

***NUCLEAR WASTE – IS IT STILL A PROBLEM?
AN ESR AUCKLAND DISCUSSION PAPER***

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1. INTRODUCTION

With concern over global warming on the increase, Nuclear Power is again being promoted in some quarters as a low carbon emission alternative to the continuing use of fossil fuels. Here in New Zealand the promotion is given additional impetus by our urgent need to identify fresh sources for the generation of electrical energy. Indeed, in recent ESR panel discussions on the topic “Future Power Supply – NZ at a Crossroad” one speaker suggested the choices as being “Coal or Nuclear”. It is not my intention to debate that issue here, but rather to explore and challenge the correctness of a comment made from the floor that *“the problem of nuclear waste has been solved”*. This problem does of course bear directly on the public acceptance of nuclear energy. The stated view is more often expressed in the form *“The safe treatment of radioactive wastes no longer presents any technical problems – the remaining problems are political in nature.”*

There is a wealth of material bearing on this question as it applies internationally, both in printed form and on the internet. My discussion will be limited mainly to the present situation in the U.S. and in Great Britain, and will point to the extreme difficulties being faced by both countries in coming to terms with the legacy of hazardous radioactive wastes generated to date by the civil nuclear power programmes.

2. NUCLEAR WASTES REVIEW

The greatest concern is with high-level wastes, the radioactive residues from the fission process in nuclear reactors. The fissile component of the Uranium used as reactor fuel is the isotope U-235, which is present only in small quantities (0.7%) in natural Uranium ore, the major part being the non-fissile isotope U-238. To allow fission to occur in light water reactors the proportion of U-235 must be increased several times through an “enrichment” process.

Splitting of the U-235 atoms by neutron capture in the fission process, yields highly radioactive elements of lower Atomic Number, the fission products, together with an intense flux of Neutrons. The fission products emit gamma radiation with half lives which range from seconds to millions of years. Neutron bombardment of the U-238 atoms results in the formation of the Transuranic elements Neptunium, Np, and Plutonium, Pu. Long before all the U-235 in a reactor fuel element has been consumed, the fission process will have been poisoned by the build-up of fission products and it becomes necessary to replace the spent fuel element by a fresh one.

In the “once-through” nuclear fuel cycle the highly-radioactive spent fuel is normally stored for 5-10 years under water in special storage tanks or ponds with forced

cooling, to allow the initial intense radioactivity and heat generation to decline before the spent fuel elements are transferred into concrete or stainless steel casks, and some more permanent form of storage or disposal is undertaken.

Alternatively the spent fuel elements may be subject to reprocessing, a chemical treatment involving dissolution in nitric acid and the recovery of Uranium and Plutonium. The residue is an intensely radioactive chemical sludge. In defence establishments the Plutonium was stockpiled for use in Nuclear weapons. The Uranium can be directly recycled into fresh fuel elements. Being a fissile material the Plutonium isotope Pu-239 is also available as a reactor fuel, although not without modification to reactor parameters. MOX (mixed oxide) fuel, a mixture of Uranium and Plutonium oxides, is fabricated in a limited number of plants and is used in some existing reactors.

The radioactive sludge is stored in stainless steel tanks, cooled and monitored, until it is converted into solid form by the process of vitrification, that is, by embedding in glass. Thereafter it might be retained in monitored near-ground-level storage, or ultimately transferred into deep geological repositories.

For the purposes of this discussion the term “high-level wastes” comprises the spent fuel elements and the reprocessing wastes whether liquid or vitrified, as well as the separated Plutonium. The “*nuclear waste problem*” has the following dimensions:

- (1) Protection of human health and the environment.
- (2) The threat of nuclear proliferation (an increase in the number of nuclear weapon states).
- (3) Safeguards against terrorist action and the diversion of fissile material.

At this point it is worth recalling that the main reason for reviewing the future role of nuclear power at this time is the contribution it might make to reducing the threat of climate change by substitution for the use of fossil fuels. It can be readily demonstrated that for nuclear power to make a substantial dent in carbon emissions, the present nuclear power output must be increased by a factor of at least ten, possibly closer to twenty. That is, instead of the existing 300 1000MWe plants worldwide, a total of not less than 4000 will be required sometime in the present century, pointing to a construction programme of say 60 1000MWe plants per annum. Of course there will be a corresponding escalation in the amount of nuclear reactor wastes being produced.

3. PREVAILING OFFICIAL POSITION ON NUCLEAR WASTE SAFETY

The following is typical of confident and soothing views long expressed by representatives of the nuclear establishment¹:

“Countries have developed and put into practice technical solutions to safely store, dispose, or otherwise manage radioactive waste from nuclear power plants Although scientists and engineers are confident that modern technology can ensure the safe disposal of nuclear wastes, the public is often not so sure. ‘What is needed is

¹ “World Overview: Radioactive Waste Management”, IAEA News Features, No. 2, 20 May 1988.

an effort to make the proposed techniques and their safety features more widely understood’, says IAEA Director General Hans Blix.”

Much interesting and useful information on the nuclear fuel cycle and the preferred treatment, storage and disposal of nuclear wastes is available in such publications as those of the Uranium Information Centre Ltd.² and the World Nuclear Association³. However they contain little to indicate the existence of problems or doubts: “*Spent fuel can be stored safely in these ponds for long periods.*” “*Reprocessing of spent fuel occurs at facilities in Europe and Russia with capacity over 5000 tonnes per year and cumulative civilian experience of 90,000 tonnes over almost 40 years.*” “*Most countries intend to introduce final disposal sometime after about 2010, when the quantities to be disposed of will be sufficient to make it economically justifiable.*” “*Final disposal of high level wastes is required in due course but there is no technical or logistical reason why this is urgent.*” “*The international nuclear industry has an exceptional safety record in the management of its wastes.*” On the other hand critics point to the sensitivity of spent fuel ponds to terrorist attacks, as well as to a range of accident scenarios. In many cases spent fuel builds up in ponds due to the lack of other secure storage or disposal options. Reprocessing was abandoned in the US during Carter’s Presidency due to nuclear proliferation concerns, and it is reported that it will shortly be terminated in the UK for both security and commercial reasons. Firm plans for the implementation of final disposal repositories have been delayed or put on hold almost everywhere including the US, for technical reasons, inadequate budgetary provision, or public protest.

The following quoted passage is from a recent book by Dr Andrew McEwan⁴, the former Head of the National Radiation laboratory of New Zealand:

“It seems that very few people understand the true nature of the nuclear waste problem. By any rational assessment, nuclear waste poses NO serious threat to public health and safety. Yet, the spectre of a hazard of unprecedented dimensions is firmly embedded in the public mind. How did this miserable state of affairs evolve? It is apparent that nuclear waste is not a problem to be solved. Rather it is a problem to be studied. Hoards of geologists, material scientists, social scientists, bureaucrats, politicians, anti-nuke activists and assorted consultants make a good living by studying the problem. Should the problem ever be solved, they would need to seek elsewhere for their livelihood.”

“Experts” have always been prone to frustration or anger at having their positions challenged by concerned lay persons, and one should not expect it to be any different in this contentious and complex field. Many of the challengers however have been scientists and technologists with strong credentials in relevant disciplines.

4. THE 2003 IAEA POSITION PAPER

A recent IAEA Position Paper⁵ was prepared by a panel of “International Experts” as part of an investigation into the role of long term storage in a sustainable programme of radioactive waste management. Reassurances are offered about the safety in

² “The Nuclear Fuel Cycle”, Uranium Information Centre Ltd., <http://www.world-nuclear.org>

³ “Radioactive Wastes 3/01”, World Nuclear Association, <http://www.world-nuclear.org>

⁴ “Nuclear New Zealand – Sorting Fact From Fiction”, Andrew McEwan, Hazard Press, 2004.

⁵ “The Long Term Storage of Radioactive Waste: Safety and Sustainability”, IAEA, Vienna 2003.

general of waste currently stored at or near ground level, but in addition the paper makes the following important observations and recommendations:

- The generation that generates radioactive waste should make all the arrangements needed for disposal of that waste.
- Hazardous radioactive wastes must be contained and isolated from the human environment for thousands of years.
- Although **storage** is a necessary (first) phase in managing most types of radioactive waste, the consensus of experts is that **disposal** in deep underground facilities – geological disposal – is the best long term option.
- As yet, no such disposal facilities are in operation. Thus, waste material continues to accumulate in storage facilities.
- Concern arises when the period of storage becomes very long – even perhaps perpetual. Degradation of packages, needs for maintenance, security against terrorist attack or diversion of nuclear materials, and obligations on future generations to maintain active surveillance of stores are of concern. It is unlikely that any societal infrastructure currently in place or envisaged would last for the period of time needed.
- The issue of whether to pursue long term storage or dispose of radioactive waste is not solely technical. Other factors of a social, political, economic and ethical nature are also very relevant. Current societal opinion does not appear to be strongly in favour of disposal. This results in continued de facto storage on the surface.

5. GEOLOGICAL REPOSITORIES

The radiation level of high level nuclear waste will subside to that of the ores from which it was derived over a period of approximately 10,000 years, offering a guide to the minimum period required for isolation from the human environment. However since the spent fuel from civil reactors contains significant concentrations of fissile materials, particularly Plutonium, it should be securely isolated virtually in perpetuity. Waste should be stored in dry form, encased in concrete, stainless steel, alloy, etc., as a primary barrier against dispersion. However it is the stability and integrity of the surrounding geological formation that provides the ultimate protection. As yet there is no operating repository for civil wastes. The US is operating a repository for defence wastes in a salt formation in New Mexico. Problems have been experienced with the structural stability of the salt rock.

5.1 Yucca Mountain

Probably the most advanced deep repository for civil wastes is that at Yucca Mountain⁶ in the US. After 30 years of discussion and analysis of alternative sites, the US Congress in 1987 directed the Dept. of Energy to study Yucca Mountain, Nevada,

⁶ “Yucca Mountain”, http://en.wikipedia.org/wiki/Yucca_Mountain

as the site of the national geological repository. The proposed repository zone will cover 1150 acres, be 300m below the surface of the mountain and 300m above the water table. By early 2002, 7 billion dollars had been spent on the project, which has made Yucca Mountain the most studied piece of geology in the world. Of volcanic origin, the geological formation is composed of tuff, contains many cracks and fissures and is in a region of significant seismic activity. Concerns have been expressed that over the 10,000 or so year life of the repository, climate change could result in a raising of the water table. The project is widely opposed in Nevada.

On February 12, 2002 the US Secretary of Energy decided that the site was suitable, but as recently as July 9, 2004, the US Court of Appeals upheld one legal challenge against the decision, which leaves the future of the repository in doubt. In August 2004 the repository became an election issue, when Senator John Kerry said that he would abandon the plans if elected. Other countries are facing similar difficulties in implementing a geological repository.

The Institute for Energy and Environmental Research (IEER)⁷ argues that the choice of Yucca Mountain was based on politics not science, that the geology is not likely to provide an adequate barrier in the long term, that serious questions have been raised about the integrity of the alloy canisters that would hold the spent fuel, that water may have welled up to the level of the repository in the geological past and may do so again in the future. Given the need for more basic research on various geological settings, it is argued that in the short term spent fuel should be stored as safely as possible on site or as close to the point of generation as possible for an interim period (several decades) to allow a long term management plan to be implemented.

The continued storage of spent fuel at the reactor sites, as recommended above, is a highly contentious issue to which I shall return later.

5.2 Scanzano (Italy)

On November 13, 2003, the Italian Government signed an emergency decree naming the small southern town of Scanzano as the site for a national waste depository. The choice was said to be “technical not political” based on the presence of deep salt rock deposits beneath hundreds of feet of clay. The proposed site was a flat area at sea level, 200 metres from the beach and 100 metres from the Cavone River. Much of the waste to be disposed of is spent fuel from Italy’s four reactors, all of which have been shut down. Trisaia, a nearby nuclear fuel reprocessing and research facility, houses a considerable quantity of liquid and solid wastes stored under conditions which were declared unsafe by a 1995 parliamentary commission. The decree was signed without a preliminary impact assessment and without public participation.

Hundreds of citizens promptly mobilised⁸, occupying the proposed site and blockading railway lines and major highways. By the time it was all over, 100,000 protesters of all political persuasions had forced Rome to withdraw Scanzano as the intended site. “Scanzano” entered Italian parlance as a word synonymous with successful anti-nuclear activism. As in other countries, there is little agreement in

⁷ “If Not Yucca Mountain, Then What?”, <http://www.ieer.org/fctsheets/yuccaalt.html>

⁸ “Nuclear Waste: Showdown at Scanzano”, Linda Clare Gunter, Bulletin of the Atomic Scientists, March/April 2004.

Italy on potential solutions to the nuclear waste problem. The communities where waste is stored want it gone; some favour a European repository while others insist that Italy must take responsibility for its own waste. A few organizations, including Greenpeace, oppose repositories altogether and instead advocate secure on-site storage.

The Italian Government wants to name a new site by December 2004 – a decision that is sure to provoke more protests after the people's victory at Scanzano.

6. ON-SITE STORAGE IN THE U.S.

A current Fact Sheet⁹ released by the US Office of Civilian Radioactive Waste Management includes the following statement:

“Since the mid-1940's, spent nuclear fuel and high-level radioactive waste have accumulated throughout the country. Currently they are stored in temporary facilities at some 125 sites in 39 states. These storage sites are located in a mixture of urban, suburban, and rural environments – most are located near large bodies of water. In the US today, over 161 million people reside within 75 miles of temporarily stored nuclear waste.

Current storage methods shield any harmful radiation and are presently safe. However, modern aboveground storage structures are designed for temporary storage only, and will not withstand rain, wind, and other environmental factors for the tens of thousands of years during which the waste will be hazardous.”

Other views of the safety of spent fuel storage at US sites are less reassuring than the official statement above. The following excerpts are from an article *“What about the spent fuel?”*¹⁰ :

“Until recently, concerns about attacks on commercial nuclear power plants focussed mainly on the vulnerability of reactor containment buildings. But nuclear power plants have a weaker link – spent fuel ponds. Reactors are inside steel vessels surrounded by heavy structures and containment buildings, spent fuel pools, containing some of the largest concentrations of radioactivity on the planet, can catch fire (possibly due to loss of pool water exposing zirconium cladding to air and steam) and are in much more vulnerable buildings. On average, spent fuel ponds hold 5 to 10 times more long-lived radioactivity than a reactor core. Particularly worrisome is the large amount of cesium 137 in fuel ponds, According to the Nuclear Regulatory Commission (NRC), as much as 100% of a pool's cesium 137 would be released into the environment in a fire. ...A single spent fuel pond contains more cesium 137 than was deposited by all atmospheric nuclear weapon tests in the Northern hemisphere combined. The NRC is now reviewing 'from top to bottom' its safety and security policies Will more gates, guards and guns be enough? About 40,000 tons of spent fuel are stored in pools at 110 operating and closed reactor sites across the United States, with over 2 billion curies of long-lived radioactivity. Over the next several years, the Energy Dept. estimates that storage space for an additional 11,000 tons of spent fuel will be needed. Casks and other storage alternatives would greatly reduce, or even eliminate, the risk of a pond fire. A handful of reactor owners have put only about 4% of the nation's spent fuel

⁹ Office of Civilian Radioactive Waste Management.

<http://www.ocrwm.doe.gov/factsheets/doeymp0338print.shtml>

¹⁰ “What About the Spent Fuel?”, Robert Alvarez, Bulletin of the Atomic Scientists, Jan./Feb. 2002

into dry storage. Because of deregulation, the owners of many reactors are limited liability companies with little or no cash reserves. There is no financial incentive to move wastes to safe and dry storage.

Other nations are taking spent fuel vulnerabilities very seriously. Germany is seeking ways to harden its dry-stored spent fuel in even more robust containers. France has installed anti-aircraft missiles around its spent fuel ponds at the La Hague reprocessing facility.”

In January 2004 the National Academy of Science, sponsored by the NRC, initiated a 12 month project “Safety and Security of Commercial Spent Fuel Storage” aimed at assessing “*the potential safety and security risks of spent nuclear fuel presently stored in cooling pools at commercial reactor sites, and the safety and security advantages, if any, of dry cask storage versus wet pool storage at these reactor sites. In light of the September 11, 2001, terrorist attacks, this study will explicitly consider the risks of terrorist attacks on these materials and the risk these materials might be used to construct a radiological dispersion device.*”

Companies operating nuclear plants pay 0.1 cents per kWh to the federal Nuclear Waste Fund for the purpose of dealing with the Nuclear Wastes. The Nuclear Waste Fund has been reserved to meeting the cost of developing the Yucca Mountain repository, but delays in this programme have been attributed in part to the failure of Congress to authorise adequate annual grants to the project. Government signed contracts with companies in 1982 to take delivery of nuclear wastes by 1998 – this has not happened. As a consequence the Nuclear Energy Industry has reported¹¹ that: “*... given that the federal government is more than six years overdue in fulfilling its obligation to take possession of used reactor fuel, more than 60 lawsuits have been filed by electric companies against the federal government for breach of contract. Damages from those lawsuits could exceed \$50 billion.*”

An interesting twist is that the U.S. is responsible for some 33,000 tonnes of spent fuel piled up in Brazil, the Czech Republic, India, Japan, Mexico, Slovenia, South Korea, Switzerland, Taiwan and the European Union. This was originally supplied by the U.S., and under the terms of a 1954 U.S. non-proliferation law the pledge was given to take back the spent fuel. But to take back all this waste is no longer politically feasible. A possible way out of this problem is that Minatom, the Russian Ministry of Atomic Energy, is pushing a bold plan to reprocess nuclear fuel from around the world at Krasnoyarsk, the nuclear city in Siberia¹². A contract with the U.S. would be a vital part of this plan. However for the U.S. there are two fundamental obstacles:

- (1) Plutonium proliferation concerns preclude reprocessing;
- (2) Minatom’s dealings with Iran, where the Russians are building the Bushehr nuclear power plant.

As to (1) the Livermore Lab. has been cooperating with Minatom in designs of possible underground repositories near Krasnoyarsk.

¹¹ “Nuclear Energy Industry Calls for Nuclear Waste Fund Reclassification”, Nuclear Energy Institute, March 25, 2004, <http://www.nei.org/index.asp?catnum=4&catid=546>

¹² “Minatom: The Grab for Trash”, Bulletin of the Atomic Scientists, Sept./Oct., 2002.

7. NUCLEAR WASTES IN GREAT BRITAIN

Britain, which boasted the world's first large-scale commercial nuclear power station, Calder Hall at Sellafield in Cumbria, has no plans to replace its ageing nuclear power stations, which generate just more than 20% of the country's electricity. All but one of the plants – Sizewell B in Suffolk – are due to close by 2023. The Government's energy plans include a refreshing emphasis on renewable energies, but the following reported statement¹³ by the Energy Minister, Stephen Timms, is significant:

“In the future we may realise that there is a place for nuclear power and new nuclear builds,” he said. But he added that, presently, he knows of no-one who wishes to invest in nuclear builds and the government still needs to address questions around the storage of waste. (my emphasis)

The history of the storage and treatment of waste in Great Britain is pretty dreadful. Official policy has been to reprocess all civil spent fuel at the British Nuclear Fuels Ltd. (BNFL) reprocessing complex at Sellafield (formerly Windscale) in Cumbria, although large quantities of spent fuel are stored in cooling ponds at Sellafield and at power stations. There are two reprocessing plants, a smaller one to process wastes from the smaller Magnox reactors which are currently being phased out, and THORP which handles spent fuel from the newer reactors at home and from 8 other countries. Sellafield is one of only two commercial reprocessing plants worldwide, the other being at Cap de la Hague in France, although Japan is building a plant at Rokkashomura.

Sellafield has a record¹⁴ of accidents, dumping of wastes into the Irish Sea, and the storage of wastes in dangerously-degraded tanks¹⁵. 21 steel tanks in above ground concrete cells contain high level waste which includes 2,400 kg of Cesium-137 as well as Strontium-90 and Technetium-99. Close to 90 tons of Plutonium is stored there. A plant for the manufacture of MOX reactor fuel from reprocessed Uranium and Plutonium has been built at Sellafield, intended principally for export since it would be suitable for only one existing British reactor. Attempts to break into the Japanese MOX fuel market were damaged when a pilot shipment was returned because it was found that manufacturing records had been falsified. Failing such a use for the Plutonium it must be regarded as waste and appropriately dealt with. It has been reported¹⁶ that BNFL faces a highly uncertain future, that reprocessing might not proceed beyond 2010, and that it could find itself being relegated to becoming mainly a nuclear cleanup contractor.

The UK govt. has recently created a new body, the Nuclear Decommissioning Authority (NDA), which will take over the ownership and responsibility for most of BNFL and UKAEA sites and be responsible for the decommissioning and cleanup of

¹³ “Minister hints at new nuclear plants”, IEE Review, July 2004, p.12

¹⁴ “Britain, Sellafield, Salmon, and the Irish Sea”, Andy Oppenheimer, Bulletin of the Atomic Scientists, September/October, 2003

¹⁵ “The Vulnerability of the UK's Nuclear Facilities to Terrorism”, Bellona Position Paper, <http://www.bellona.no/en/energy/nuclear/sellafield/27116.html>

¹⁶ “BNFL running low on energy as French nuclear rival powers ahead”, Andrew Taylor, Financial Times, Nov. 18, 2004

contaminated facilities. The NDA is expected to have an annual budget of around GBP 1 billion for the next 10 years, and more after that.

Another body that has been involved in waste management issues is Nirex, a company set up in the early 1980's by the nuclear industry with Govt. agreement, to examine aspects of the deep geological disposal of radioactive waste. Nirex began looking for a deep repository site in 1987, and in 1991 concentrated their investigation on a site near Sellafield. Following a hearing, planning permission was however refused. Nirex had a bad public image, having been described as 'secretive and arrogant'. However it is planned to transform Nirex into an independent company, funded by NDA, to advise another new Govt. Committee, CoRWM (Cttee. on Rad. Waste Mgmt.).

CoRWM is engaged in a detailed consultation as the first stage in a programme to develop and implement a long term strategy for radioactive waste. Agreement on the strategy is not expected before 2006. It is little wonder that the UK Government is loathe to contemplate fresh nuclear builds or that willing investors are scarce, when so much of a 50 year backlog of waste remains un-conditioned and in a vulnerable state.

It is ironic moreover that the UK now has the problem of disposing not only of its own nuclear wastes, but also those arising from lucrative reprocessing contracts for spent fuel from Japan, Germany, Italy, Spain, Switzerland and Sweden. A 30-year-old policy that the UK would not become a dumping ground for other countries' nuclear waste but that after reprocessing it should be returned to the country of origin, has been overturned by a decision announced by the Trade Secretary Patricia Hewitt¹⁷. The bulk of the toxic wastes, which amount in total to 225 nuclear shipments, will be kept and disposed of in Britain as a money-making venture. Mrs Hewitt said the additional income – up to 680 million pounds – would be “used for nuclear clean-up which will result in savings for the UK taxpayer over the longer term”.

8. PROLIFERATION AND ILLICIT DIVERSION

The preceding remarks illustrate some aspects of the global nuclear waste disposal challenge as it exists at present. Insufficient resources are available globally to deal adequately with wastes accumulated over the past 50 years, and these wastes keep on growing. At 25 tons of spent fuel per standard reactor (1,000MWe) year, the world's reactors produce some 8,000 tons per year. Were nuclear power to supply half the world's primary energy in the future, this amount would grow to some 120,000 tons per year – more each year than the ultimate capacity of the planned Yucca Mountain repository!

Reactors fuelled with Uranium create Plutonium-239, the material of choice for nuclear weapons. Reactor-grade Plutonium extracted from spent fuel also contains up to 20% of Plutonium-240, formerly thought to make it unsuitable for weapon use. A Dept. of Energy public report¹⁸ issued in Jan. 1997 however stated:

“In short, reactor-grade plutonium is weapons-usable, whether by unsophisticated proliferators or by advanced nuclear weapons states. Theft of separated plutonium, whether weapons-grade or reactor-grade, would pose a grave security risk.”

¹⁷ “UK to keep foreign nuclear waste”, The Guardian, 15 Dec. 2004.

¹⁸ “Final Non-proliferation and Arms Control Assessment of Weapons-usable Fissile Material Storage and Excess Plutonium Disposition Alternatives”, U.S. Department of Energy, Washington, D.C., 1997

The amount of weapon-usable material produced thus far by the nuclear power industry is enormous. In excess of 100 tons have been separated in processing operations, and more than 1,000 tons are present in spent fuel (possibly a gross underestimate of quantities). 100 tons of separated plutonium would suffice to make about 16,000 nuclear weapons. I will refrain from doing the sums appropriate to a 20-fold expansion of the nuclear industry. Think as well of the scale of expansion of nuclear sites, the implications of transporting vast quantities of nuclear materials between Uranium enrichment, Fuel fabrication, Reprocessing, Power Production, Secure Storage and Geological repository sites, and the potential for terrorist attacks and illegal diversion of weapons-usable material.

Here is one view¹⁹:

“In the long run, nuclear power of a magnitude to address the greenhouse challenge probably would be very difficult to make proliferation-resistant even if reprocessing and recycling could be avoided. Perhaps the only way to make a tenfold to twentyfold increased nuclear system adequately proliferation-resistant would be to require that nuclear power be placed in very centralised international parks under international control. Whether this approach would work is open to question, as countries would have to give up sovereignty over their energy systems.”

Hands up those who could envisage such a degree of international cooperation!

¹⁹ “An Arms Controller’s View”, (p. 231), Harold A Feiveson, in “Nuclear Power and the Spread of Nuclear Weapons”, Brassey’s Inc., Washington D.C., 2002