated reactors).

Plutonium is characterised as either weapons grade, fuel grade, or power reactor grade based on the percentage of Plutonium-240 that is contained in the plutonium. Weapon grade plutonium contains less than 7 percent Pu-240. Fuel grade plutonium contains from 7 percent to less than 19 percent Pu-240, and power reactor grade contains from 19 percent and greater Pu-240. The quality of the plutonium has a great impact on the critical mass and therefore on the necessary quantity of material for a nuclear weapon – and on size and predictability of the weapon. However, it should be stressed that practically all plutonium generated in a nuclear reactor can be used to fabricate an explosive device.

Longer storage periods prior to reprocessing lead to additional build-up of americium-241 (through decay of plutonium-241 that, like plutonium-239, is also fissile), which is highly radioactive and is not wanted in nuclear weapons. In fact, part of the 'maintenance' of nuclear weapons is the regular replacement of the plutonium and the americium taken out. But americium is also separated during the reprocessing process so that, in case of delayed reprocessing, the only effect is a reduction of the total fissile plutonium content. There is nothing that would prevent a potential proliferator to use 'old' spent fuel.

The quality of the uranium would not be modified significantly even during storage of several decades. But the strategic value of reprocessed uranium is very low (even lower than natural uranium).

Which storage method is preferred? How proven is it?

Antony Froggatt: Currently there is no operating waste repository for civilian high level radioactive waste. A number of options are under consideration for either the long term storage – above or below ground – or the final disposal of high level radioactive waste.

The preferred method of disposal of high level waste therefore varies from country to country.

Is community acceptance of nuclear waste the main barrier to nuclear power?

Antony Froggatt: It is clear that nuclear waste is one of the key issues for public acceptance for nuclear power, but it is by no means the only issue. Other issues include:

- Nuclear Safety: Following the accident at Chernobyl in 1986 nuclear power orders were cancelled across the world.
- Nuclear Economics: The high cost of nuclear power has stopped private and public utilities choosing to put nuclear power in their energy mix.

- Nuclear waste is an important issue for the public, both because of the scientific uncertainties over nuclear waste disposal, due to the polarised debate over the impact of radionuclides on human health and the longevity of many of the radio-isotopes involved and because it is in many countries the only visible ‘dirty’ side of nuclear power. As uranium is often mined and made into nuclear fuel in another country, the disposal of nuclear waste highlights to many people the environmental consequence of nuclear power.

What guarantees exist about groundwater supplies at proposed waste dump sites both in Australia and around the world?

Antony Froggatt: It is not possible to answer this question either for Australia or for other proposed sites around the world. Some radioactive waste requires isolation from the environment for thousands and even hundreds of thousands of years; it is impossible to give any guarantees and even if they were it is highly questionable of what value they would be.

What guarantee is there that levels of security and safety for the storage of nuclear waste in relation to governance and environmental/geological conditions will remain the same in hundreds of years time?

Antony Froggatt: The intergenerational aspects of nuclear waste storage or disposal raise a number of important questions. Given that some waste needs to be isolated from the environment for hundreds of thousands of years, it is difficult to know what guarantees could or should be given.

Is the main objective of GNEP to resolve the problem of spent fuel storage?

Mykle Schneider: According to the US Department of Energy that initiated the Global Nuclear Energy Partnership (GNEP), the purpose of GNEP is:

“to facilitate the safe, secure, and economic expansion of nuclear energy use by:

- developing and deploying advanced, proliferation resistant nuclear energy systems that avoid separation of pure plutonium and make it as difficult as possible to misuse or divert nuclear materials to weapons;
- promoting small and medium size proliferation-resistant reactors designed to meet the needs of developing economies; and
- providing assurances of fresh fuel and spent fuel management to states that agree not to pursue enrichment and reprocessing programs.”²⁵

The key purpose, complementary to the Generation IV International Forum (GIF) which was launched in 2000 and designed to optimise R&D into new reactor technologies, is to revamp initiatives for the internationalisation of uranium enrichment and reprocessing. The concept of an international store for spent fuel is part of the idea. Attempts to internationalise the siting of spent fuel storage or even disposal facilities have failed in the past and there is no sign they will succeed in the future.

Peter Bradford: In early 2006 the Bush administration announced a new nuclear power initiative, the Global Nuclear Energy Partnership, or GNEP, intended to further expand worldwide use of nuclear power, facilitate disposal of nuclear waste and diminish the

²⁵ DOE Ass. Secretary for Nuclear Energy Dennis Spurgeon, Vienna, 19 September 06, see <http://energy.gov/news/4173.htm>

likelihood of nuclear weapons proliferation. GNEP entails development of a plutonium separation technology that does not separate the plutonium from other actinides present in spent fuel. This plutonium is therefore useable for fuel but not immediately as a bomb.

The not-completely separated plutonium would be used as fuel in a generation of advanced (and as yet unproven) reactors. Fuel enrichment and waste processing services would be provided by the nuclear weapons states for other nations desiring to develop nuclear power, willing to forego enrichment and to turn their spent fuel over to the weapons states for processing.

Among the difficulties are that the separated plutonium would not be all that proliferation resistant; the advanced reactor technology is undeveloped and therefore the economics are at best unknown, and the waste disposal advantages of the GNEP approach are largely illusory.

The response of the nuclear industry has been discrete, but strong and technologically knowledgeable proponents of nuclear power have written to the effect that GNEP is “unlikely to achieve these goals and will also make nuclear power less competitive economically”²⁶ and “In general I admire the goal of GNEP, but visions that ignore technical reality have often led to disasters, since they preclude more conventional and incremental approaches”.²⁷

In short, GNEP illustrates the vulnerability of nuclear power to the excesses of its proponents, an old theme with many examples ranging from excessive licensing and regulatory shortcuts and secrecy to hurried and uneconomic technological choices. Nuclear power as it might unfold under conditions of perfect statesmanship is far removed from that which will unfold in the real world. Implementation counts for more than intention. It is the real world version – determined in large part by bureaucratic economic imperatives – that will determine the actual hazards that accompany the building of large numbers of new nuclear units.

The 1979 Ford Foundation study concluded its chapter entitled “Nonproliferation and Terrorism” with a list of seven measures that “have major non-proliferation significance”:

- A clear decision to defer plutonium reprocessing and recycle.
- De-emphasis of the breeder program with deferral of the early date for commercialization.
- Reduced priority for nuclear power in energy research and planning, in a framework giving equal weight to coal in the short term and alternative replenishable energy sources over the long term.
- Avoidance of promotion of nuclear power both at home and abroad.
- Orderly expansion of enrichment facilities to correspond to realistic projections of future demand at home and abroad.
- Continued refusal to export plutonium separation and enrichment technology, coupled with efforts to achieve similar action by other suppliers.
- Approval of nuclear exports only where consistent with US security interests and obligations and non-proliferation policy.

²⁶ Richard Lester, MIT professor of nuclear science and engineering, “New Nukes”, *Issues in Science and Technology*, Summer, 2006, p. 40.

²⁷ Testimony of Richard Garwin before the House Science and Technology Committee, June 26, 2006, http://www.fas.org/RLG/062606GNEP5_1.pdf, p3

More Nuclear? What international experts say about our energy future

Longstanding national policy, primarily the enactment of the Nuclear Nonproliferation Act of 1978, made these measures cornerstones of US nonproliferation policy for three decades. GNEP – in combination with the pending nuclear arrangement with India²⁸ and today’s Congressional policies – compromises all of them, except the fifth.

²⁸ The legislation to implement the arrangement that President Bush has reached with India would remove the 1978 Nuclear Nonproliferation Act’s restrictions on nuclear exports to India, which does not comply with the existing law because, inter alia, it does not allow IAEA inspections of all of its nuclear facilities. The 1978 law was adopted after India in 1974 tested a nuclear explosive using technology and materials furnished under assurances of peaceful use by the US and Canada. India explained that it intended to use its nuclear explosives peacefully. Pakistan’s President Zulfikar Ali Bhutto said that once India built a bomb “we will eat grass or leaves, even go hungry, but we will get one of our own”.

Australia and the Global Nuclear Industry

Can Australia play a role as champion of safe nuclear power?

Professor Steve Thomas: No. If Australia is to build nuclear power plants, it should only be using technology that meets the highest standards. The plants should be built, operated and maintained to similar high standards. However, this applies to any other country seeking to build new plants. Australia is not in a position to demand from vendors higher standards than apply elsewhere in the world.

Mycle Schneider: The question implies two underlying assumptions: that there is something like ‘safe nuclear power’ and that a nation could become a ‘champion’ in the domain.

There is currently no operating nuclear power reactor (so-called generation I and II) that is safe in the sense that an accident involving releases of large quantities of radioactive substances could be excluded. All of the 442 operating reactors contain very large inventories of radioactivity that could be released to the environment in case of catastrophic core melt or power excursion accidents.

There is no nuclear operator in the world that considers its facilities fail-safe. Nuclear operators have nevertheless justified the operation of nuclear power plants on the basis of a theoretical very low probability of large-scale radioactivity releases on the basis of the equation.

Very high impact x very low calculated probability of occurrence = Acceptable risk.

While many people have never accepted this equation in the first place, the situation has dramatically changed with the outspoken possibility of terrorist acts against nuclear facilities, shipments and materials. From the moment onwards that the ‘low probability of occurrence’ is wiped out by the possibility of deliberate attack, many safety features of a nuclear facility become pointless and we are left with ‘high impact’. Sabotage with catastrophic effects can be carried out with relatively simple means. For example, several hours of interruption of power supply to a nuclear plant can be sufficient to prevent efficient core cooling and therefore lead to a core melt-down accident.

The first so-called Generation III prototype reactor is currently under construction in Finland. While it has certain additional safety features that make it also more resistant to terrorist or military attack, the unit is by no means inherently safe. In fact, the radiotoxic inventory of the plant will be higher than that of currently operating nuclear reactors because it is the largest unit ever built (1,600 MW) and is planned to be operated with higher enriched and plutonium bearing fuels.

So-called Generation-IV reactors are in the early design phase and it is much too early to predict to what extent the level of safety would be increased over existing designs. However, one important feature expected to be implemented is that they would be much smaller units (100 MW to 200 MW) and therefore accordingly have smaller radioactive inventories.

According to Oxford American Dictionaries, a ‘champion’ is someone “who has defeated or surpassed all rivals in a competition”. While the question is speculative whether Australia ‘can play a role as champion’ of nuclear power, the least one can say is that this is highly

unlikely for decades to come. Australia's competitors in the field have built and operated over 550 commercial nuclear plants around the world (about 110 have been shut down already). The world's largest and most experienced nuclear builder, the Franco-German AREVA NP that is currently building the Generation III reactor Olkiluoto-3 in Finland, has great difficulties in implementing the project. This is not only due to the prototype nature of the project but especially due the lack of competence and experience in nuclear power plant building and the harsh competitive economic environment. The last construction start of a nuclear unit in Western Europe dates back to 1993 in France. In a stinging report²⁹, the Finnish nuclear safety authority STUK has highlighted a large number of problems. Here are a few examples on what seems to be very basic technology – pouring the base slab concrete:

- “In the selection of the concrete supplier, the special quality requirements applied in a nuclear power plant construction were not brought up in the tender invitations, whereas cost factors were strongly emphasised in the selection.”
- The concrete supplier “was using a concrete specification that had not been officially approved” by AREVA NP;
- “The availability of quality records was not verified and the requirements of IAEA's quality standards were not taken into consideration in the quality management system.”
- “The levelling and the steel trowelling of the slab surface, in particular, were not done properly because the workers were too tired.”
- “The non-conformance report ... stated that the reference strength of the concrete according to the site test specimens did not meet the requirement ...”
- “However, it is not right to blame an individual supplier for the poor safety culture, as the consortium's practices in the selection and guidance of the concrete supplier were deficient. The consortium should acknowledge the fact that jobs in the nuclear field are rare and it is therefore to be expected that nuclear safety is not the number one priority in the subcontracting companies operating in different fields.”
- “The owner is everything else than happy about the situation. We are very disappointed”, the Finnish utility TVO's project manager Landtmann stated in a recent interview.³⁰ In the meantime the reactor builder AREVA NP has provisioned a loss of an estimated €300 million or roughly 10% of the project value due to a delay of at least one year after only one year of construction.

It is hard to conceive that the Australian industry as a total newcomer to nuclear power would do better than the largest and most experienced builders in the world, and these builders struggle getting one large project off the ground.

²⁹ STUK, *Management of Safety Requirements in Subcontracting During the Olkiluoto-3 Nuclear Power Plant Construction Phase*, 10 July 2006, http://www.stuk.fi/stuk/tiedotteet/en_GB/news_419/files/75831959610724155/default/STUK%20Investigation%20report%201_06.pdf

³⁰ Radio France International, German Edition, broadcasted on 10 November 06

Has nuclear energy proven to be ‘very safe’ as claimed by Mr Murdoch this week? ³¹

Mykle Schneider: The term ‘very safe’ needs to be defined. The Oxford American Dictionaries define ‘safe’ as “not likely to cause or lead to harm or injury; not involving danger or risk”. The enhancement ‘very safe’ could therefore stand for “highly unlikely to cause or lead to harm or injury; never involving danger or risk”. Considering its history of accidents and near-misses, it is hard to understand how anyone could then label nuclear power as ‘very safe’.

The 20th Anniversary of the Chernobyl disaster in Ukraine has illustrated once again the terrifying practice to account for human detriment in terms of number of visible body bags. An expert controversy about how many people were and will be killed was sparked by the anniversary of the most terrible accident of the industrial age.

Thousands of coal mining workers get killed in Chinese coal mines every year: an appalling and totally unacceptable safety level. By the way, this is a situation that has never seemed to disturb the non-Chinese companies that are producing far more than half of the Chinese exports and consuming considerable amounts of coal-fired electricity.

However, as the exact type and extent of future impacts of the emissions of greenhouse gases are hardly known yet, a lot of the impacts of radioactive emissions are unknown yet. Worse, the established consequences are far from part of the collective consciousness. While the Chernobyl death toll is still a matter of debate, it is established that several tens of thousands of people around the planet will likely die from fallout.³²

Besides the ‘body count’, the devastating effects of the disaster on the environment, on the economy, on some 400,000 dislocated people, and the general state of health in the most affected areas are well documented but not well known. In fact, 40% of the European territory was contaminated to various degrees and the radioactive fallout continues to impact agriculture and food management in several Western European countries. Twenty years after the accident, highly contaminated game in Germany, reindeer in Scandinavia and mushrooms in various countries cannot be consumed. About 200,000 sheep in the UK have to undergo a complex pasture management scheme in order to allow them on clean pastures for the natural decay of radioactivity taken up on contaminated pastures before.

The Chernobyl-4 reactor generated power for two years, four months, and four days but human suffering, health detriment and environmental pollution will go on for generation after generation. Who would dare to say it was worth the risk?

³¹ Paul Starick and Christopher Russell, *Murdoch slams lack of planning*, November 15, 2006, Courier Mail (Brisbane) <http://www.news.com.au/sundaymail/story/0,,20766452-953,00.html>:

Mr Murdoch, chairman and chief executive officer of News Corporation (publisher of The Courier-Mail), was in Adelaide yesterday for a shareholder information meeting. Speaking after the meeting, he said nuclear energy had proven to be “very safe”, if expensive. “It takes time ... but we should be getting on with it. Right away,” he said. He conceded waste disposal was “a problem” for community acceptance of nuclear power but it should not be a large barrier. Mr Murdoch also said climate change was too serious an issue to ignore and it was up to private enterprise to act. News Corporation was determined to take a responsible position on reducing greenhouse gases, he said.

³² see for example: Ian Fairlie, et al. *The Other Report on Chernobyl*, commissioned by Rebecca Harms, MEP and the Combecher-Altner and Hatzfeld Foundations, Berlin, Brussels, Kiev, April 2006, http://www.greens-efa.org/cms/topics/dokbin/118/118499.the_other_report_on_chernobyl_torch@ru.pdf

While an ‘identical accident’ as in the Chernobyl type reactor is unlikely to take place in any other type of reactor, an accident that releases the same amount of radiation or even more is perfectly plausible. Worse, many units operate in densely populated areas that would make the effects of an accident even much more severe than in the case of Chernobyl.

But also the normal operation of nuclear power plants leads to radiological risks. A very large research project into the impact of radiation on worker health published the results in 2005:

*“On the basis of these estimates, 1-2% of deaths from cancer among workers in this cohort may be attributable to radiation. Conclusions: These estimates, from the largest study of nuclear workers ever conducted, are higher than, but statistically compatible with, the risk estimates used for current radiation protection standards. The results suggest that there is a small excess risk of cancer, even at the low doses and dose rates typically received by nuclear workers in this study”.*³³

Nuclear power will never be ‘very safe’.

What are the pros and cons of nuclear leasing?

Antony Froggatt: Nuclear fuel leasing is being proposed within the framework of the GNEP in an attempt to address some of the proliferation concerns associated with the current and in particular the future civil nuclear power programmes. If introduced it would require a number of states to supply fresh fuel to nuclear operators around the world and then take back the used fuel. The former Soviet Union adopted a similar system with those countries that it supplied nuclear technology during the 1970s and 1980s.

There are a number of technical and political concerns over fuel leasing. In particular it will require a small number of States to become the final disposal site for nuclear waste from other countries. This may be politically problematic given the level of public concern over nuclear waste disposal. Furthermore, any leasing schemes are likely to lead to an increase in the transportation of nuclear material around the world with a subsequent increase in the environmental and non-proliferation risks. Finally, there may be some reluctance by states to agree to fuel leasing as the example of the former Soviet Union shows, political changes can rapidly destabilise schemes and leave operators more exposed to the risks associated with a lack of availability of fresh fuel or waste disposal options.

What are the pros and cons of the so called Generation IV reactors?

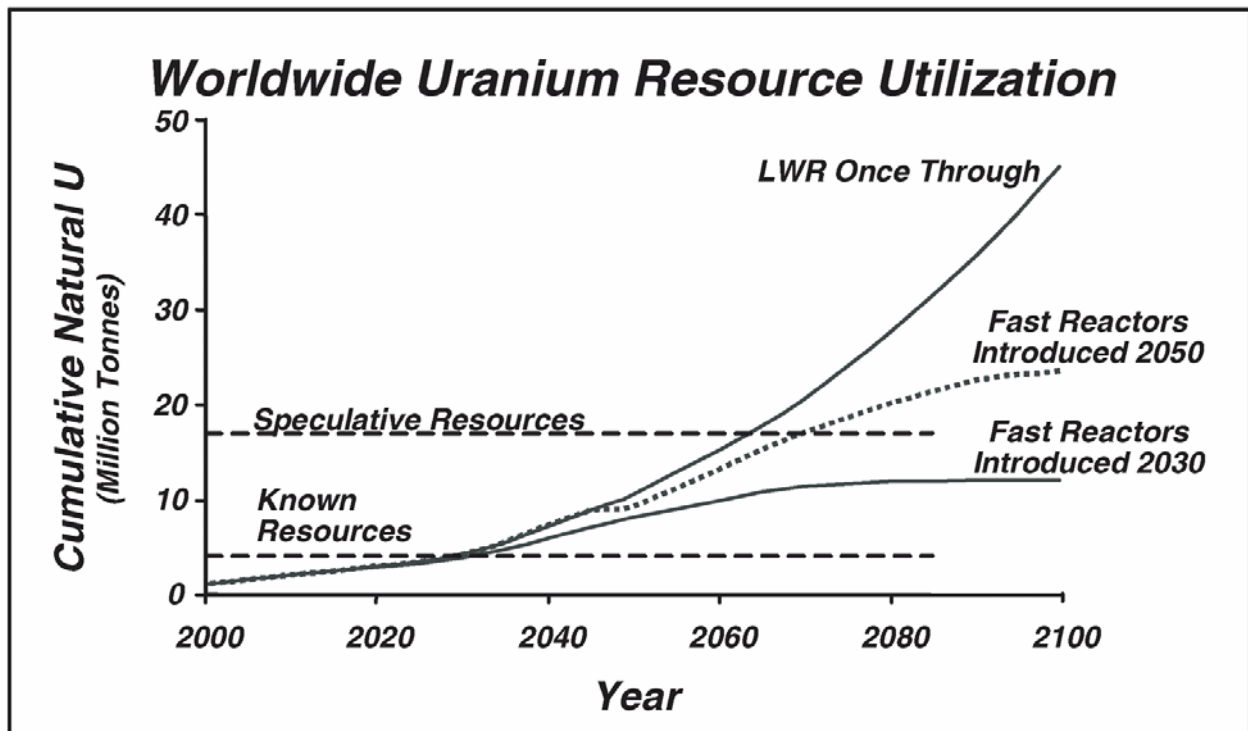
Antony Froggatt: The US Department of Energy (DoE) launched the “Generation IV International Forum” (GIF) in 2000. This is undertaking to develop six designs of reactors: GFR – Gas-Cooled Fast Reactor System: LFR – Lead-Cooled Fast Reactor System: MSR – Molten Salt Reactor System: SCWR – Supercritical-Water-Cooled Reactor System: SFR – Sodium-Cooled Fast Reactor System: VHTR – Very-High-Temperature Reactor System:

According to GIF, a closed fuel cycle is celebrated as a major advantage of Generation IV concepts. This is because there is recognition that ‘in the longer term, beyond 50 years, uranium resources availability also becomes a limiting fact, unless breakthroughs occur in mining or extraction technologies’³⁴. This is demonstrated by the graphic below, which

³³ Elisabeth Cardis, et al. *Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries*, British Medical Journal, 29 June 2005

³⁴ A technology Roadmap for Generation IV Nuclear Energy Systems/NERAC Review Version, September 2002 page 13

suggests that under current conditions the next generation of fast breeders needs to be being deployed in a couple of decades.



Source: *A Technology Roadmap for Generation IV Nuclear Energy Systems (NERAC 2002)*

This requires the reprocessing of spent fuel to extract the plutonium and then using plutonium as a fuel. This has significant proliferation implications, in particular if these types of reactors are widely deployed around the world. The reprocessing of plutonium has been widely criticised for its negative impact on the environment as well as its costs and security implications. The widespread introduction of the closed fuel cycle requires a reversal of current anti-proliferation policy in a number of countries, including the United States, and a revision of current industry policy in most nuclear countries. A movement towards the deployment of Generation IV reactors utilising the closed fuel cycle would require large scale investment to construct reprocessing plants.

The costs of such fuel cycle concepts – the use of reprocessing – would be very high. According to “The Future of Nuclear” by the US Massachusetts Institute of Technology³⁵, a convincing case has not yet been made that the long term waste management benefits of advanced closed fuel cycles involving reprocessing of spent fuel are not indeed outweighed by the short term risks and costs, including proliferation risks. Also, the MIT study found that the fuel cost with a closed cycle, including waste storage and disposal charges, to be about 4.5 times the cost of a once-through cycle. Therefore it is not realistic to expect that there will ever be new reactor and fuel cycle technologies that simultaneously overcome the problems of cost, safe waste disposal and proliferation. As a result the study concludes that the once-through fuel cycle best meets the criteria of low costs and proliferations-resistance.

³⁵ An Interdisciplinary MIT Study: John Deutch (Co-Chair), Ernest J. Moniz (Co-Chair), Stephen Ansolabehere, Michael Driscoll, Paul E. Gray, John P. Holdren, Paul L. Joskow, Richard K. Lester, and Neil E. Todreas; *The Future Of Nuclear Power*, January 2003

Furthermore, the Nuclear Control Institute (NCI) warned that transmutation of spent nuclear fuel is no guarantee against proliferation. The growing concerns about the safe and secure transportation of nuclear materials and the nuclear security of nuclear facilities from terrorist attacks are not adequately taken into account in any of the concepts.

If nuclear power is to play a major role in meeting global energy needs, then there will need to be a massive scaling up of the current programmes. Nuclear power currently supplies around 6% of commercial primary energy consumption and 16% of electricity consumed. The Intergovernmental Program on Climate Change (IPCC) put forward a scenario in which nuclear power plays a more central role in reducing CO₂ emissions and increases to 3000 GW of installed capacity in 2075 (providing 50% of the world's electricity) and then to 6500 GW in 2100 (75% of electricity). Under this scenario it would reduce by one fourth the CO₂ emission predicted by 2100. Even assuming an operating life of around 50 years (beyond the current design life-time of most operating reactors), it would require the construction of around 7000 reactors in the next century, or 70 reactors per year. Given that, at the peak of the global nuclear industry in the 1980s, the highest number of reactors connected to the grid in a year was 33, this scenario is extremely optimistic. If only uranium fuelled reactors were used, this would result in 600 tonnes of plutonium being produced annually. However, given the number of reactors necessary and the extent of the known uranium reserves it is expected that plutonium fuelled reactors would have to be in operation. If plutonium fuelled reactors were deployed around 4000 tonnes of plutonium would be generated per year.³⁶

The Generation IV designs are currently just that: preliminary paper designs. In order for even prototype versions to be built, technological breakthroughs in material development will have to be made.

A closer look at the technical concepts shows that many safety problems are still completely unresolved. Safety improvements in one respect sometimes create new safety problems. And even the Generation IV strategists themselves do not expect significant improvements regarding proliferation resistance.

But even real technical improvements that might be feasible in principle are only implemented if their costs are not too high. There is an enormous discrepancy between the catch-words used to describe Generation IV for the media, politicians and the public, and the actual basic driving force behind the initiative, which is economic competitiveness.

To what extent has the risk of major accidents been resolved?

Peter Bradford: It seems likely that decades of operating experience with existing plants will have led to safety improvements in the design of plants now under consideration. However, the unfavourable economics of nuclear power also lead to considerable pressure to reduce costs in ways that may offset some of the safety gains. Without substantial operating experience with the AP 1000, definitive statements about its safety performance are not to be relied upon.

³⁶ Nuclear Power, Nuclear Proliferation and Global Warming, H.A. Feiverson, Forum on Physics and Society of the America Physical Society, January 2003

Is there any published assessment of the risk of terrorist attack on nuclear power plants?

Mycle Schneider/Peter Bradford: The risk of terrorist attacks on nuclear facilities can be seen under the following aspects:

- the degree of vulnerability of nuclear facilities;
- the potential effect of an attack;
- the probability of nuclear facilities being targeted by terrorists.

Nuclear facilities are highly vulnerable to terrorist attacks. While their radioactive inventory is usually more limited, nuclear shipments are by far the most vulnerable. The safety of most nuclear facilities crucially depends on parts of the system that are easily accessible and highly sensitive to insider sabotage (e.g. main steam line, power supply in nuclear reactors).

In a landmark document, in 2003, eight leading nuclear analysts published a detailed analysis of the potential hazard of a lack of cooling accident in a spent fuel pool.

“Spent fuel recently discharged from a reactor could heat up relatively rapidly to temperatures at which the zircalloy fuel cladding could catch fire and the fuel’s volatile fission products, including 30-year half-life ¹³⁷Cs, would be released. The fire could well spread to older spent fuel. The long-term land-contamination consequences of such an event could be significantly worse than those from Chernobyl.”³⁷

The authors quote the Swiss regulatory authorities as having stated that:

“From the construction engineering aspect, nuclear power plants (worldwide) are not protected against the effects of warlike acts or terrorist attacks from the air ... one cannot rule out the possibility that fuel elements in the fuel pool or the primary cooling system would be damaged and this would result in a release of radioactive substances”

The largest radiotoxic inventories are in spent fuel pools, close to nuclear reactors and in particular at reprocessing plants that can contain the equivalent of over 100 reactor cores in the form of spent fuel and several dozen tons of separated plutonium. Analysis on the potential impact of an airplane crash on a spent fuel pool at the French La Hague site or on the high-level waste tanks at the UK Sellafield site have shown that radioactive releases could reach several dozens times the amount released during the Chernobyl disaster.³⁸

There are numerous accounts of alleged interest by terrorist organisations in nuclear facilities. The latest include a statement by Dame Eliza Manningham-Buller, head of the British intelligence service MI5, who stated on 9 November 2006:

“Today we see the use of home-made improvised explosive devices; tomorrow’s threat may include the use of chemicals, bacteriological agents, radioactive materials and even nuclear technology.”

In Australia reportedly there has also been interest in the only nuclear reactor in the country, the research facility at Lucas Height. According to the BBC, the reactor, in November 2005, “was a possible target for a group of men arrested on terrorism charges”.³⁹

³⁷ Robert Alvarez, et al. *Reducing the Hazards from Stored Spent Power Reactor Fuel in the United States*, Science and Global Security, 21 April 2003, see

http://www.princeton.edu/~globsec/publications/pdf/11_1Alvarez.pdf

³⁸ see http://www.wise-paris.org/english/ourbriefings_pdf/011029AircraftCrashSellafield3.pdf and

http://www.wise-paris.org/english/ourbriefings_pdf/010926BriefNRA1v4.pdf

³⁹ <http://news.bbc.co.uk/1/hi/world/asia-pacific/4434270.stm>

Additional analysis has been published, for example, by the Oxford Research Group.⁴⁰ Also see the “Nuclear Terrorism” link on the website of the Nuclear Control Institute (<http://www.nci.org/>).

How much water is used by the current generation of nuclear power plants, and what are the expectations for water use by the next generation of nuclear reactors?

Antony Froggatt: The cooling water needs of one of the British 1170 MW power stations are 108 million litres per hour⁴¹.

The Generation-III EPR (European Pressurised Water Reactor) destined for the French Flamanville site projects the use of about 270,000 m³ of fresh water per year. The unit will also pump 67 m³ per second (!) of water out of the sea that are used to evacuate the heat of the tertiary circuit and re-injected into the sea.

It's been suggested that a number of nuclear power plants closed in the European summer this year due to high water temperatures and other factors. Is that likely to be an issue in Australia if we go with nuclear power? If so, how?

Professor Steve Thomas/Antony Froggatt: Nuclear power plants do require large amounts of cooling water either from the sea or a river. Where sea-cooling is used, temperature is not likely to be an issue because fluctuations in sea-temperature are relatively small and a nuclear power station would have a negligible impact on the sea temperature. For a river water cooled plant, if the ambient temperature is very high, the river will be warmer than forecast and could reduce the output of the plant. From an environmental point of view, if there is a drought and high temperatures, the nuclear plant if operated could warm the water to such an extent as to damage life in the river. The level of the water could also drop to a level that caused problems.

A more expensive method of cooling and one which uses some of the output of the plant, but which requires less water, is a cooling tower.

In general, when a nuclear plant is sited, the characteristics of the cooling water will be known. Problems in France have arisen because the weather has been hotter and drier than anticipated.

The impacts of climate change will not be restricted to higher temperatures as a general trend in the increasing frequency of extreme weather patterns is also expected. Nuclear power plants have in the past been susceptible to storms and flooding. Furthermore nuclear power plants are also vulnerable to disruptions in the grid as a result of storms or flooding.

Antony Froggatt/ Peter Bradford: An adequate water supply for cooling is a must but depends on reactor size, heat load and whether a closed cycle with cooling towers is used. A large transmission link is also a must (both to transmit power and to assure power for safety systems when the plant is shut down). Proximity to population centers is not necessary and is undesirable from a safety standpoint.

⁴⁰ a list of various briefings can be found at <http://www.oxfordresearchgroup.org.uk/publications/briefings.htm>

⁴¹ Nuclear Electric plc, brochure for Hinkley Point.

Some advanced reactor designs (the Pebble Bed and the GT-MHR) may be able to be sited underground which would be a major safety advance.

Is a nuclear power plant able to follow demand/load, or does it simply run at a flat output? If so, how much energy then is wasted?

Mycle Schneider: Generally speaking nuclear power plants are not designed to do load following but to operate at stable output as much as possible. However, current French reactors are adapted to do load following, which consists in the modification of power output according to a pre-defined level on a daily basis. For safety reasons load following has been restricted on units loaded with plutonium fuels. The so-called Generation-III reactors most likely will not be designed to do load following. They are supposed to operate in base load only, which means as many hours as technically possible per year. The combination of huge base load overcapacity and the high share of nuclear power in the grid in France (close to 80%) has pushed the state utility to find innovative solutions: one consisted in large scale load following, the other in the shut-down of certain plants ... over the weekend.

The problems linked to the load following practice are less linked to waste of energy than to economics and safety. A nuclear plant operates more safely (less transient prone load manipulations) and more economically (high capital cost, lower share of operating costs) when used in base load. It is therefore almost certain that some of the current generation French nuclear plants will not be replaced by new nuclear plants in order to lower the nuclear share in the base load.

How many years worth of economically recoverable high grade uranium exists in the world?

Antony Froggatt: The amount of economically recoverable reserves will depend on a number of factors. At the current time one of the most important is the price of uranium. Over the last few years the price of uranium has risen considerably, and currently stands at around \$120/kg and therefore the expected volume of economically recoverable reserves has risen.

The most comprehensive, but not universally agreed too, publication on Uranium reserves, is the so-called 'Red Book' from the Nuclear Energy Agency and International Atomic Energy Agency and reaches the following conclusions⁴².

At a price of <\$ 80/kg U: there are 3 804 000 tonnes

At a price of < \$ 130/kg U: there 4743 000 tonnes

The uranium requirement in 2004 was 67 320 tU. Therefore at the lower price uranium will last 56 years, at the higher price level 70 years.

It is important to note that in 1998 the World Energy Assessment calculated that of all the major energy reserves, coal, oil, gas and uranium, uranium resources based on the then consumption levels would be depleted first.

⁴² It is not possible to access the report for free on line, but can be seen at:
<http://www.nea.fr/html/pub/ret.cgi?div=NDD>

More Nuclear? What international experts say about our energy future

If nuclear power is to play a major role in reducing CO₂ emissions then its use must be significantly scaled up. A doubling of current number of nuclear reactors would mean that the reactors would not be able to operate for their anticipated design lives as uranium resources would be depleted.

This is why the international nuclear community is developing Generation IV reactors, which are largely fuelled by plutonium. These reactors are still in the design stage and therefore their technical and economic viability is still to be proven. However, the use of plutonium fuels has significant proliferation concerns. For more information see the Greenpeace Reactor Hazards study⁴³.

⁴³ <http://www.greenpeace.org/international/press/reports/nuclearreactorhazards>

Miscellaneous

Does Australia's electricity grid have the capacity to have nuclear power plants added to it and what are the problems?

Mycle Schneider: In principle, whether a nuclear plant or a coal or gas fired plant of the same size is connected to the grid has little impact on the grid. There are a number of conventional power plant projects of 1,000 MW and even 1,500 MW underway in Australia. The question is rather whether to have the centralised expansion of capacity that ultimately always leads to large-scale power transport needs (including inherent large investments and power losses) versus decentralised energy generation.

Will people be able to opt out of receiving any energy generated by nuclear power plants?

Professor Steve Thomas: It may be that, in a competitive retail electricity market, there will be 'green' electricity suppliers who only buy wholesale power from sustainable sources and retail it to consumers who choose 'green electricity'. However, industry and commerce would be unlikely to have any interest in making such a moral judgement – they will only be interested in price. Nor, if experience in Europe is anything to go by, would most residential consumers. So if there was a cost penalty to green electricity, it could account for only a small part of the market and would have no impact on nuclear (which in most countries with nuclear power makes up much less than half of all electricity supplies). Of course, if green electricity was cheaper than other forms of electricity, there would be no reason for the electricity industry to build anything other than green sources.

While it is probably right that people should have the ability to choose to buy green electricity, relying on personal choices for such an important issue seems morally questionable. The impact of 'dirty' electricity is felt by everyone, not just the individual consumer. Consumers are not given the choice of whether their sewage is treated properly or discharged raw to the sea so why should they have to choose between 'clean' and 'dirty' electricity?

To what extent does the burning of coal in power stations create nuclear radiation?

Mycle Schneider: The radiation linked to the mining and burning of coal is part of what is called "technically enhanced naturally occurring radioactive materials" or TENORM. Most coal contains small amounts of uranium and/or thorium. Concentrations can vary by two orders of magnitude. Also radon gas is released a by-product.

Here is an extract from a US Environmental Protection Agency report on TENORM.⁴⁴

Principal non-radioactive ash constituents are the metal oxides of silica and alumina, often comprising 80-90 percent, with smaller percentages of other metal oxides, including iron, calcium, sodium, tin, magnesium, and potassium. Pollution control devices in modern power plants usually capture about 99 percent of fly ash, and devices in some older plants capture about 90 percent. However, those devices do not capture radon gas. In addition to ash, power plants produce slag, sludge, and other waste products that may contain uranium TENORM. The amount of ash generated is

⁴⁴ see <http://www.epa.gov/radiation/docs/tenorm/402-r-05-007-ch-1.pdf>

proportional to the amount of coal consumed and the coal ash content. The ash content of coal will vary according to the depositional environment. The average ash content of coal burned by the US electric utility industry is approximately 10 percent, meaning that uranium in coal is concentrated roughly 10 times in the ash. For coal with 10 percent ash content, a 1,000 megawatt plant may produce over 1,500 tons of ash during a 24 hour period. However, the actual quantity of ash produced also depends on the plant's design and efficiency and the coal's energy content. Though the concentrations are low, the total amount of TENORM in fly ash is noteworthy (et al. 1980; Beck 1989). For example, in 2004, US electric power plants burned approximately 921 million MTs of coal (US DOE/EIA 2005d). If that amount of coal is burned with 1.5 ppm uranium, 1,381 MTs of uranium would be concentrated, in addition to other TENORM quantities. Other coals are quoted as ranging from up to 25 ppm of uranium and 80 ppm of thorium. Based on analyses of nearly 7,000 samples, of all coal provinces and coal ranks, an EPA study found that the range of uranium in US coal was 0.010B75 ppm (US EPA 1995b). Most fly ash is buried, but increasingly fly ash is being used for commercial applications. A significant quantity of fly ash (Class C) is considered cementitious (having the properties of cement, the principal binding agent in concrete) which makes it a very useful material. The relatively uniform small particle size, surface reactivity, and bulk chemical composition – particularly if alkali elements are abundant – lend properties to coal ash, slag, flue gas waste material that have numerous useful commercial applications. These include: flowable fill, structural fill, road base/subbase, coal mining applications, mineral filler in asphalt, snow and ice road control, blasting grit and roofing granules, grouting, waste solidification and stabilization, and wall board (ACAA 1995, 1996; US DOE/EIA 1993; EPRI 1988).