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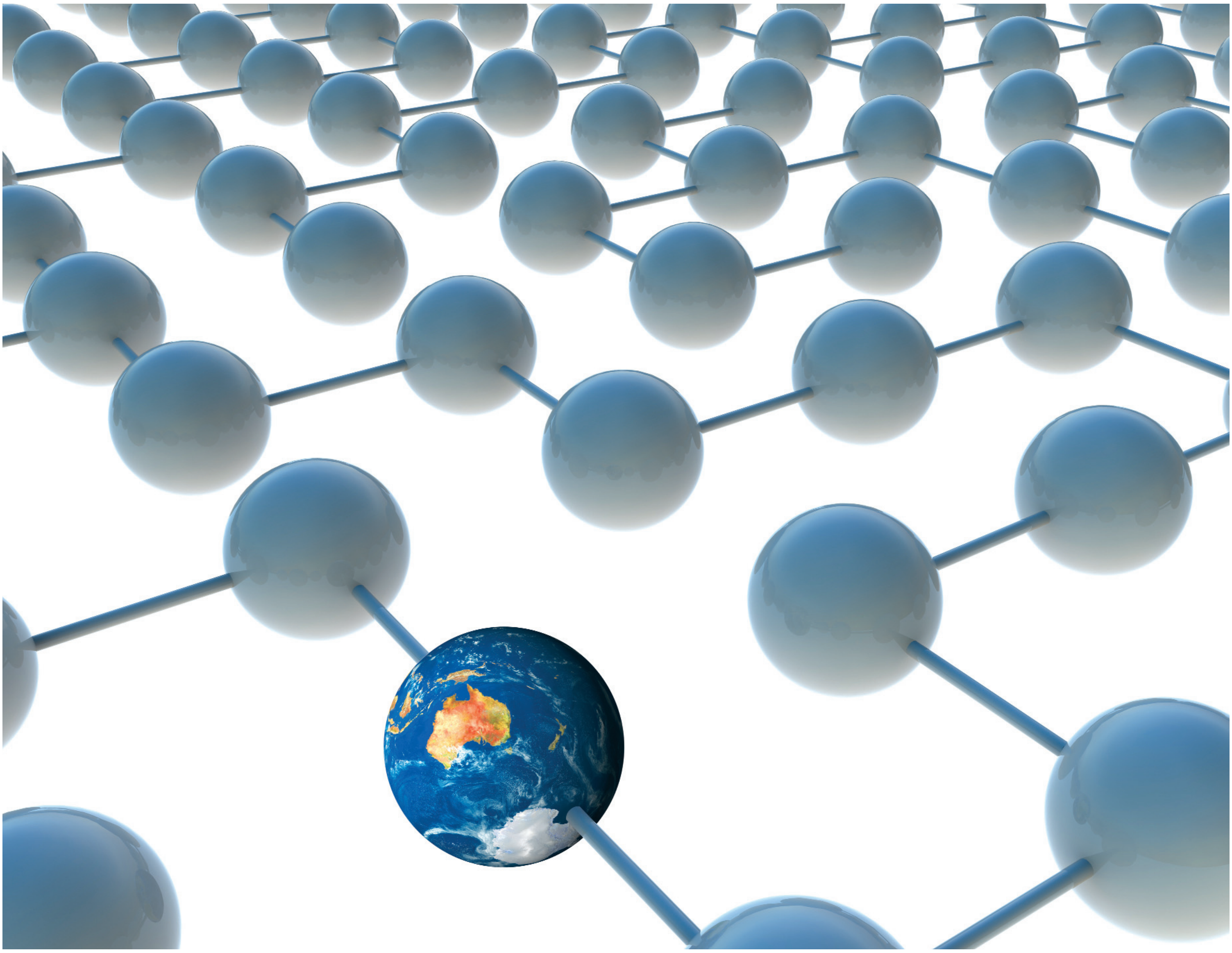
March 2006.

INTRODUCING NUCLEAR POWER TO AUSTRALIA

An Economic Comparison

A Report Prepared for the Australian Nuclear Science and Technology Organisation



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Introduction

Over the past year, the debate on whether Australia should consider using nuclear generation as part of its electricity generation infrastructure has intensified. This has been largely driven by the growing acceptance of climate change as a result of increased atmospheric carbon dioxide produced by the burning of fossil fuels. The magnitude of the probable effects of this climate change on future generations, as well as the immediate effects on our economy through severe weather events, have increased public awareness of this issue.

The magnitude of the problem means that there is no single solution that is capable of reducing carbon emissions to levels which would allow the atmosphere to stabilise. Rather, a range measures need to be implemented. Included in this range is the use of nuclear power, which is one of the lowest carbon dioxide-emitting technologies available for base load electricity generation.

International studies have consistently shown that nuclear generation produces the lowest cost electricity, even without considering the payment of a carbon tax. Australia has abundant supplies of high quality coal and natural gas resources and these could potentially affect the economics of nuclear generation in Australia. For this reason, ANSTO engaged Professor John Gittus to prepare an analysis of the economics of nuclear power in an Australian context, contributing to the nuclear power debate in Australia.

This document represents the report of his analysis of the situation.

Ian Smith

Executive Director
Australian Nuclear Science and Technology Organisation
May 2006

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John Gittus obtained an external First Class Honours degree in mathematics from London University. He is a Fellow of the Royal Academy of Engineering and has Doctor of Science degrees from the Universities of London and Stockholm.

He was elected a Regents' Professor at the University of California in Los Angeles in 1990.

He is a Royal Academy of Engineers Professor, teaching at the Universities of London, Plymouth and Swansea.

Professor Gittus is a consultant and advisor to Government Ministries, public bodies and private industry in the UK, Canadian, Japanese and Australia on nuclear and energy matters, Annex 12.

Synopsis.

This report analyses the potential of nuclear energy in Australia, primarily from the financial standpoint.

THE ECONOMICS OF NUCLEAR POWER AS PART OF AN OVERALL AUSTRALIAN ENERGY POLICY.

A Financial Model has first been developed to permit a comparison between the generation costs of new nuclear, coal-fired and CCGT power stations in Australia. The costs of generating electricity from new power stations having the parameters of our Model and interest-rates corresponding to the rates of return achieved in 2002-2003 by specified Australian States have been calculated and compared with the actual average costs of generation from the coal-fired stations of NSW and Queensland. Our Model forecasts that nuclear power would be competitive with the actual costs of generation. Model forecasts based on ABARE etc projections of gas, coal and uranium prices show that nuclear will be continuously competitive with gas and coal in Australia through 2011 (the limit of the information on coal prices).

WOULD NUCLEAR POWER NEED SUBSIDIZING IN AUSTRALIA?

Two alternative Finance Plans are developed, to pay for the construction of a nuclear power station in Australia.

First Finance Plan: No Government subsidy is involved in this plan. Instead the financial risks are shared between stakeholders, government and the risk-transfer market. This results in a cost of electricity of 38 Aus \$/MWe.h for the fifth copy of an AP1000, as compared with 36 Aus \$/MWe.h for the "nth" copy of the reactor.

Second Finance Plan: A Government subsidy is involved in the second plan: a Government grant of 14.31% of the "5th of a Kind" cost of the fifth copy of an AP1000 would have a 99.5% chance of being adequate to secure a generating cost of 36 Aus \$/MWe.h, we calculate. Government would also pay a subsidy of 21.41% of the cost of the electricity produced by the station, for the first 12 years of its operation.

To these costs must be added, we estimate, 2% for spent-fuel-management and 2% towards decommissioning. A similar sum is required for disposal of ILW and LLW. Either of these plans is then shown to be capable of funding the construction of a profitable nuclear power station in Australia.

FUEL SUPPLIES.

With the original burnups attained by nuclear fuel, the world's nuclear power stations would in 2006 require 13,677 tons of fuel. We show that, at 13,819.tons/year, the world's nuclear fuel manufacturers have the capacity to produce this fuel. However the burnups now achieved are in many cases substantially higher than the original values and, conservatively, reduce the estimated weight of fuel required for 2006 to 9,863 tons. This is 74% of the global manufacturing capacity and as burnups continue to rise, the fuel required will be less than 74% of the capacity of the world's nuclear fuel manufacturers. It is concluded that there will be competition between fuel manufacturers to supply Australia with the fuel for a new nuclear power station, should one be built.

SECURITY.

Safety: Nuclear power, we show, is demonstrably the safest way of generating electricity and that it is an excellent source of secure supplies, little affected by accidental or political interruption. Its price is little affected by the price of uranium. It will remain stable even when the price of electricity from CCGT rises steeply, as it has recently risen in the UK and elsewhere. Thus:

- There have been 0.006 fatalities per GWe.year of nuclear electricity,
- Fifteen times as many fatalities per GWe.year for natural gas and
- One thousand times as many fatalities per GWe.year for coal, oil and hydropower.
- LPG has produced a given number of fatalities ten times more frequently than oil, coal or natural gas in OECD countries.

Terrorist Attack: We estimate that the total risk presented by an Australian nuclear power station, now seen to fall in the same class of World Terrorism Targets as the WTC and the Pentagon is now fifty percent higher than we would previously have thought. It is the fact that the WTC and the Pentagon were subject to massive terrorist attacks, of an unprecedented magnitude, that has brought about this revision. The risk was very low before the terrorist attacks occurred and it is still very low, despite the revision that we have made: much lower than the risks presented by coal, gas, oil and hydro and summarized above. This assessment is accepted by the UK, Canadian and Japanese Governments, who commissioned me to make it. These Governments insure the upper reaches of this terrorist risk in their countries and other countries are following suit. Commercial insurers also accept my analysis and insure the terrorist risk up to Aus $400m.

Security of Uranium, Gas and Coal Supplies: Insecurity in the supply of gas can lead to price-spikes and loss of electricity-generating capacity. Nuclear power, by adding diversity to Australia's sources of electricity, would improve the security of electricity supplies and help to stabilize electricity prices when gas prices peak and gas imports are interrupted. We show that some countries with major reserves of natural gas, such as Russia and Saudi Arabia pose much bigger political and financial risks than, for example, Australia, Canada and the UK. Papua New Guinea, a country from which Australia may import natural gas via a pipeline and whose reserves are similar to those of Australia, poses a risk as high as does Russia. Australia is completely self-reliant for uranium and coal: only domestic strikes could pose any threat to the security of those supplies.

NON-PROLIFERATION.

Australia is already a signatory of the NPT. The Australian Safeguards & Non-Proliferation Office (ASNO) operates the system of bilateral safeguards applying to Australian uranium exports based on customer countries being parties to the NPT. It also administers the domestic safeguards system required by Australia's own NPT agreement with the IAEA. In addition, ASNO keeps account of nuclear material and associated items in Australia through its administration of the Nuclear Non-Proliferation (Safeguards) Act 1987. ASNO provides information to the IAEA on the small amount of nuclear material in Australia which is subject to safeguards, and on uranium exports. It also facilitates IAEA inspections, including those under the Additional Protocol. ASNO could expand its activities to cover the NPT requirements of the Australian nuclear power station should it be decided to build such a facility.

AT WHAT STAGE SHOULD AUSTRALIA JOIN THE GENERATION IV REACTOR FORUM?

It could well be that, by the time Australia is ready to use nuclear power for part of its electricity generation, one or more of these Generation IV designs will be sufficiently advanced to merit consideration. Even if it is not, engagement with the GIF would give Australian nuclear specialists an unrivalled opportunity to collaborate with the world's leading reactor-development engineers and scientists and this would ready them to give good advice to the Australian Government on the type of plant to choose should Australia decide on the nuclear option.

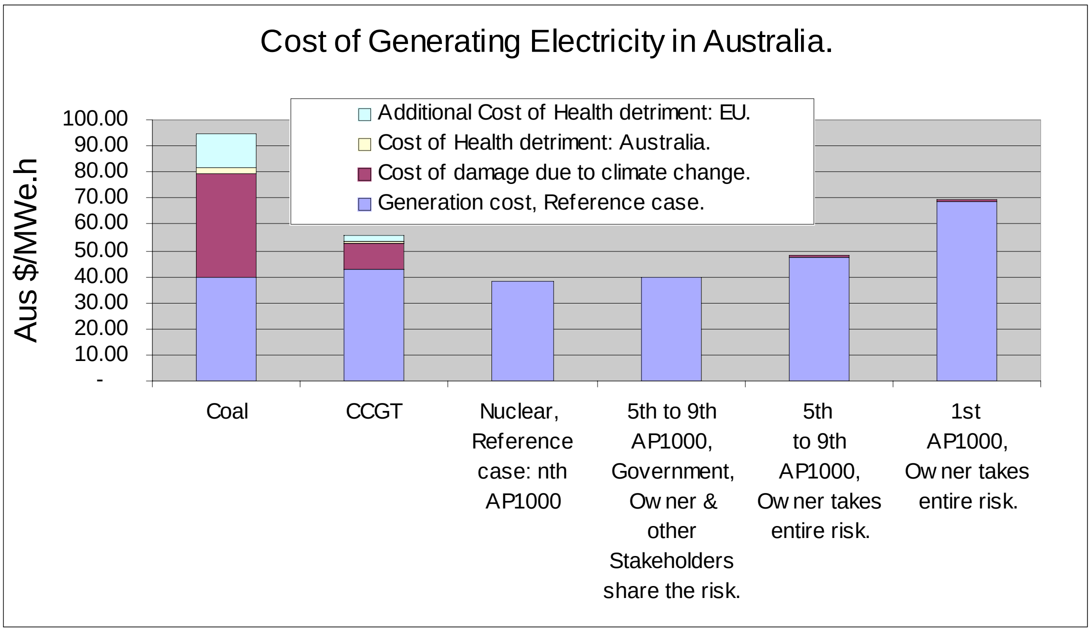
GLOBAL WARMING

Australia needs to consider building nuclear power stations in order to help it fulfil the obligations that it has made to the Asia Pacific Partnership on Clean Development and Climate. The five measures that Australia currently plans to mitigate global warming will, taken together, reduce Australia's Greenhouse gas emissions by 38 million tonnes per year. An equal reduction would be provided by substituting 4 to 5 GWe of nuclear generation for present and planned coal-fired power stations. This would comprise, for example, three AP1000's.

CONCLUDING REMARKS: FORECAST TOTAL COSTS OF GENERATING ELECTRICITY IN AUSTRALIA.

In the Figure we bring together our conclusions in the form of costs for the generation of electricity in Australia.

From this figure the following conclusions may be drawn:



1. The cost of generating electricity in Australia from the "nth copy" of a nuclear power station such as the AP1000, including financial provision for managing the spent fuel, radioactive wastes and ultimate decommissioning, is cheaper than generating it from coal or a CCGT station. The "nth copy" has settled-down costs, both capital and operating, unlike the first and other early copies which will have "First of a kind" costs.
2. If Australia were to build the world's 5th, 6th, 7th, 8th or 9th AP1000 then the risk of unexpectedly high costs of building and operating the station is higher than for the settled down case. However if this financial risk is shared between the owner, Government and other stakeholders in the manner developed in this Report the cost of the electricity that the station produces will still be no higher than that from new coal or CCGT power stations.
3. If, for the world's 5th, 6th, 7th, 8th or 9th AP1000, the owner takes the entire financial risk, then the nuclear station produces electricity at a cost that is significantly higher than would a new coal fired or CCGT power station. The FOAK risk for the fifth to ninth copy of an AP1000 is reflected in the excess of the cost of electricity, produced from this power station, over the cost of electricity from the nth AP1000. This risk can be reduced to an acceptably low level by a Government subsidy of 14.31% of the fifth-of-a-kind cost together with a subsidy of 21.41% of the cost of electricity for the first 12 years of operation.
4. If Australia builds the world's first copy of the AP1000, just as Finland has commenced building the world's first copy of the EPR, then it will not be competitive with coal or CCGT power stations. The FOAK risk for the first copy of an AP1000 is reflected in the excess of the cost of electricity, produced from this power station, over the cost of electricity from the nth AP1000. As we have shown, this risk can be reduced to an acceptably low level by a Government subsidy of 53.17% of the first-of-a-kind cost together with a subsidy of 21.41% of the cost of electricity for the first 12 years of operation.
5. The forecast cost of damage to the environment due to the climate change produced by CO_2 from a new, Australian coal fired power station is similar in

magnitude to the actual cost of generating the electricity. If Australia were to join the Kyoto Emissions Trading Scheme, ETS, then users of this electricity who exceed their quota would have to pay sums that are similar in magnitude to the climate-change costs that we have here calculated.

6. The forecast cost of damage to the environment due to the climate change produced by CO2 from a new, Australian CCGT power station is no more than a third that for coal. However our preferred nuclear finance plan, in which stakeholders share the financial risks for a 5th or later copy of an AP1000, is cheaper than CCGT if the total environmental plus generating costs are taken together, as they reasonably might be should Australia sign up to the ETS.
7. The five measures that Australia currently plans to mitigate global warming will, taken together, reduce Australia's Greenhouse gas emissions by 38 million tons per year. An equal reduction would be provided by substituting 4 to 5 GWe of nuclear generation for present and planned coal-fired power stations. This would comprise, for example, three or perhaps four AP1000's or EPR's.
8. The cost of the harm done to people's health by generating electricity from a nuclear power station in Australia is negligible. These health costs are not significant for coal-fired or CCGT generation, either, in Australia. By way of contrast, the health costs for coal-fired generation in EU countries are significant. This is largely due to the higher population and population-density in the EU, compared with Australia.

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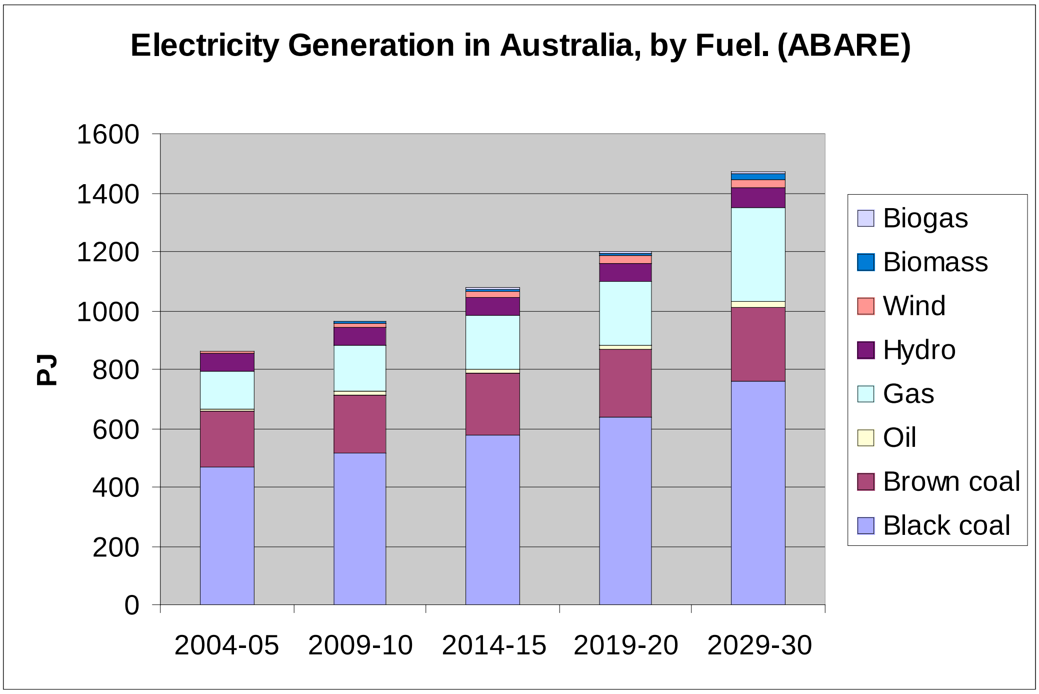
Executive Summary

This report analyses the potential of nuclear energy in Australia, primarily from the financial standpoint.

THE ECONOMICS OF NUCLEAR POWER AS PART OF AN OVERALL AUSTRALIAN ENERGY POLICY.



The above figure shows that coal will, on present forecasts, continue to supply about three quarters of Australia's electricity from now to 2029-30 and beyond. Gas will supply most of the remainder of Australia's electricity. Generation from natural gas in Australia is forecast to grow strongly, by a factor of 2.6, to 89 TWh by 2029-30. Of the world's mature market economies, only Australia has no nuclear capacity and plans none between today and 2025.

Financial Model for Electricity Generation from New Nuclear, Coal and CCGT Power Stations in Australia.

A Financial Model has been developed to permit a comparison between the generation costs of new nuclear, coal-fired and CCGT power stations in Australia. A comparison between the forecasts for Australia produced with this model and those for 12 other countries that were published by the OECD NEA in 2005 shows good agreement, lending confidence in the Model. The average cost of nuclear generation for 11 of the 12 countries in this table (Japan is excluded since it is exceptionally costly) is 38.58 Aus $/MWe.h. which is virtually indistinguishable from the figure of 38.20 Aus$/MWe.h derived from the present model, for Australia with the same 85% load factor that was used for the other 12 countries in the OECD study. Moreover, in all 12 countries, nuclear is the least expensive, followed by coal and then CCGT. This is the forecast that the present model makes for Australia, too.

The costs of generating electricity from new power stations having the parameters of our Model and interest-rates corresponding to the rates of return achieved in 2002-2003 by specified Australian States have been calculated and compared with the actual average costs of generation for NSW and Queensland. Our Model forecasts that nuclear power would be competitive with the actual costs of generation.

The price of uranium has increased 400% in recent years but our Model shows that the effect of this on the cost of electricity from a new Australian nuclear power station would not be of commercial significance. By way of contrast, the 35% increase in UK natural gas prices that has occurred over the last 12 months has increased the cost of CCGT electricity by 28% according to our Model and in accord with this prediction UK consumers have just been confronted by a price increase of 25% in the price of electricity. Australia, which does not need to import gas, has not seen a comparable rise in gas-prices.

Model forecasts based on ABARE projections of gas and coal prices show that nuclear will be continuously competitive with gas and coal in Australia through 2011 (the limit of the information on coal prices).

WOULD NUCLEAR POWER NEED SUBSIDIZING IN AUSTRALIA?

It could well be that nuclear power would need a subsidy to cover start-up costs in Australia. In this section we estimate the start-up costs and develop a finance plan to deal with them. We show that no subsidy is needed, although a subsidy would undoubtedly make things easier.

It may be that the Australian Government will in fact be prepared to give a Grant towards the construction of an Australian nuclear power station. In the first Financial Plan, here presented, we have however assumed that it will ***not*** give a Grant (which would not have to be repaid to Government) but that it ***would*** give an ***Insured Loan,*** which would be repaid to Government, together with a Retrospective Premium, out of revenues from the Station when once it began to generate electricity. I have established that Commercial Insurers might be prepared to act as ***leaders***[1] and write part of the Insurance of this loan: the part covering costly delays due to accidents and unforeseen, new regulatory requirements. Government would write the remainder.

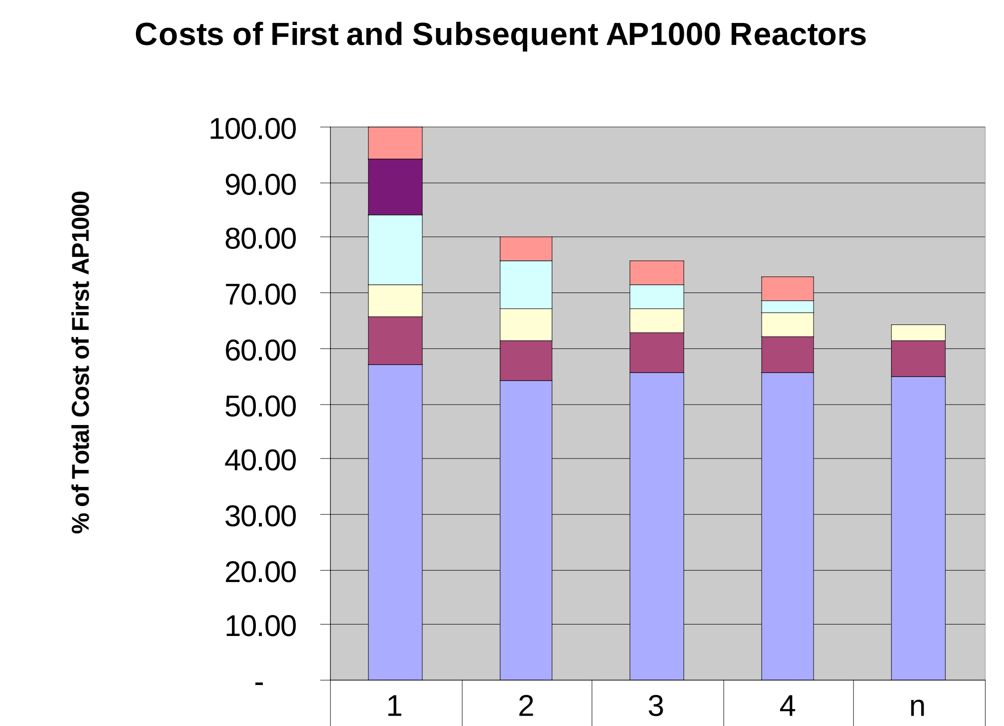
This arrangement is familiar to Government, since it already forms the basis of nuclear Third Party Liability Insurance. Indeed I am personally involved as Principal Consultant to the ***leader*** in that market. What I am suggesting is simply the

[1] Where a number of Insurers share a risk, it is usual for one of them to take the lead: in insurance parlance he is "***the leader***" . The leader has stature in the market. Even though he may only be able to insure a comparatively small percentage of the risk, his analysis of the risk is trusted by "***the following market***" of other Insurers. They therefore agree to follow his lead and take a share of the risk. The insurers each "***write***" a share of the risk and receive a proportionate share of the premium paid by the Insured Party.

application of the same, well-understood principal, not only to the ***operation*** of a nuclear power station but also to its ***construction***.

Under the first Financial Plan, then, the Government would advance a First Of A Kind (FOAK) loan. This would pay the excess capital cost that would undoubtedly be incurred if Australia builds one of the first copies of a new design of nuclear reactor such as the Westinghouse AP1000.

The following figure shows Westinghouse's own estimate of the magnitude of these excess, "FOAK" costs:



	1	2	3	4	n
Extra Finance	5.71	4.29	4.29	4.29	
FOAK Eng	10.00	-			-
Learning curve	12.86	8.57	4.29	2.00	-
Buyer's Contingency	5.71	5.71	4.29	4.43	2.86
Finance Cost	8.57	7.14	7.14	6.43	6.43
EPC	57.14	54.29	55.71	55.71	55.00

Now of course Westinghouse's estimates of the magnitude of the FOAK costs are approximate: they match the experience that the South Koreans had with the KSNP, a new design of reactor of which they have built half a dozen copies but, in the nature of things, the "FOAK loan" calculated from Westinghouse's forecasts could prove inadequate, for unforeseen reasons. There are established ways of forecasting the likelihood that more capital will be needed and we have used them. In this manner we arrive at values that can be covered by Risk-Transfer to the Stakeholders and to insurance bodies. Commercial EPC insurers would take the lead in writing this insurance and they would draft the "Policy Wording", which describes the circumstances (such as accidents, unforeseen regulatory intervention &c) under which insurers would top-up the FOAK loan. The Government and the stakeholders would provide the balance of the FOAK loan insurance and would take their share of the Insurance Premium: the commercial insurers that led the insurance would take their share too.

The Insurance Premium would be paid retrospectively. This is a familiar arrangement in the insurance markets[2]. In the present case the premium would be paid out of the revenues produced when the station begins to generate and sell electricity. Conceivably the insurance policy may specify that the premium will increase if there is a claim: but it would not increase by the amount of the claim since the essence of insurance is ***risk-transfer***. The insurer takes the risk that he will make a loss and the premium is calculated accordingly.

Of course commercial insurers will expect the various other parties: the Sponsor, Vendor, Shareholders, Bondholders, Banks &c to take their fair shares of the risks of the project, too. We analyse this distribution of risks between the parties and in the first Financial Plan arrive at a suggested partition, likely to be acceptable to the parties. In this Financial Plan Australia builds the 5th and possibly later AP1000 reactors (the first four having been built say in China and the USA).

The question that immediately arises is this: how is the risk to be partitioned in a planned way between the Sponsor, Vendor, Shareholders, Bondholders, Banks &c?

In this First Financial Plan, the following is the partition of the **Construction Risks** which we provisionally believe will be acceptable to the parties:

- **Insurers take 19% of the Construction R**isks. They will be paid to do this by means of a retrospective premium, taken out of the profits the station makes when once it is generating electricity. There will be a chance that for unforeseen reasons the FOAK cost exceeds the estimate and in that case the insurers will have to top it up. They may not recover this top-up out of premiums and this is the chance that they agree to take.
- **Government takes 56% of the Construction Risks**. They will be paid to do this by means of a retrospective premium, taken out of the profits the station makes when once it is generating electricity. So Government should not be out of pocket. However there will be a ***chance*** that for unforeseen reasons the FOAK cost exceeds the estimate and in that case the Government will have to help the insurers to top it up. They may not recover this top-up out of premiums and this is the chance that they agree to take.
- **25% of the Construction Risk is shared equally between Shareholders, Banks, the Vendor and the Owner**. The insurers, who are taking 19% of the construction risk and the Government, which is taking 56% will insist on this. Indeed they may well require the Vendor to take a substantially higher amount of risk under an EPC contract and we shall consider this in one of the other Financial Plans. The risk they take is that the stations will require extra FOAK money because, for example, there is an increase in FOAK costs, which it

[2] Retrospective premiums are commonplace in the nuclear insurance market: the US Government (as insurers of nuclear power stations) and the mutual insurers EMANI and NEIL use them in the insurance of both third party and material damage risks.

transpires, ***should have been foreseen***. Insurers will not pay it and so Government follows suit. As recompense for taking this share of the construction risk, the shareholders will require dividends, the banks will require loan interest, the Vendor will require profit on the EPC contract and the Owner will require profit on the electricity he eventually sells.

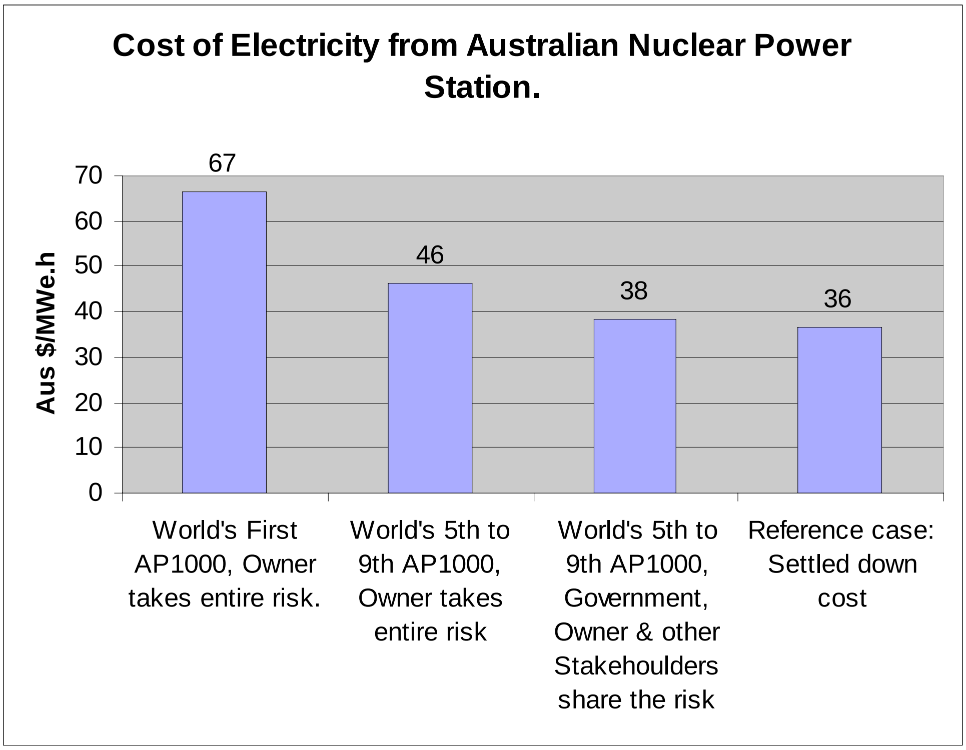
- **The remainder of the Construction R**isk is taken by the Fuel Supplier, who will lose profit if the stations are delayed or cancelled; and the Electricity Distributors who hoped to buy the electricity at a price below the market average and will not be able to do so if the plants are cancelled.

In this First Case, for the **<u>Operational Risks</u>**, all of which I provisionally believe will be acceptable to the parties:

- Government takes, as Governments do with all existing nuclear power stations, half the Operational Risk. It does this by agreeing to pay all costs, to Third Parties, of the most severe nuclear accidents. We do not expect any such accidents to occur, either because of machinery-breakdown, human fallibility, fire, earthquake, flood or terrorism &c. However the likelihood of severe accidents is estimated, by Probabilistic Risk Assessment[3], for all new (and most existing) nuclear power stations and when the PRA forecasts are used to estimate the magnitude of the Risk it transpires that Government is in fact taking a significant part of the Operating Risks by, in effect, providing Third Party insurance against the consequences of severe nuclear accidents. The Government charges a premium (which I have calculated under Contracts to both the UK and Canadian Governments) for covering the terrorist risk, but Government charges no premium for the other elements of the Third Party Risk.
- Most of the remaining Operational Risk is shared equally between Insurers, Shareholders, Banks, the Vendor and the Owner. As recompense for taking this share of the Risk,
  - *The insurers receive premiums,*
  - *The shareholders dividends, the Banks interest,*
  - *The Vendor receives the profit he made on constructing the stations and*
  - *The owner the profit he makes on selling electricity.*

The advantages of this Finance Plan become very clear when the forecasts of the following Figure are understood:

[3] I produced the first PRA for Sizewell B and presented it as CEGB Proof of Evidence No 16 at the Sizewell Public Inquiry that preceded the construction of Sizewell B.



The Figure provides a comparison between our ***Reference cost*** of electricity, from an Australian nuclear power station and the cost that includes allowance for the risks of building and operating it: from it the following conclusions may be drawn:

1. The settled-down cost of electricity, which we calculated using the Financial Model developed in this Report, is shown: it is 36 Aus $/MWe.h.
2. If Australia builds the world's first AP1000 (just as Finland is currently building the world's first EPR) then the cost of electricity that we forecast is virtually double the reference case: 67 Aus $/MWe.h. This is due to the FOAK costs forecast by Westinghouse. To the Westinghouse estimates of the FOAK costs we have added the financial values[4] of the two risks, which are:
   a. The Construction Risk which is the risk that the FOAK costs will be higher than Westinghouse has forecast, Figure 24; and
   b. The Operating Risk, also calculated in this Report.
3. In the case where we are concerned with the World's first copy of the AP1000, we have assumed that the owner shoulders the financial value of these two risks, a and b. He would clearly go into liquidation in this case since, in the Australian Energy Marketplace, no one would pay 67 Aus $/MWe.h for electricity when he can buy it for half that price from established coal-fired power stations. This problem has been identified in the USA where it has caused the US Government to offer to pay half the capital cost of the first 6 new nuclear power stations to be built in that country and to subsidize the electricity that they produce.
4. If Australia builds either the 5th, 6th, 7th, 8th or 9th AP1000 then if the owner takes all of the financial risks the cost of the electricity will be 46 Aus

[4] Strictly it is the statistical ***expectation*** that has been calculated and added to the Westinghouse FOAK costs: the Risk-Based method of accounting favoured by the UK Financial Services Authority and its counterpart in Australia.

$/MWe.h. This is not a competitive cost, either. It is nearly a third higher than our Reference Cost.

5. Finally, if our Financial Plan is implemented and the risk of the 5th-9th AP 1000 is shared between the Owner, Government and the other Stakeholders, the cost of electricity from Australia's nuclear power station is 38 Aus $/MWe.h, as compared with 36 Aus $/MWe.h for our reference case which is for the "nth" copy of the reactor. This is an economic cost. The electricity will be competitively priced and saleable in Australia. Unlike the American scheme, ours does not involve a Government ***subsidy***: the Government is asked to be a source of debt and to act as one of the reinsurers of the FOAK costs. The loan is repaid with commercial interest rates and in addition the Government receives commercial insurance premiums for doing this.

The Government Subsidy that would be needed if our Risk-Sharing Finance Plan is not Adopted.

Above we showed the costs of electricity from an Australian nuclear power station in which all of the financial risks are shared between the stakeholders. The Government takes just over half of the financial risk but it is paid an insurance premium for doing so out of the revenue received from the sale of electricity when once the plant is operating. The rest of the risk is borne by the Stakeholders. The Government also loans the FOAK costs, but again this loan is repaid, plus interest, out of the revenue produced by the station. So there is no Government subsidy, although the Government, like the other stakeholders, does take the risk that more capital will be needed: it is for being ready to supply its share of that extra capital that the Government is paid an insurance premium.

An alternative scheme is one in which Government ***subsidizes*** the nuclear power plant. This is what the US Government has undertaken to do, for the first 6 new nuclear stations built in the USA[5]. Clearly if Government is to subsidize the station then it will have to give a sum that has a good chance of being adequate: how much should that be? An answer is suggested by the requirements of the Government bodies that regulate the world's finance markets. In the UK the Financial Services Authority, FSA, requires insurers to have enough capital to suffice for needs that arise at the 0.5% level of probability. This then is the level that we take here: the Australian Government should give a subsidy such that there is only a 0.5% chance that it will prove inadequate. Of course if less is needed then less must be given and financial management tools will have to be put in place to avoid, to the extent possible, intentional overspends.

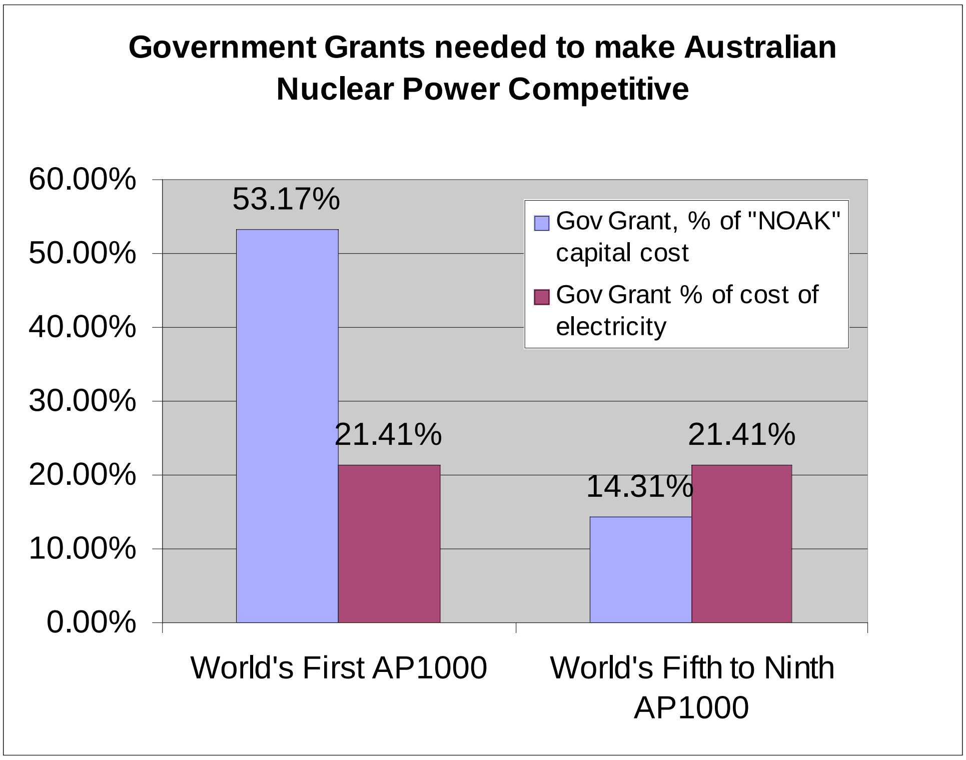
Our calculations then show that a Government grant of 14.31% of the "NOAK" cost of the fifth to ninth AP1000 would have a 0.5% chance of being inadequate. The risk of excessive operating costs would also be taken off the books of the Utility by Government, which would pay a subsidy of 21.41% of the cost of the electricity

[5] The 2005 USA energy bill offers new plant investment protection in the form of "standby support" to offset the financial impact of delays beyond industry's control that may occur during construction and during the initial phases of plant startup for the first six new reactors. The bill provides for 100 percent coverage of the cost of delays for the first two new plants, up to $500 million each, and 50 percent of the cost of delays, up to $250 million each, for plants three through six.

produced by the station, for the first 12 years of its operation. Such a subsidy is to be paid by the US Government for the first 6 new nuclear reactors built in the USA. The USA legislation provides a production tax credit of 1.8 cents per kilowatt-hour for 6,000 megawatts (MW) of capacity from new nuclear power plants for the first eight years of operation.

This forecast of the need for a subsidy of “only” 14.31% on the capital cost of the station seems at first sight to be much smaller than the 50% subsidy offered by the US Government. However the latter is for the first six copies of a new nuclear reactor and in fact the estimate arrived at from the present financial model for the World’s first AP1000 is virtually identical: it is 53.17% for the World’s first AP1000. There is also the 21.41% Government subsidy on the cost of electricity produced when the power station is in operation.

The following Figure shows these values.



HOW DO YOU ACCOUNT FOR THE WHOLE FUEL CYCLE COST?

The costs of the whole fuel cycle for nuclear electricity comprise the following components:

1. ➢ capital
2. ➢ operation and maintenance
3. ➢ fuel
4. ➢ spent fuel and waste management

5. ➢ decommissioning

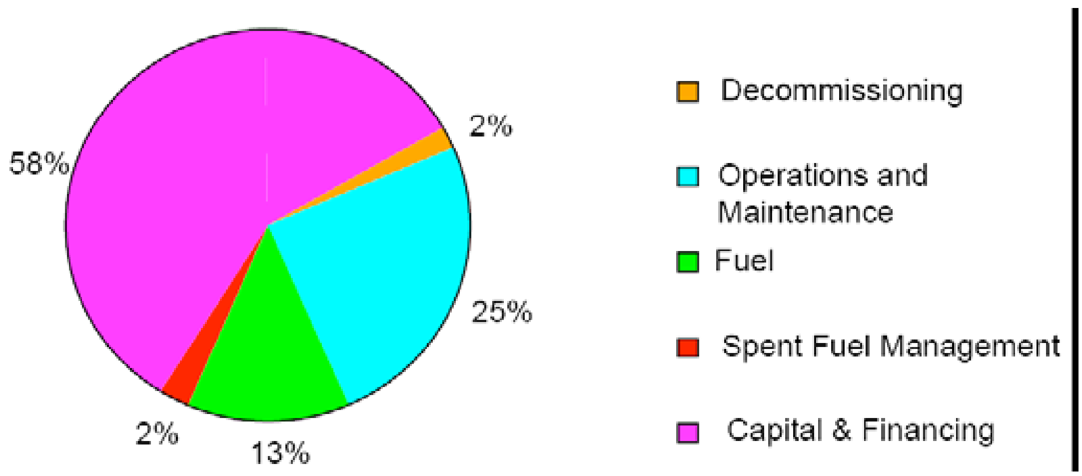
Of these five items, all except numbers 4 and 5 are costed into our reference cost of electricity generated from an Australian nuclear power station. Dealing with items 4 and 5:

Spent fuel management.

Spent Fuel Management relates to storage at the reactor site, transport to interim storage, costs of interim storage, conditioning of the fuel for disposal, plus disposal of the associated high level waste and any other linked waste arisings. The back-end of the fuel cycle, including spent fuel storage or disposal in a waste repository, contributes up to 10% to the overall costs per kWh, - less if there is direct disposal of spent fuel rather than reprocessing, the situation that we expect to exist in Australia. The $18 billion US spent fuel program is funded by a 0.1 US cent/kWe.h levy which is 4% of our Reference Cost of electricity from an Australian nuclear power station. We take the figure of 2% of the Reference Cost as the provision for spent fuel management for the AP1000 in this Report: see the Figure below.

Decommissioning

Money is also provided to cover eventual decommissioning of the reactor, including care and maintenance prior to that final stage, the direct civil engineering costs and ultimate disposal of wastes arising from decommissioning. Decommissioning costs, when they become payable, are estimated at 9-15% of the initial capital cost of a nuclear power plant. When discounted, they contribute only a few percent to the investment cost and even less to the generation cost. In calculations made by British Energy, the decommissioning cost is Aus $ 1.414/Mwe.h which is 3.89% of our Reference Cost of electricity from an Australian nuclear power station. In the USA they account for 0.1-0.2 US cent/kWh, which is between 4% and 8% of our Reference Cost of electricity from an Australian nuclear power plant. The more modern types of reactor are designed to make decommissioning easier and cheaper. We take the figure of 2% of the Reference Cost shown in the following Figure as the provision for decommissioning the AP 1000 in this Report.



WASTE.

In this Report we assume that the provisions that Australia would make for management of the radioactive waste from its nuclear power station would be the same as in most parts of the world currently. That is to say:

Spent Fuel.

It is assumed that the spent fuel would remain in the reactor pond for 20 years so that the level of radioactivity could decay substantially. This occurs with all LWR nuclear power stations. Then the fuel will, it is assumed, be placed in dry casks and stored for up to a century in a building on the surface awaiting the construction of an ultimate repository. Storage of spent fuel in dry casks has become the norm in Europe and the USA.

- Dry cask storage is environmentally benign.
- Thick shielding makes radioactivity harmless to human health during accidents and natural disasters.
- Extremely heavy cask construction makes release of radioactive material extremely unlikely.
- Casks can safely withstand earthquakes, tornados, floods, fires, and lightning.
- The US NRC has stated that dry cask storage remains safe for at least one hundred years.

The spent fuel will finally be placed in a repository, which may be underground. It is believed that the spent fuel will not be reprocessed since this is amore expensive option.

From the estimates and experience that have accumulated in the EU we forecast that building dry storage at an Australian nuclear power station will require an initial investment of Aus $13.6 million to Aus $27 million. Once operational, it will cost about Aus $6.8 million to Aus $9.6 million a year to maintain the facility and add containers as storage needs grow. These costs will arise after the period of 12 years during which, in our Financial Plan, retrospective repayment of the FOAK loan and associated insurance premiums takes place. These payments total Aus $ 9.04m/year and when they cease we shall have to pay almost the same sum—Aus $ 9.6m/year, to manage the storage of spent fuel in dry casks in the dry cask store,

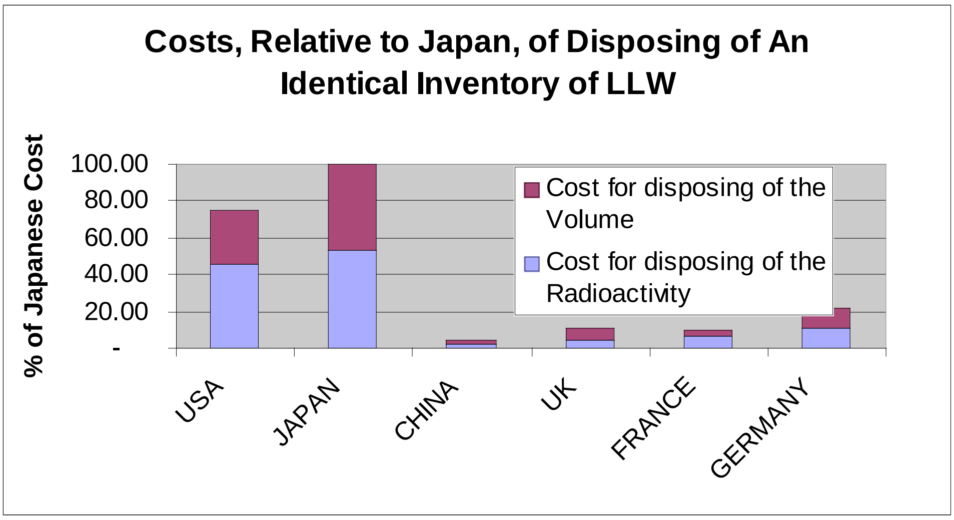
As for the capital cost of the Dry Store: this comprises an addition, that we have already made, of Aus $ 5m to the Capital Cost of the Nuclear Power Station. This provides the sum of Aus $ 27m needed 20 years after the reactor starts-up, to pay the capital cost of the Dry Cask store.

Intermediate Level Waste, ILW.

It is assumed that the Intermediate Level Waste from the Australian Nuclear Power Station will be consolidated into concrete blocks, which will be kept in a shielded store on the surface until an ultimate repository is constructed. This is what is done with ILW in the UK.

Low Level Waste, LLW.

It is assumed that Low Level Waste will be permanently disposed to a surface repository similar to Drigg in the UK and Barnwell in the USA.



The above Figure shows that the cost of disposing of LLW varies by a factor of more than ten between five countries, including the UK and the USA.
In recent years all suitable LLW has been supercompacted before disposal to Drigg, Figure 35. In this process drums or boxes of waste are compacted under high pressure of up to 2,000 tonnes per square metre. Waste is placed in large metal containers, which are then filled with cement. These containers are then placed in concrete lined vaults.

From an analysis of these figures we forecast that storage of the ILW and LLW from the Australian nuclear power station will cost the same annual sum, Aus $ 9.6m/year (which is Aus $ 0.96/MWe.h or 3% of the cost of generation), as will the management and storage in a Dry cask store, of the spent fuel. We have included in the capital cost of the power station the sum of Aus $ 20 m as a contribution towards the capital cost of these stores, which will, like the Dry Cask Store, be needed some years after the construction and initial operation of the power station.

FUEL SUPPLIES.

Fuel fabrication for the bulk of installed LWR nuclear capacity is now open to full competition. This includes

- Westinghouse, Framatome, and Mitsubishi Heavy Industries (MHI) reactor types (comprising 57% of all LWR capacity),
- General Electric (GE) types (including Hitachi and Toshiba) (23%), and Siemens reactors (9%).

The maximum turnover of the nuclear fuel business of Westinghouse is $1bn and the R&D effort is of the order of 17% of turnover, which is quite a high figure and requires very high margins.

Table 18 shows that, with the original burnups attained by nuclear fuel, the world's nuclear power stations would in 2006 require 13,677 tons of fuel. Table 15 shows that, at 13,819.tons/year, the world's nuclear fuel manufacturers have the capacity to produce this fuel. However the burnups now achieved are in many cases substantially higher than the original values and, conservatively, reduce the estimated weight of fuel required for 2006 to 9,863 tons. This is 74% of the global manufacturing capacity and as burnups continue to rise, the fuel required will be less than 74% of the capacity of the world's nuclear fuel manufacturers.

It is concluded that there will be competition between fuel manufacturers to supply Australia with the fuel for a new nuclear power station, should one be built.

SECURITY.

Nuclear power, we show, is demonstrably the safest way of generating electricity and that it is an excellent source of secure supplies, little affected by accidental or political interruption. Its price is little affected by the price of uranium and so will remain stable even when the price of gas rises steeply, as it has recently risen.

Safety.

Dealing first with safety: there have been accidents in the coal, oil, natural gas, LPG and hydro sectors that dwarf the Chernobyl nuclear accident. The latter was in any case irrelevant to the safety of Western designs of nuclear power station since the RBMK design of reactor used at Chernobyl is intrinsically unstable and incapable of operating to acceptable safety levels [6]. The original purpose of the RBMK was not the generation of electricity but the provision of military-grade plutonium for nuclear weapons and it was hurriedly designed for that express purpose, without proper attention to its safety.

Figure 38 relates accident statistics to the amount of electricity produced. We see that

- There have been 0.006 fatalities per GWe.year of nuclear electricity,
- Fifteen times as many fatalities per GWe.year for natural gas and
- One thousand times as many fatalities per GWe.year for coal, oil and hydropower.
- LPG has produced a given number of fatalities ten times more frequently than oil, coal or natural gas in OECD countries.

Our forecasts for the safety of nuclear power stations derive in part from Probabilistic Risk Assessments, since for example there have been no nuclear fatalities in OECD countries. However the records of commercial nuclear insurers show a good

[6] The Chernobyl Accident and its Consequences. J H Gittus et al. Foreword by Lord Marshall of Goring. ISBN 085356216-4. London, HMSO.

correlation between the financial losses that they have had to pay and the forecasts of Probabilistic Risk Assessments for the world's nuclear installations, Figure 40. This raises our confidence in PRA.

Security of Supply.

By summing the products of (Accident-likelihood) and (Outage-duration) we arrive at a figure of ***1 day per year*** as the average outage duration due to nuclear accidents at an Australian nuclear power station and this could be used to derive the effect on the cost of electricity in our Reference Model calculation. However the losses due to interruptions lasting between 90 days and one year are insurable, as are the material damage and third party liability losses. Accordingly these losses are not additional to the cost of electricity. The insurance premiums are additional costs, however and they are included in the operational costs that figure in our calculations of the cost of nuclear electricity in Australia

It is with the catastrophic events that we are most concerned since they lead to long or even indefinite outages. What our forecasts reveal is that very long outages of the kind that jeopardize security of supply will be very infrequent for nuclear power in Australia, making it a very reliable source of electricity.

In particular, there is little risk of politically inspired interruptions to the supply of nuclear fuel from foreign suppliers. The main reason for this is the fact that the country from which Australia will buy its nuclear fuel would almost certainly be one to which Australia would export uranium. Another reason is the fact that there are a dozen suppliers of nuclear fuel, in different countries, competing for orders.

The Prospect of Terrorist Attack on Australian Nuclear Installations.

Since the attack on the World Trade Centre there have been worries that a similar "Kamikaze" terrorist attack could be made on a nuclear power station, reprocessing plant, waste store, truck or other similar target. Immediately after the attack on the World Trade Centre commercial insurers all over the world determined that it was no longer practicable for them to continue insuring nuclear installations against terrorist attack. Accordingly Governments stepped in and took over this aspect of nuclear insurance. With the passage of time, however, commercial insurers have gained confidence and now insure a large part of the terrorist risk to nuclear installations. There mounting confidence is based on a sober interpretation of the true nature of the risk and stems in part from the analyses that I have made for Governments and Insurers, of its magnitude. I was commissioned, first by the UK Government and then by the Canadian and Japanese Governments to assess the magnitude of the risk of terrorist attacks to nuclear installations in the UK, Japan and Canada.[7]. I made use of Bayes' theorem. This theorem is in widespread use for such purposes. It enables us to use sparse data (terrorist air strikes on two targets in this case) to logically-modify our prior belief about the likelihood, in future, of such terrorist acts.

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7 Professor John H Gittus. November 2004. Review of the Premium for Government Reinsurance of Terrorist Coverage under the Canadian Nuclear Liability Act, (NLA). © PROPERTY OF Dr John H Gittus; PERMITTED GOVERNMENT USE DEFINED UNDER NRCAN CONTRACT N° NRCan-04-0525.

From this analysis we conclude that the total risk presented by nuclear installations that fall in the same class of World Terrorism Targets as the WTC and the Pentagon is now fifty percent higher than we previously thought. It is the fact that the WTC and the Pentagon were subject to massive terrorist attacks, of an unprecedented magnitude, that has brought about this revision. The risk was very low before the terrorist attacks occurred and it is still very low, despite the revision that we have made: much lower than the risks presented by coal, gas, oil and hydro and summarized above.

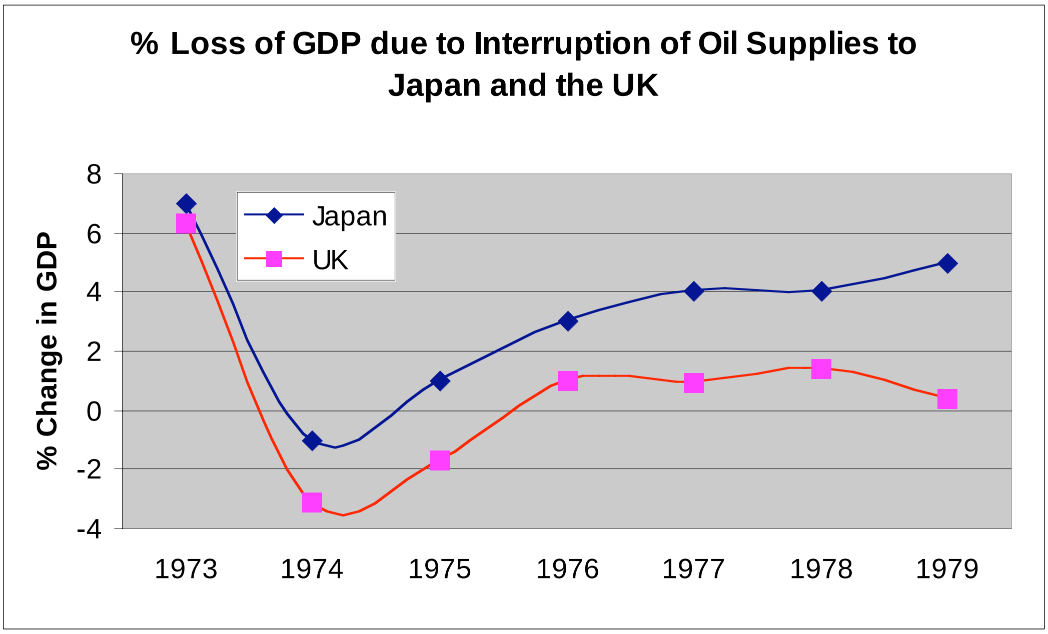
This conclusion is not very sensitive to various assumptions that have had to be made in arriving at it. It is clearly consistent with the views of operators, insurers and regulators round the world, since if they believed that the risk had increased by more than a small factor they would insist on the defuelling of many of the world's nuclear power stations so as to reduce to a much lower level the terrorist risk that they present.

The insurance premiums charged by the UK Government for insuring UK nuclear installations against terrorist attack immediately after "9/11" were calculated in the manner here described. Those charged by the Canadian Government are calculated in the same way. This premium is included in the Operating Costs of our Finance Model for an Australian nuclear power station.

Security of Australia's Natural Gas Supplies.

There are now major concerns, particularly in Europe, that countries that have the majority of the world's oil and gas will use these reserves as a political weapon. Superficially one might have thought that a country like Australia or the UK that has its own reserves of oil and gas would be immune to this problem. However the UK has suffered large, very volatile increases in the price of natural gas over the last 12 months. Significantly these increases coincide with the period during which, for the first time in 20 years, the UK has had to import some of the natural gas it consumes, its own rate of production having fallen below the peak demand. Now Australia plans to import natural gas and so one must assess the likelihood that it, too, will be faced with price-hikes and even shortages when it begins to rely on foreign suppliers for some of the natural gas that it intends to import for electricity generation.

In other parts of the world, attention is now focussed on nuclear power as a more secure source of supply than imported natural gas. Is it likely that nuclear power would improve the security of electricity supplies in Australia? Would it help to stabilise electricity prices? Having analysed the situation we conclude that the countries from which Australia is likely to import natural gas are as likely to interrupt supplies as have been the Arab states that export oil. The massive fall in GDP that occurred when, in 1974-5, these Arab states interrupted their oil exports to the UK and Japan is shown in the following Figure:



Similar insecurity in the supply of gas can lead to price-spikes and loss of electricity-generating capacity. Nuclear power, by adding diversity to Australia's sources of electricity, would improve the security of electricity supplies and help to stabilize electricity prices when gas prices peak and gas imports are interrupted.

Figure 47 shows that some countries with major reserves of natural gas, such as Russia and Saudi Arabia pose much bigger political and financial risks than do Australia, Canada and the UK. Papua New Guinea, a country from which Australia may import natural gas via a pipeline and whose reserves are similar to those of Australia, poses a risk as high as does Russia.

Security of Australia's Coal Supplies.

Australia has large reserves of cheap coal and it is for this reason that most of its power stations are coal-fired. However it does not follow that the availability of this coal is guaranteed: there have been substantial coal strikes in Australia, just as there have been in the UK and although the industry appears stable now, history could repeat itself. These Australian coal strikes were not a threat to electricity generation but more severe stoppages are conceivable: another good reason to diversify Australia's sources of electricity. Nuclear would be a source of such diversification.

Windpower.

Wind power is a minor source of electricity in Australia and ABARE forecasts that it will remain so. Windpower and other renewables are only economically viable in Australia because the Australian Federal Government, like many governments in the world, is encouraging the uptake of renewable energy through legislated measures. The Mandatory Renewable Energy Target (MRET) requires that a certain amount of the energy sold by Australian retailers be from renewables such as wind and solar.

Solar Electricity.

Sales of solar PV modules are increasing strongly as their efficiency increases and price falls. But the cost per unit of electricity - at least ten times that of conventional sources, limits its potential to supplementary applications on buildings where its maximum supply coincides with peak demand.

Hydropower.

The current installed hydro power production capacity in Australia is over 7600MW, producing approximately 17,700GWe.h per annum of electrical energy, or approximately 9% of the total energy production in Australia. Hydro is almost the sole form of energy produced in Tasmania, but this is the exception in Australia. Even in New South Wales – the state with the next highest installed capacity of hydro power plants – hydro energy production amounts to only 12% of the total energy mix in that state. Modest expansion of this capacity is forecast by ABARE.

NON-PROLIFERATION

A Nuclear power station requires nuclear fuel, which contains the fissile isotope of Uranium, U235 and which may in addition contain fissile isotopes of plutonium, Pu239 and other odd-numbered Pu isotopes. These isotopes, after they have been concentrated by physical processes, can be used as nuclear explosives. Terrorists or other countries may acquire them and use them in nuclear weapons. This is an example of proliferation.

The Non-Proliferation Treaty (NPT) is also known as the Treaty on the Non-Proliferation of Nuclear Weapons. The NPT aims to prevent spread of nuclear weapons to states that do not already possess them while trying to ensure fair access to peaceful nuclear technology under international safeguards. There are two categories of parties to the treaty - nuclear weapon states (NWS) and non-nuclear weapon states (NNWS). Under the treaty, NWS are defined as the five states that exploded a nuclear device before January 1967 (the US, the USSR or now Russia, the UK, France, and China). If Australia builds a nuclear power station then it will be expected to extend its activities under the NPT as a NNWS.

Australia, as a Non-nuclear-weapon state, NNWS already undertakes not to acquire or produce nuclear weapons. Australia would also be required to accept safeguards to detect diversions of nuclear material from its nuclear power generation, to the production of nuclear weapons. This has to be done in accordance with the individual safeguards agreement, concluded between Australia as a non-nuclear-weapon State Party and the International Atomic Energy Agency (IAEA), whereby the nuclear power station, like the ANSTO nuclear site, would be open for audit and inspection.

Australia has 14 bilateral safeguards agreements covering 24 countries (the Euratom agreement covering several). It has always taken the position that rigorous bilateral safeguards are an important and effective complement to the international safeguards system.

Australia's position as a major uranium exporter is influential in the ongoing development of international safeguards and other non-proliferation measures, through membership of the IAEA Board of Governors, participation in international expert groups and its safeguards research program in support of the IAEA.

The Australian Safeguards & Non-Proliferation Office (ASNO) operates the system of bilateral safeguards applying to Australian uranium exports based on customer countries being parties to the NPT. It also administers the domestic safeguards system required by Australia's own NPT agreement with the IAEA.

In addition, ASNO keeps account of nuclear material and associated items in Australia through its administration of the Nuclear Non-Proliferation (Safeguards) Act 1987. ASNO provides information to the IAEA on the small amount of nuclear material in Australia which is subject to safeguards, and on uranium exports. It also facilitates IAEA inspections, including those under the Additional Protocol.

ASNO could expand its activities to cover the NPT requirements of the Australian nuclear power station should it be decided to build such a facility.

AT WHAT STAGE SHOULD AUSTRALIA JOIN THE GENERATION IV REACTOR FORUM?

Australia should join the Generation IV Forum, GIF, since GIF’s interests coincide with those of Australia.

Thus Australia’s concerns over energy resource availability, climate change, air quality, and energy security suggest an important role for nuclear power in Australia’s future energy supplies. While the current Generation II and III nuclear power plant designs provide a secure and low-cost electricity supply in many markets, further advances in nuclear energy system design can broaden the opportunities for the use of nuclear energy. To explore these opportunities, the U.S. Department of Energy's Office of Nuclear Energy, Science and Technology has engaged governments, industry, and the research community worldwide in a wide ranging discussion on the development of next generation nuclear energy systems known as **"Generation IV"**.

It could well be that, by the time Australia is ready to use nuclear power for part of its electricity generation, one or more of these Generation IV designs will be sufficiently advanced to merit consideration. Even if it is not, engagement with the GIF will give Australian nuclear specialists an unrivalled opportunity to collaborate with the world’s leading reactor-development engineers and scientists and this will ready them to give good advice to the Australian Government on the type of plant to choose should Australia decide on the nuclear option.

GLOBAL WARMING

Australia needs to consider building nuclear power stations in order to fulfil the obligations that it has made to the Asia Pacific Partnership on Clean Development and Climate, formed between Australia, China, India, Japan, the Republic of Korea and the United States. The Partnership intends to play a strategically important role in the development, deployment and transfer of more energy efficient and cleaner technologies to curb emissions while at the same time enhancing the growth prospects of economies[8].

In 2001 around 40 per cent of global carbon dioxide emissions were generated by the electricity sector. Emissions from electricity generation in partnership economies accounted for about 17 per cent of global greenhouse gas emissions and about 22 per cent of global carbon dioxide emissions.

Australia has refused to sign the Kyoto Agreement due to issues with the protocol. The Australian Prime Minister, John Howard, has argued that the protocol would cost Australians jobs, and that Australia is already doing enough to cut emissions. The Federal Opposition, the Australian Labour Party is in full support of the protocol and it is currently a heavily debated issue within the political establishment. The opposition claims signing the protocol is a "risk free" prospect as they claim Australia would already be meeting the obligations the protocol would impose. As of 2000, Australia was the world's eleventh largest emitter per capita of greenhouse gases.

Australia's Global Warming Abatement Programme.

The Australian Government has allocated more than $1 billion for greenhouse gas abatement. Major elements include:

1. Minimum Energy Performance Standards for appliances, equipment and buildings will deliver 8.3 Mt of abatement in 2010 as well as more than $4 billion in net economic benefits over the 2003–2018 period.
2. The Greenhouse Challenge programme will deliver 13.2 Mt of abatement in 2010 and has helped more than 700 Australian companies identify and act on emissions abatement opportunities while saving money and increasing product quality.
3. The Mandatory Renewable Energy Target will deliver 6.5 Mt of abatement in 2010 and drive over $2 billion in investment in new renewable energy generation.
4. The Greenhouse Gas Abatement programme has allocated over $100 million to companies to achieve large scale abatement in the 2008–12 period, and will deliver 10.3 mt of abatement.
5. The Ozone Protection and Synthetic Greenhouse Gas Management Act 1989, as amended in 2003, sets the international standard for managing synthetic greenhouse gases.

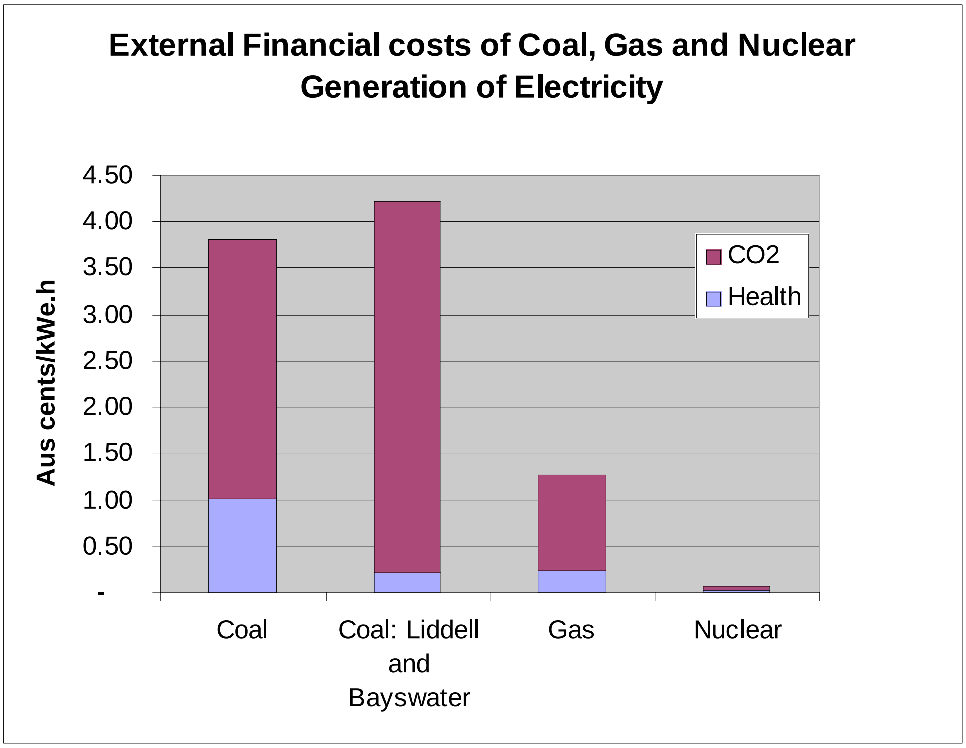
Substituting one 1GWe Nuclear Reactor for a Coal-Fired Power Station saves 7 to 9 million tons of CO_2.

[8] Technological Development and Economic Growth. Inaugural Ministerial Meeting of the Asia Pacifi c Partnership on Clean Development and Climate Sydney, 11–13 January ABARE research report 06.1. Brian S. Fisher, Melanie Ford, Guy Jakeman, Andrew Gurney, Jammie Penm, Anna Matysek and Don Gunasekera. January 2006

The 5 measures listed above will, taken together, reduce Australia's Greenhouse gas emissions by 38 million tonnes per year. An equal reduction would be provided by substituting 4 to 5 GWe of nuclear generation for present and planned coal-fired power stations. This would comprise, for example four AP1000's or EPR's.

The cost of the detriment to the global climate due to the global warming that Australia's coal-fired power stations at Liddell and Bayswater are producing is shown in the next Figure. Ben Maddox of the University of Newcastle, Australia did the calculation for Liddell and Bayswater. The other forecasts are for Germany. These forecasts were done by means of the ExternE methodology that has been developed at a cost of Aus $ 10 million by countries of the EU over the last eight years.

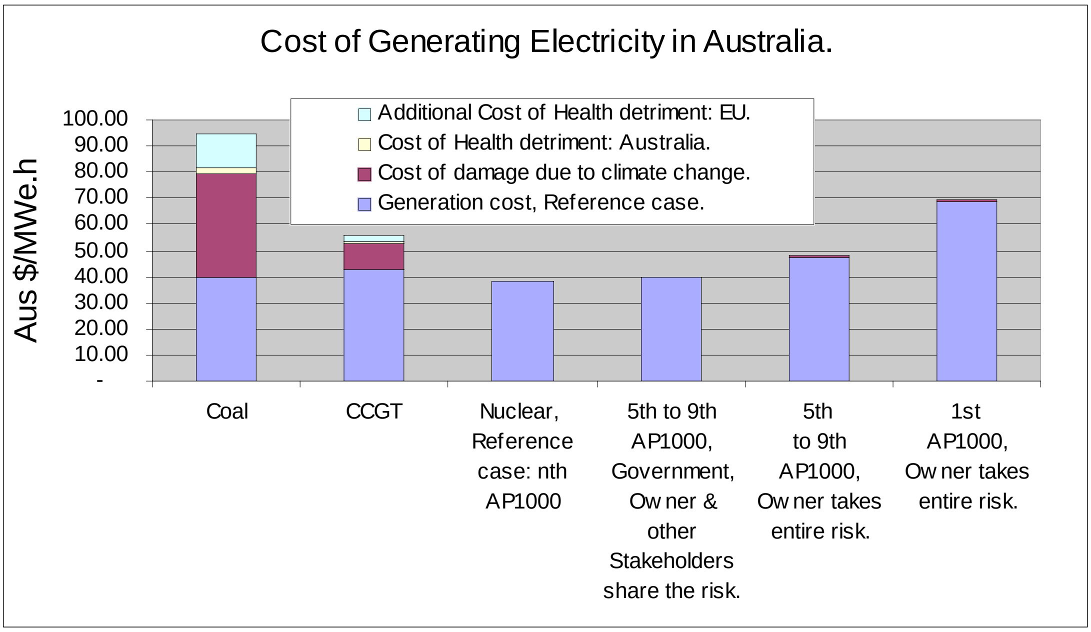
The cost of the impact of the emissions from power stations upon the health of people living round them are also shown in the following Figure. These costs reflect the health effects produced by normal emission of radioactivity from the nuclear power stations and the emissions produced by accidents, including the rare big accidents that can harm many people. Accidents are included in the estimation of health effects for gas and coal as well. These accidents, unlike the purely hypothetical nuclear accidents, are well documented and have already been discussed in this Report.



CONCLUDING REMARKS: FORECAST TOTAL COSTS OF GENERATING ELECTRICITY IN AUSTRALIA.

In the next Figure we bring together our conclusions in the form of costs for the generation of electricity in Australia.

From this figure the following conclusions may be drawn:



1. The cost of generating electricity in Australia from the "nth copy" of a nuclear power station such as the AP1000, including financial provision for managing the spent fuel, radioactive wastes and ultimate decommissioning, is cheaper than generating it from coal or a CCGT station. The "nth copy" has settled-down costs, both capital and operating, unlike the first and other early copies which will have "First of a kind" costs.
2. If Australia were to build the world's 5th, 6th, 7th, 8th or 9th AP1000 then the risk of unexpectedly high costs of building and operating the station is higher than for the settled down case. However if this financial risk is shared between the owner, Government and other stakeholders in the manner developed in this Report the cost of the electricity that the station produces will still be no higher than that from new coal or CCGT power stations.
3. If, for the world's 5th, 6th, 7th, 8th or 9th AP1000, the owner takes the entire financial risk, then the nuclear station produces electricity at a cost that is significantly higher than would a new coal fired or CCGT power station. The FOAK risk for the fifth to ninth copy of an AP1000 is reflected in the excess of the cost of electricity, produced from this power station, over the cost of electricity from the nth AP1000. This risk can be reduced to an acceptably low level by a Government subsidy of 14.31% of the fifth-of-a-kind cost together with a subsidy of 21.41% of the cost of electricity for the first 12 years of operation.
4. If Australia builds the world's first copy of the AP1000, just as Finland has commenced building the world's first copy of the EPR, then it will not be competitive with coal or CCGT power stations. The FOAK risk for the first copy of an AP1000 is reflected in the excess of the cost of electricity, produced from this power station, over the cost of electricity from the nth AP1000. As we have shown, this risk can be reduced to an acceptably low level by a Government subsidy of 53.17% of the first-of-a-kind cost together with a subsidy of 21.41% of the cost of electricity for the first 12 years of operation.

5. The forecast cost of damage to the environment due to the climate change produced by CO2 from a new, Australian coal fired power station is similar in magnitude to the actual cost of generating the electricity. If Australia were to join the Kyoto Emissions Trading Scheme then users of this electricity who exceed their quota would have to pay sums that are similar in magnitude to the climate-change costs that we have here calculated.
6. The forecast cost of damage to the environment due to the climate change produced by CO2 from a new, Australian CCGT power station is no more than a third that for coal. However our preferred nuclear finance plan, in which stakeholders share the financial risks for a 5th or later copy of an AP1000, is cheaper than CCGT if the total environmental plus generating costs are taken together, as they reasonably might be should Australia sign up to the ETS.
7. The 5 measures that Australia currently plans to mitigate global warming will, taken together, reduce Australia's Greenhouse gas emissions by 38 million tons per year. An equal reduction would be provided by substituting 4 to 5 GWe of nuclear generation for present and planned coal-fired power stations. This would comprise, for example, three AP1000's.
8. The cost of the harm done to people's health by generating electricity from a nuclear power station in Australia is negligible. These health costs are not significant for coal-fired or CCGT generation, either, in Australia. By way of contrast, the health costs for coal-fired generation in EU countries are significant. This is largely due to the higher population and population-density in the EU, compared with Australia.

Introduction.

This report analyses the potential of nuclear energy in Australia, primarily from the financial standpoint. A Financial Model is first developed. This permits the cost of electricity from a coal-fired, CCGT or nuclear power station to be calculated from various given parameters such as capital cost and interest rate. The model is checked against other published forecasts and against the actual cost of generating electricity in Australia to gain confidence in its forecasts. Then two alternative Finance Plans are developed, either of which would permit the construction and operation of a nuclear power station in Australia. One is a conventional plan, for which it is concluded a government subsidy would be needed and the other is a completely new, specially-developed plan in which the financial risks are shared between the Stakeholders, Government and the Risk-transfer market: no Government subsidy is needed for this second plan.

The whole fuel cycle cost is then examined and the costs of decommissioning, spent fuel management and waste disposal are estimated for the Australian case. It is assumed that spent fuel will not be reprocessed. Then the world market in nuclear fuel assemblies is laid out together with the demand for fuel from all countries that have nuclear power. This permits the competitive nature of the market to be estimated and with it the availability of fuel for an Australian nuclear power station.

Attention is then turned to security. The comparative safety and health impacts of nuclear power, coal and CCGT are examined first. Then the security of supply is calculated for all sources of electricity in Australia: coal, gas and windpower plus other renewables. Security of nuclear electricity supplies is forecast, for Australia.

Next the impact of a decision to build a nuclear power station upon Australia's membership of the Non-Proliferation Treaty is considered, together with how this can be managed. The possible participation of Australia in the Generation IV Forum, GIF is examined.

The attraction of a nuclear power station from the standpoint of Australia's contribution to Global Warming is then analysed, together with the health-impacts of coal, CCGT and nuclear generation.

Finally the potential of nuclear energy for Australia is examined from the standpoint of all these elements and a conclusion drawn.

THE ECONOMICS OF NUCLEAR POWER AS PART OF AN OVERALL AUSTRALIAN ENERGY POLICY.

Australia's Current Energy Policy.

Energy Regulation in Australia.

The Australian Energy Regulator (AER) commenced operations on Friday 1st July 2005 and will be responsible for regulation and rule enforcement in the national electricity and gas energy markets. The AER was established under the Trade Practices Act, with the primary aim of reducing the regulatory burden on the energy sector, thus encouraging maturation of fair market competition and a more effective service delivery.

The need for a single regulator has been argued ever since natural gas joined electricity in the competitive market. The AER will make regulatory decisions independently of the Australian Competition and Consumer Commission (ACCC), although the two will share a single body of advisory staff. By replacing 13 regulatory commissions, the AER is designed to make regulation more efficient and consistent by avoiding duplication of resources and to improve functionality between Australian states and the energy industry.

Regulatory conflicts with the energy industry and amongst the states which make up the national energy market have been identified as hindering vital infrastructure investment that ultimately penalizes end-users. Different regulatory approaches create additional costs and obstacles for service providers operating in more than one sector of the energy industry. By simplifying compliance directives and lines of communication, it is anticipated that the single regulatory entity will reduce the paper shuffle and financial burden in the energy industry.

A homogeneous regulatory environment will not only reduce costs for current players, but will also encourage competition by allowing interstate suppliers to compete on a more level playing field. The underlying principle is that end-users should not choose gas over electricity or vice versa because of different regulations, but due to certain economic and operational merits.

The AER is not taking over the reins of a smooth coach. Energy regulation in Australia has been a series of triumphs and failures with some industry associations asserting that regulation to date has been too academic and bureaucratic and is out of touch with the mechanics and market realities of energy provision.

The newly appointed and inaugural head of the AER, Steve Edwell, has made it clear there will be greater market participation in the regulatory process. He has also stated that end-user input, which was lacking and not encouraged under the former system, is an essential element of effective regulation. His pronouncement has been greeted with a fair amount of skepticism by some industry participants who see the AER's close relationship with the ACCC as a bias towards protecting consumers at the expense of fair dealings with suppliers.

Political antagonists argue that stripping the states of their regulatory powers in favor of a one-stop shop will lead to serious non-representation of geographically challenged areas. They strongly argue that the nature of energy distribution necessitates local oversight. Economic antagonists, on the other hand, view the shift toward AER regulation as a smoke screen designed to divert attention from much bigger issues, such as price capping. From a purely monetary standpoint, it has been argued the less regulation the better. Companies should be free from all profit constraints thus encouraging greater infrastructure investment to serve the public good. It has been said that any level of price capping is a sign of a failed supply model which should have matured over the last 10 years.

Overall the introduction of the AER is certainly a positive step. However, as the country is faced with such a complex set of energy issues, simplification should be viewed as a help, but not the overall cure.

It seems that not so long ago, in the dawning of competition in the Australian electricity market, all the talk was about disassembling the country's vertically integrated structures. However, today many are questioning whether the competitive market is at risk for "creeping" re-integration.

Most States achieved the unbundling of their electricity industry by selling off assets – at very high prices by today's standards. At the time, buyers of state-owned assets viewed electricity prices remaining high, thus leading them to attractive profits. This expectation however was counter to the principle of competition which intended a lowering of prices.

Most UK and US buyers have since left the scene, absorbing huge losses. The new owners, accustomed to the Australian energy business, began introducing re-integration into the market with possessing total or partial ownership of generation, distribution, retailing and even transmission.

AGL, for instance, a traditional gas distributor and retailer, now owns a significant stake of electricity generation, distribution and retailing assets. Most recently, AGL acquired a stake in the Loy Yang power station in Victoria. Singapore Power, already the owner of Victoria's transmission system, recently bought TXU's distribution and retail businesses and while they have agreed to segregate the business operations, there is concern in some quarters that this "consolidation" may be another example of market re-integration. Singapore Power also owns Victoria's major gas storage facility and has an interest in the Victoria/South Australia pipeline.

The Australian Competition and Consumer Commission (ACCC) has limited powers to stop such re-integration if it cannot demonstrate that market competition is being hindered. AGL and Singapore Power have agreed to certain measures in relation to their latest acquisitions, but the ACCC would probably prefer that they did not proceed at all.

The fear is that common ownership from generation to retailing has the generator with a guaranteed customer-base for all or part of its output, thereby reducing their need to compete. For the most part, generators are owned by consortia and, as in AGL's case, argue that their other non-electricity business partners would ensure competition in the market.

The judge in AGL's High Court challenge to the ACCC's original "knock back" agreed with AGL's submission that their arrangements had the characteristics of an investment rather than an attempt at vertical integration.

For a market created in the spirit of "deregulation", it will be ironic should the ACCC push for more regulation in an attempt to stave off vertical ownership. However, the alternative offers unchecked re-integration perhaps leading us back to where we were with the exception of private ownership rather than public.

Over the years, State ownership of generators and retailers has been considered an obstacle to greater efficiency and lower prices in the national energy market. The NSW Labour Government did attempt privatization of physical assets several years ago; however, they were blocked by various trade unions and backbenchers.

Currently, there is a new privatization proposal aimed at allowing private companies the right to trade energy produced from state-owned generators. The plan includes four private retail managers to look after contestable customers on contract and also have them provide billing, accounts management, and customer enquiry services on behalf of the state-owned retailers.

The recent move towards privatization is rooted in the fact that State government utilities have lost hundreds of millions of dollars stemming from disastrous trading strategies taken in the late 1990s. The latest proposal would have state-owned electricity businesses shifting away from high risk financial trading and becoming more focused on the physical operation of supply customers.

The Government is counting on the plan as a means of encouraging more private investment in building generation. However, there is likely to be stiff opposition from the various unions, as these proposals are likely to lead to significant job losses. The Government denies this outcome; however, many energy companies have confirmed this is likely to be so.

The jury is out whether the proposal would lead to lower or higher electricity prices. Whilst greater competition and greater market efficiency should, in theory, lead to a price reduction, there are still other factors that could lead to an increase in prices. For example, prices are likely to increase if existing suppliers increased their market shares of traded electricity. Additionally, the private sector would likely charge substantial fees to cover higher risks associated with trading in such an uncertain market.

At last word, the Government is expected to continue the consultation process for a few more months before reaching any decisions. .

Energy and Electricity in Australia.

Figure 1: Electricity Generation in Australia by Fuel.

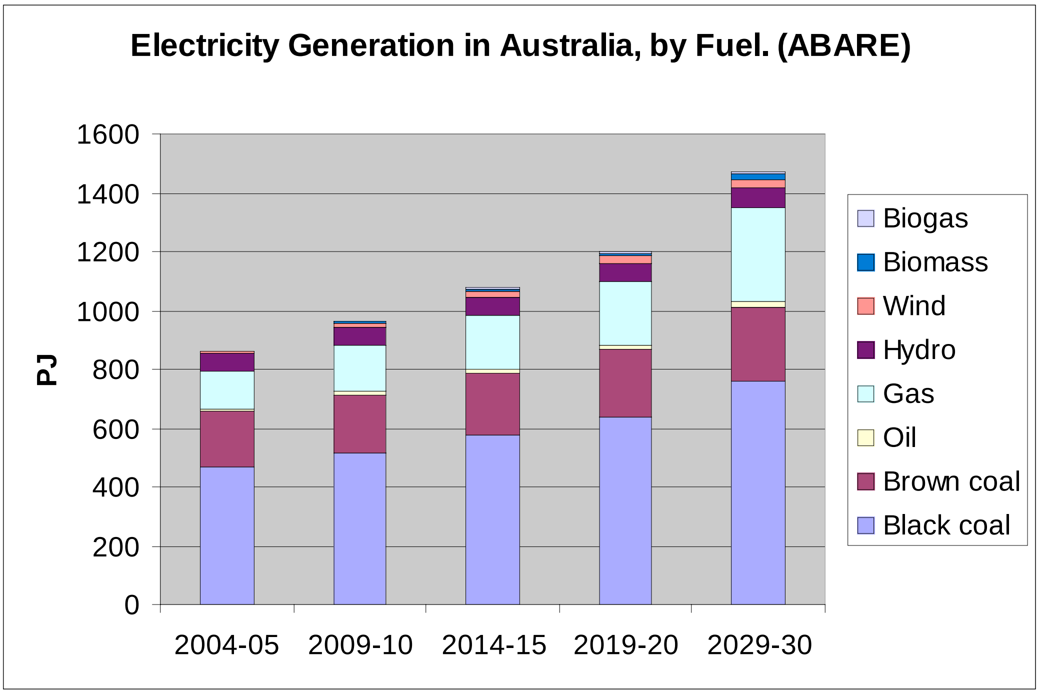


Figure 2: Gas-fired Electricity Generation by Australian State.[9]

[9] AUSTRALIAN ENERGY: national and state projections to 2029-30. Muhammad Akmal and Damien Riwoe. October 2005. ABARE.

13 Gas fired electricity generation, by state

	Generation				Average annual growth	
	2003-04	2009-10	2019-20	2029-30	2003-04 to 2009-10	2003-04 to 2029-30
	TWh	TWh	TWh	TWh	%	%
New South Wales a	2.2	2.9	4.7	7.2	4.5	4.7
Victoria	2.4	3.2	5.2	8.4	5.1	5.0
Queensland	3.5	7.4	12.1	22.2	13.5	7.4
Western Australia	14.9	18.1	25.0	33.7	3.3	3.2
South Australia	8.0	8.5	9.9	11.7	0.9	1.5
Tasmania	0.7	0.7	0.9	1.1	2.0	2.0
Northern Territory	2.1	2.8	3.7	4.7	4.6	3.1
Total	33.8	43.6	61.5	89.1	4.4	3.8

a Includes the Australian Capital Territory.

Gross generation of electricity in Australia is projected to grow over the outlook period by an average 2.1 per cent a year, increasing from 237 TWh (854 petajoules) in 2003-04 to 409 TWh (1473 petajoules) by 2029-30 Figure 1. Gross generation is defined here to include electricity purchased by all consumers and includes own use by generators, onsite private generation and/or cogeneration and transmission and distribution losses. That is, it is the total amount of electricity generated in Australia.

Largely reflecting some existing capacity overhang and the influence of a number of government policy initiatives, electricity generation from black coal is estimated to grow modestly over the outlook period, increasing by around 80 TWh by 2029-30. Generation from natural gas in Australia is forecast to grow strongly, by a factor of 2.6, to 89 TWh by 2029-30.

Growth in gas fired electricity generation is projected to be particularly strong in the medium term, largely reflecting the impact of a number of policy initiatives and investment in peak capacity, Figure 2. Reflecting the impact of Queensland Government’s 13 per cent gas scheme, gas fired electricity generation in Queensland is projected to more than double in the medium term to 2009-10. This expansion in the state’s gas fired electricity includes, among other projects, Origin’s 1000 MW Spring Gully plant at Durham Downs. The combined cycle gas plant is currently under construction, with production planned to commence in 2008-09 (ESAA 2005). This trend is projected to moderate over the longer term, with growth in gas fired electricity generation in Queensland over the entire projection period averaging 7.4 per cent a year (compared with 2.9 per cent a year in total electricity generation).

The New South Wales greenhouse gas benchmark scheme is expected to provide economic incentives for investment in gas fired electricity in the state. Reflecting the impact of this scheme and growth in peak electricity demand, gas fired electricity in the state is projected to grow by 4.7 per cent a year over the full outlook period, to 7.2 TWh in 2029-30. The outlook for gas fired electricity in other regions/states is also positive. In Western Australia, gas fired electricity generation is forecast to grow at an average rate of 3.2 per cent a year, accounting for 76 per cent of the projected expansion in the state’s electricity generation over the outlook period.

With an average annual growth rate of 1.6 per cent, coal fired electricity in Western Australia is forecast to account for 19 per cent of the projected increase in the state's electricity generation. In the Northern Territory, gas fired electricity generation is forecast to grow by an average 3.1 per cent a year, underpinning almost all the growth in electricity generation in that state.

The use of natural gas in the electricity generation sector also commenced in Tasmania in 2002-03 after the completion of the gas pipeline from Victoria to Tasmania and the conversion of existing oil fired generating facilities at Bell Bay Tasmania to natural gas. Over the entire projection period the use of natural gas in the electricity generation sector in Tasmania is expected to increase to 8.0 petajoules, providing approximately 1.1 TWh of electricity by 2029-30.

The projected growth in brown coal fired electricity generation is relatively modest. Electricity generation based on brown coal is projected to increase by 1.2 per cent a year over the outlook period, reflecting high capital costs and potential policy uncertainty. Nevertheless, even this outlook implies the need for new investment in brown coal fired generation capacity in the foreseeable future.

Most of the increase in the generation of electricity from renewable sources over the projection period is expected to be wind and biomass (mainly bagasse, woodwaste and bagasse cofired with woodwaste). More than 80 per cent (or 5.5 TWh) of the estimated wind energy growth over the entire outlook period is forecast to occur in Victoria, South Australia and Tasmania. In contrast, Queensland alone is expected to account for more than 80 per cent of the projected growth in biomass electricity.

The expansion in non-hydro renewables reflects falling investment costs and rising availability factors. Hydroelectricity generation is constrained to grow only modestly over the projection period, reflecting the limited availability of suitable locations for the expansion of large grid based hydroelectricity generation. The expansion in hydroelectricity capacity that is modelled reflects upgrading of existing equipment and facilities and/or increasing utilisation through optimising maintenance and scheduling.

Nuclear Power in the World's Mature Market Economies.

Figure 3: Nuclear Generating Capacity, to 2025, projected for the World's Mature Market Economies.[10]

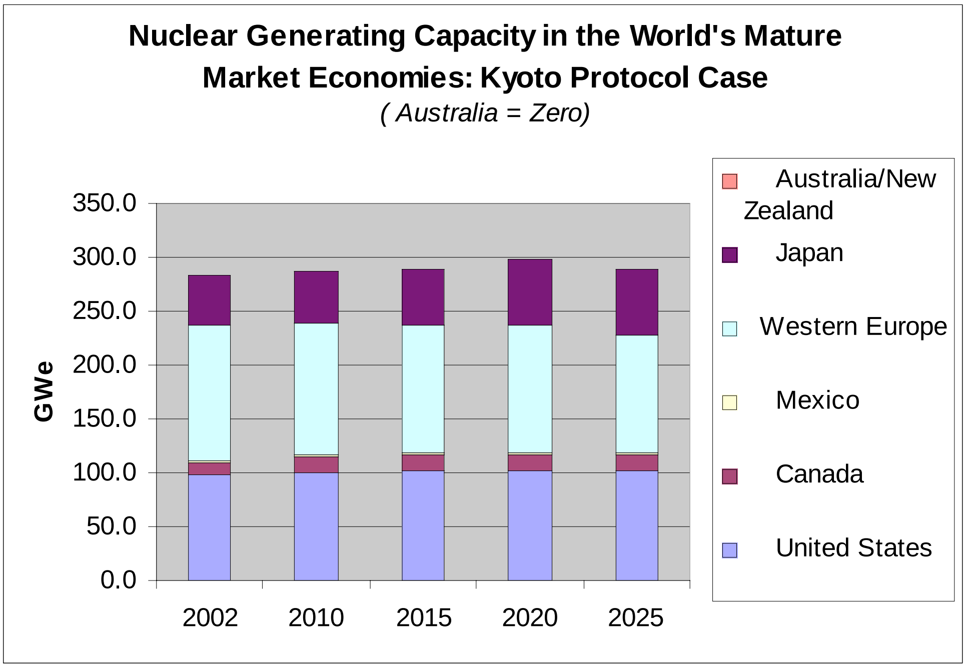


Figure 3 shows that, of the world's mature market economies, only Australia has no nuclear capacity and plans none between today and 2025. This figure is one that the USA EIA has provided. It is for the "Kyoto Protocol Case". That is to say it assumes that these economies fulfill the promises that they made at Kyoto.

Financial Model for Electricity Generation from New Nuclear, Coal and CCGT Power Stations in Australia.

Table 1 shows the parameters of the Financial Model that Professor Gittus has developed for use in this work to forecast the cost of generating electricity in Australia from new power stations. These parameters have been chosen so that they should apply to any of the new designs of nuclear power station that are currently available: the EPR, AP1000 etc. The parameters should also be a good representation of the modern designs of coal-fired and CCGT power station.

Table 1: Parameters of the Financial Model.

[10] International Energy Outlook 2005. Report #: DOE/EIA-0484(2005). Released Date: July 2005. Next Release Date: July 2006.

	Nuclear	Coal	CCGT
MWe	1250	500	400
Efficiency, %	35	41	55
Investment cost, Million Aus$	3,556	662	373
Investment Aus$/kWe	2,846	1,324	931
Fuel price Aus$/MWh(f)	1.63	6.83	17.78
Fuel costs of electricity production, Aus$/MWe	4.65	16.69	32.34
Annual fixed operation and maintenance costs, % of investment	1.5	2	1.5
Variable operation and maintenance costs, Aus$/MWe	5.55	8.00	0.50
Economic lifetime (years)	40	25	25
Interest rate %	5	5	5
Annuity factor %	5.83	7.10	7.10

Table 2 shows the forecasts of the model for the reference parameters of Table 1. Table 3 to Table 9 then show the forecasts for various examples of cases in which changes are made in the reference parameters of Table 1.

Table 2: Generation costs forecast from reference values of parameters

	Insert Values Below	Nuclear.	Coal.	CCGT.
Change in Economic Lifetime, years	0	-	-	-
Change in fuel costs, %	0%	-	-	-
Change in investment costs, %	0%	-	-	-
Operating hours per year, hours	8000	-	-	-
Interest Rate, %	5	0.03	0.01	0.00
Generation cost, Aus$/Mweh		36.34	39.77	42.84

In Table 2 we see that, for the reference values of the parameters, nuclear power is cheapest, followed by coal and CCGT.

Table 3: Effect of reducing the Economic Lifetime by 10 years.

	Insert Values Below	Nuclear.	Coal.	CCGT.
Change in Economic Lifetime, years	-10	1.48	2.56	1.77
Change in fuel costs, %	0%	-	-	-
Change in investment costs, %	0%	-	-	-
Operating hours per year, hours	8000	-	-	-
Interest Rate, %	5	0.03	0.01	0.00
Generation cost, Aus$/Mweh		38.75	43.93	45.73

Table 3 shows that if the economic lifetime of a power station is 10 years less than planned, then this has the smallest effect on nuclear power and the largest effect on coal-fired power: CCGT comes in between. Note that the figures in the body of the Table are the actual values of the changes, in Aus$/MW) in the Generation costs. It is by adding these changes to the Reference Generation costs of Table 2 that the new values, at the foot of each Table, are derived.

Table 4: Effect of a 50% increase in fuel costs.

	Insert Values Below	Nuclear.	Coal.	CCGT.
Change in Economic Lifetime, years	0	-	-	-
Change in fuel costs, %	50%	1.43	5.13	9.93
Change in investment costs, %	0%	-	-	-
Operating hours per year, hours	8000	-	-	-
Interest Rate, %	5	0.03	0.01	0.00
Generation cost, Aus$/Mweh		38.67	48.11	59.01

Table 4 reveals that if fuel-costs rise 50%, then this has little effect on the cost of nuclear electricity. It has the greatest effect on CCGT electricity.

Table 5: Effect of a 10% Increase in Investment Costs.

	Insert Values Below	Nuclear.	Coal.	CCGT.
Change in Economic Lifetime, years	0	-	-	-
Change in fuel costs, %	0%	-	-	-
Change in investment costs, %	10%	1.28	0.72	0.51
Operating hours per year, hours	8000	-	-	-
Interest Rate, %	5	0.03	0.01	0.00
Generation cost, Aus$/Mweh		38.42	40.94	43.67

Table 5 shows that a 10% increase in Investment costs has the biggest effect on nuclear power. However, nuclear is still the cheapest.

Table 6: Effect of a 2000-hour reduction in Operating Hours, per year.

	Insert Values Below	Nuclear.	Coal.	CCGT.
Change in Economic Lifetime, years	0	-	-	-
Change in fuel costs, %	0%	-	-	-
Change in investment costs, %	0%	-	-	-
Operating hours per year, hours	6000	5.46	3.15	2.08
Interest Rate, %	5	0.03	0.01	0.00
Generation cost, Aus$/Mweh		45.22	44.89	46.23

Table 6 forecasts that, if the stations only operate for 6000 hours instead of 8000 hours in a given year then electricity from coal fired stations will become the least expensive, with nuclear next and CCGT the most expensive.

Table 7: Effect of increasing the Interest Rate from 5% to 7%

	Insert Values Below	Nuclear.	Coal.	CCGT.
Change in Economic Lifetime, years	0	-	-	-
Change in fuel costs, %	0%	-	-	-
Change in investment costs, %	0%	-	-	-
Operating hours per year, hours	8000	-	-	-
Interest Rate, %	7	3.51	1.45	1.02
Generation cost, Aus$/Mweh		42.01	42.11	44.50

Table 7 shows that nuclear remains the least expensive option even if the Interest rate is raised from 5% to 7%. However it is the most-affected by this change.

Table 8: Effects of changes to several parameters simultaneously.

	Insert Values Below	Nuclear.	Coal.	CCGT.
Change in Economic Lifetime, years	-10	1.48	2.56	1.77
Change in fuel costs, %	50%	1.43	5.13	9.93
Change in investment costs, %	10%	1.28	0.72	0.51
Operating hours per year, hours	8000	-	-	-
Interest Rate, %	8	5.26	2.17	1.53
Generation cost, Aus$/Mweh		51.65	56.96	65.19

Table 9: Another Example of the effect of changing several parameters simultaneously.

	Insert Values Below	Nuclear.	Coal.	CCGT.
Change in Economic Lifetime, years	5	- .43	- 0.57	- 0.41
Change in fuel costs, %	20%	0.57	2.05	3.97
Change in investment costs, %	50%	6.38	3.60	2.53
Operating hours per year, hours	7600	0.79	0.46	0.30
Interest Rate, %	9	7.00	2.89	2.04
Generation cost, Aus$/Mweh		59.57	53.46	56.56

Table 8 and Table 9 show the effect of changing several parameters simultaneously. In each row of these Tables the actual changes in cost due to the change in the stated parameter are shown for each type of power station. Then the sum of these effects is reflected in the Generation cost, at the foot of each Table.

Comparison with Other Forecasts for Other Countries.

Table 10 gives a comparison between the forecasts for Australia of this present study and those for 12 other countries that were published by the OECD NEA in 2005 [11].

Table 10: Comparison between this study and an OECD study for other countries.

Aus$/MWe.h	nuclear	coal	CCGT
Finland	37.71	49.73	
France	34.70	45.49	53.56
Germany	39.07	48.09	66.94
Switzerland	39.35		59.57
Netherlands	48.91		82.52
Czech Rep	31.42	40.17	67.90
Slovakia	42.76	65.30	76.37
Romania	41.81	62.16	
Japan	65.58	67.63	71.18
Korea	31.97	29.51	63.53
USA	41.12	37.02	63.80
Canada	35.52	42.49	54.65
Australia, JHG Model	38.20	40.83	43.55

The average cost of nuclear generation for all the countries in this table except Japan (which is very costly) and Australia is 38.58 Aus $/MWe.h. which is virtually indistinguishable from the figure of 38.20 Aus$/MWe.h derived from the present model, for Australia with the same 85% load factor that was used for the other 12 countries in the OECD study. Moreover, in all 12 countries, nuclear is the least expensive, followed by coal and then CCGT. This is the forecast that the present model makes for Australia, too.

[11] *OECD/IEA NEA 2005.*

Comparison with Generating Costs Calculated in other, Recent Studies.

Table 11 gives generating costs from other recent studies[12].

Table 11: Generating costs calculated in other recent Studies.

	MIT (2003)	PIU (2002)	Chicago (2004)	RAE (2004)	DGEMP (2003)	Tarjanne (2003)	OECD (2005)	JHG (2006)
JHG Estimate of Generating Cost, Aus$/MWe.h)	*65.91*	*68.48*	*63.76*	*44.59*	*40.87*	*34.83*	*38.20*	*36.34*
Study Generating Cost, Aus$/MWe.h)	93.15	82.54	79.00	55.42	47.17	40.09	38.58	36.34
Interest, %	11.5	12.5	12.5	7.5	8	5	5	5
Capital Cost, Aus$/ kWe	2732	2732	2049	2732	2299	3091	2122	2846
Load Factor %	85	77	85	90	90	90	85	90
Economic Life, years	15	20	15	32.5	42.5	40	40	40
Construction period, years	5	?	6	5	5	5	5	5

These values may be compared with the Reference value of 36.34 Aus$/MWe.h arrived at in the present study (Table 2). Values similar to those in the studies of Table 11 are obtained when the present Financial Model is applied to the parameters of each study and this is shown in Table 11. Differences will be due to the fact that the earlier studies do not give values for all of the parameters demanded by the present model. There will also be differences due to varying exchange rates. There is no significant difference between the *study-value* and the *forecast of the present model* for the OECD studies updated six months ago, which are the most recent studies in Table 11. We have already seen that there is excellent agreement between these studies, for 11 out of 12 countries, and the forecasts of the present model, Table 10.

[12] MIT(2003) “The Future of Nuclear Power”.
PIU (2002): UK Performance and Innovation Unit (PIU) Energy Review Working Paper, “The Economics of Nuclear Power”.
Chicago (2004): University of Chicago Study, “The Economic Future of Nuclear Power”.
RAE (2004): UK Royal Academy of Engineering, “The Cost of Generating Electricity”.
DGEMP (2003): General Directorate for Energy and Raw Materials (DGEMP) of the French Ministry of the Economy, Finance and Industry.
Tarjanne (2003): Tarjanne, Lappeenranta University of Technology, Finland.
OECD (2005): Projected Costs of Generating Electricity (2005 Update).

Comparison with Actual Costs of Generation in Australia.

Table 12 shows the actual wholesale prices paid for electricity in NSW, Queensland, Victoria and South Australia over the period 1999 to 2005. Some 2004 pool prices were:

- Average Victoria 2.8 c/kWh
- Average NSW 3.9 c/kWh
- Average Qld & SA 3.2 c/kWh

Table 12: Actual Wholesale prices of Electricity in Australia.

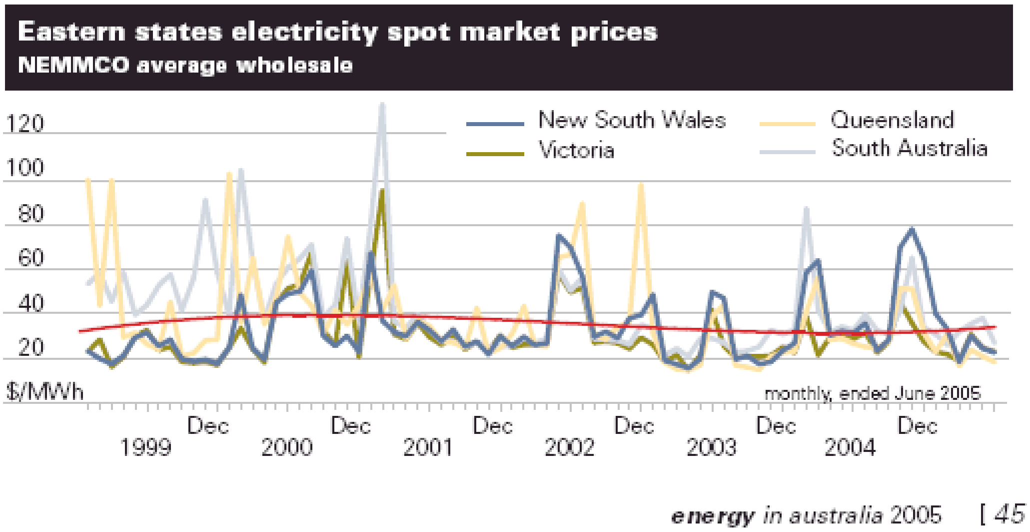


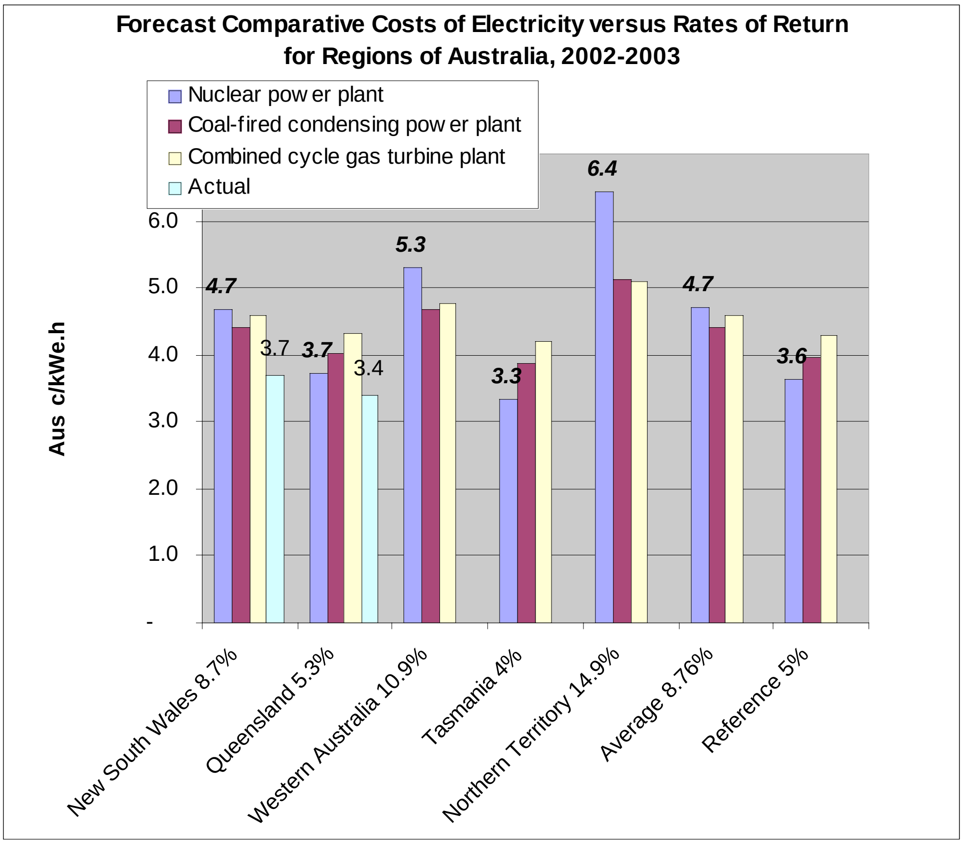
Table 13 shows the rates of return earned by Australian electricity generators in 2002-2003.

Table 13: Rates of Return achieved by electricity generators, 2002-2003

	% Rate of Return on Generation
New South Wales	8.7
Queensland	5.3
Western Australia	10.9
Tasmania	4
Northern Territory	14.9
Average rate of return for generation	8.76

Figure 4 shows the costs of generating electricity from new power stations having the parameters of our Model and interest-rates corresponding to the rates of return achieved in 2002-2003 by specified Australian States. Also shown are the actual average costs of generation for NSW and Queensland, shown in Table 12.

Figure 4: Forecast Comparative Costs of Electricity versus Rates of Return for Australian States, 2002-2003.



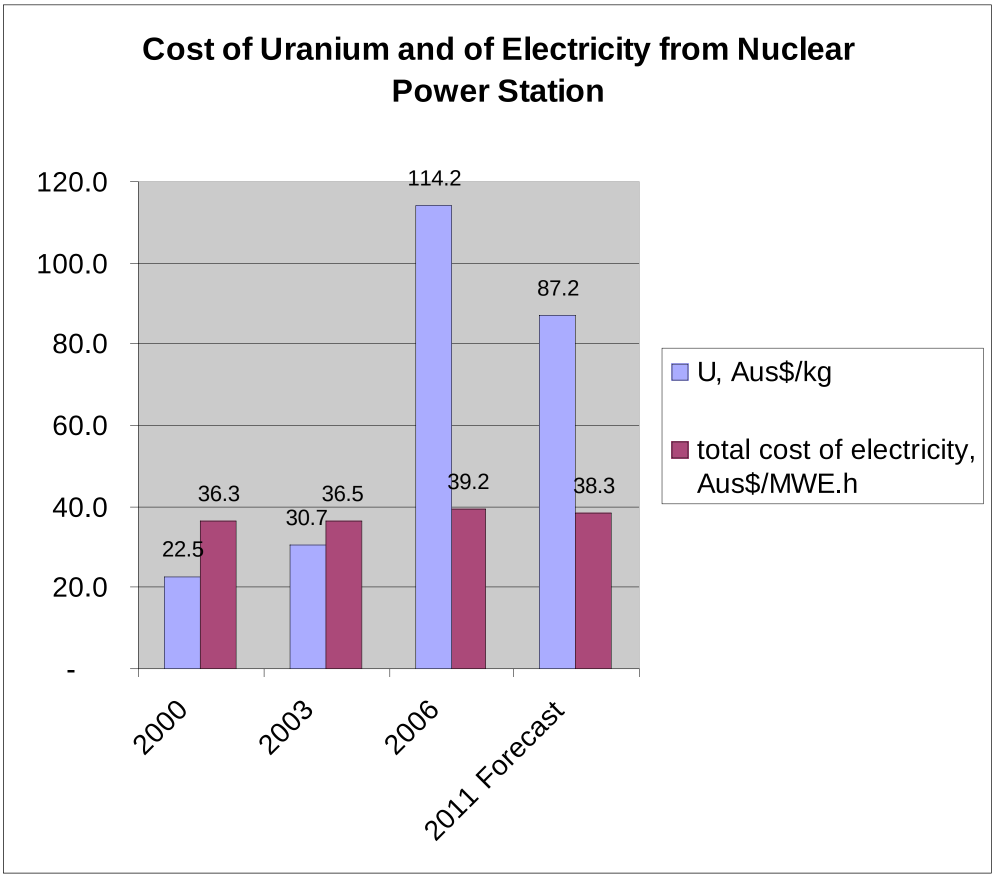
The following conclusions can be drawn from Figure 4:

1. Nuclear power would be, on these figures, between 5% and 10% more expensive than the actual generating costs that were achieved. This difference is not significant and one would certainly not see it as a cause for rejecting nuclear power. Thus the rates of return in Table 13 will undoubtedly have been calculated with respect to the *written-down* values of the generating plant. If the plant has been written down by more than 25% then the real rate of return on the *original* capital cost will be 25% less than the values in Table 13 and this rate of return can be produced from a nuclear power station that charges the wholesale prices of Figure 4.
2. Dealing now with the generating costs of *new plant:* only in the case of the Northern Territory is nuclear significantly more expensive than coal or CCGT power stations. Nuclear is the least expensive option in Queensland and Tasmania, which have rates-of-return that closely bracket our reference value of 5%.
3. Industry sources in 2004 said that 4 c/kWh was needed to justify investment in black coal plant. In Figure 4 we calculate values that average a little over 4 Aus c/kWeh for the cost of generating electricity from new, coal-fired power stations in these Australian States: excellent agreement.

Effect of Future Price of Uranium.

The price of uranium has quadrupled in the last few years: values are shown in Figure 5, together with the generation-cost of nuclear electricity in Australia, calculated from our model.

Figure 5: Forecast future prices of uranium and effect on generation-cost of nuclear electricity in Australia.

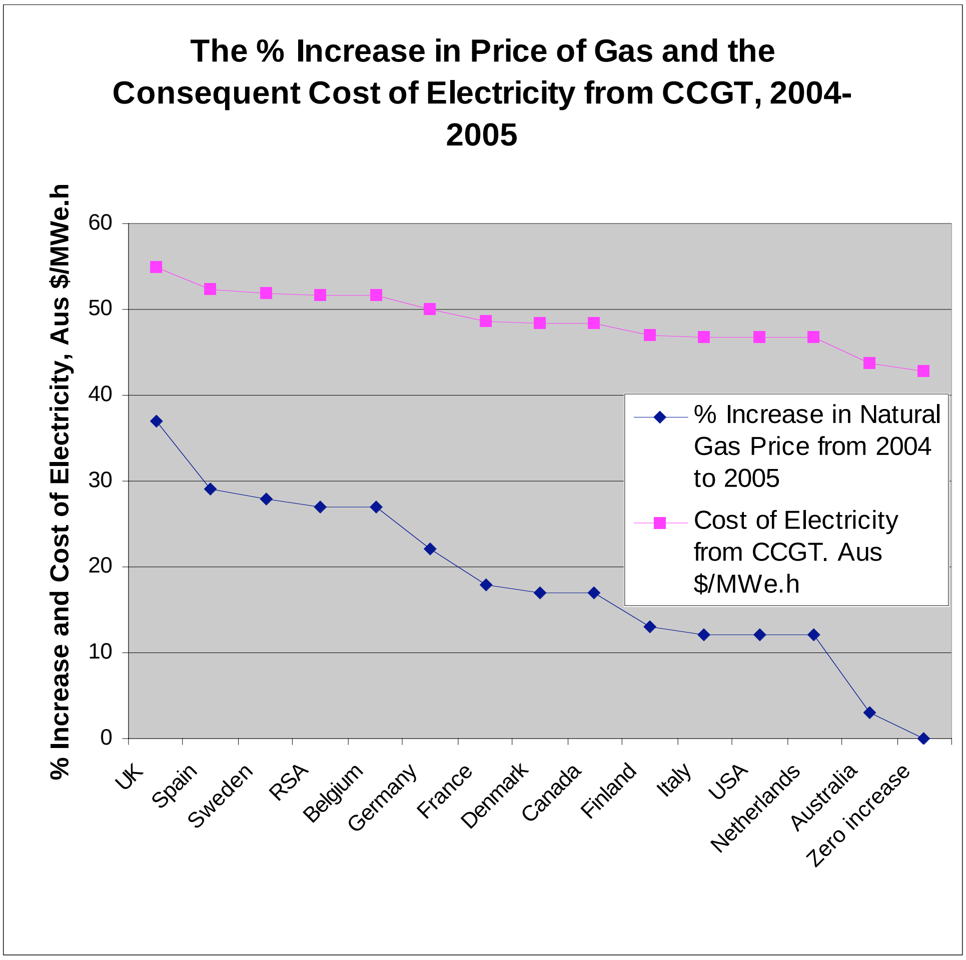


We had already noted that the cost of nuclear power is very insensitive to the price of uranium and Figure 5 makes this very plain.

Effect of the Future Price of Natural Gas.

Australia does not import significant amounts of natural gas at the moment and this is reflected in the stability of natural gas prices in Australia. Natural gas prices were stable in the UK until, last year, she had to import a significant amount for the first time in 20 years or more. As a result the price of natural gas in the UK rose by more than one third in the 12 months period 2004-2005. Other countries suffered smaller increases in gas prices during the period and in Figure 6 we show these, together with the calculated cost of electricity from CCGT power stations in each country. The effect is smallest in Australia where gas prices have scarcely changed. In the UK it increases the cost of CCGT electricity to the equivalent of 55 Aus$/MWe.h, up from a value of 43 Aus$/MWe.h in just 12 months. This is an increase of 28% and in fact consumers have been presented with a price increase of 25%.

Figure 6: The % increase in the price of natural gas in various countries, 2004-2005, and the forecast increase in cost of electricity from CCGT.



Combined Effects of the Future Prices of Uranium, Imported Gas, Domestic Gas and Coal.

Finally, we arrive at Figure 7, using

- ABARE and other data for the future price of Australian coal together with
- The prices of uranium used earlier and
- Estimates of the prices of domestic and imported natural gas.

Figure 7: Effects of forecast prices of coal, domestic gas, imported gas and uranium on electricity-generation costs in Australia.

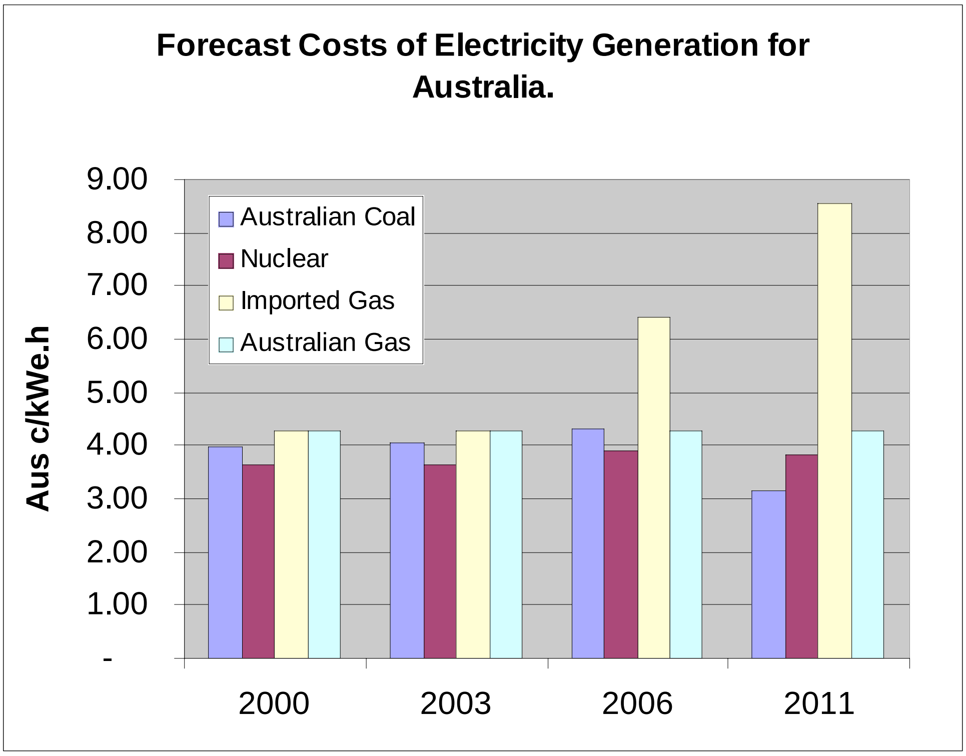


Figure 7 shows that nuclear will be continuously competitive with gas and coal in Australia through 2011 (the limit of the information on coal prices).

By 2011 on present industry-forecasts the price of coal will have fallen to a level at which it provides marginally cheaper electricity than nuclear—the cheapest, in fact. However the reality will be that coal prices will follow the prices of oil and gas. That is what the Energy Market will dictate. So we can expect the price of electricity from coal fired power stations to be higher than the values in Figure 7 and this will make nuclear even more competitive.

Similarly, in computing Figure 7, we have assumed that the price of domestic Australian gas will remain constant whereas that of imported gas will rise in the manner in which it is now rising for other countries, Figure 6. Here again the realities of the Energy Market will dictate that Australia's domestic gas prices will rise in harmony with the price of gas from overseas and so the prices of electricity from domestic gas are optimistic to an extent that only the future will reveal. This makes nuclear even more competitive than is forecast in Figure 7.

WOULD NUCLEAR POWER NEED SUBSIDIZING IN AUSTRALIA?

Clearly, if the forecasts of this Report were correct, nuclear power would be financially competitive in Australia, just as it is in many other countries.

However, the nuclear stations for which we have here made forecasts are stations that are built to time and to cost and operated to cost. This is certainly true of the nuclear power stations that are being built, for example, in South Korea, but that country has built many nuclear plants and has therefore learned most of the lessons concerning their construction and operation. Australia would have to learn those same lessons and that will inevitably slow down construction and add to costs. It could well be that nuclear power would need a subsidy to cover start-up costs, therefore. In this section we estimate the start-up costs and develop a finance plan to deal with them. We shall show that no subsidy is needed, although a subsidy would undoubtedly make things easier.

Australian Finance Plan: Structure of the EPC Project to Build a Nuclear Power Station in Australia.

It may be that the Australian Government will be prepared to give a Grant towards the construction of an Australian nuclear power station. In the first Financial Plan, here presented, I have however assumed that it will ***not*** give a Grant (which would not have to be repaid to Government) but that it ***would*** give an ***Insured Loan,*** which would be repaid to Government, together with a Retrospective Premium, out of revenues from the Station when once it began to generate electricity. I have established that Commercial Insurers might be prepared to act as ***leaders***[13] and write part of the Insurance of this loan: the part covering costly delays due to accidents and unforeseen, new regulatory requirements. Government would write the remainder.

This arrangement is familiar to Government, since it already forms the basis of nuclear Third Party Liability Insurance. Indeed I am personally involved as Principal Consultant to the ***leader*** in that market. What I am suggesting is simply the application of the same, well-understood principal, not only to the ***operation*** of a nuclear power station but also to its ***construction***.

Under the first Financial Plan, then, the Government would advance a FOAK loan. The risk that it proved inadequate, for unforeseen reasons, would be covered to the extent possible by insurance. Commercial EPC insurers would take the lead in writing

[13] Where a number of Insurers share a risk, it is usual for one of them to take the lead: in insurance parlance he is "***the leader***" . The leader has stature in the market. Even though he may only be able to insure a comparatively small percentage of the risk, his analysis of the risk is trusted by "***the following market***" of other Insurers. They therefore agree to follow his lead and take a share of the risk. The insurers each "***write***" a share of the risk and receive a proportionate share of the premium paid by the Insured Party.

this insurance and they would draft the "Policy Wording", which describes the circumstances (such as accidents, unforeseen regulatory intervention &c) under which insurers would top-up the FOAK loan. The Government would provide the balance of the FOAK loan insurance and would take its share of the Insurance Premium: the commercial insurers that led the insurance would take their share too.

The Insurance Premium would be paid retrospectively. This is a familiar arrangement in the insurance markets[14]. In the present case the premium would be paid out of the revenues produced when the station begins to generate and sell electricity. Conceivably the insurance policy may specify that the premium will increase if there is a claim: but it would not increase by the amount of the claim since the essence of insurance is ***risk-transfer***. The insurer takes the risk that he will make a loss and the premium is calculated accordingly.

Of course commercial insurers will expect the various other parties: the Sponsor, Vendor, Shareholders, Bondholders, Banks &c to take their fair shares of the risks of the project, too. I analyse this distribution of risks between the parties and in the first Financial Plan arrive at a suggested partition, likely to be acceptable to the parties. In this Financial Plan Australia builds the 5th and possibly later AP1000 reactors (the first four having been built say in China and the USA).

The question that immediately arises is this: how is the risk to be partitioned in a planned way between the Sponsor, Vendor, Shareholders, Bondholders, Banks &c? I shall produce an answer to that question in the next Contract, a proposal for which forms part of this Advice.

In this First Case, the following is the partition of the **Construction Risks** which I provisionally believe will be acceptable to the parties:

- **Insurers take 19% of the Construction R**isks. They will be paid to do this by means of a retrospective premium, taken out of the profits the station makes when once it is generating electricity. There will be a chance that for unforeseen reasons the FOAK cost exceeds the estimate and in that case the insurers will have to top it up. They may not recover this top-up out of premiums and this is the chance that they agree to take.
- **Government takes 56% of the Construction Risks**. They will be paid to do this by means of a retrospective premium, taken out of the profits the station makes when once it is generating electricity. So Government should not be out of pocket. However there will be a ***chance*** that for unforeseen reasons the FOAK cost exceeds the estimate and in that case the Government will have to help the insurers to top it up. They may not recover this top-up out of premiums and this is the chance that they agree to take.
- **25% of the Construction Risk is shared equally between Shareholders, Banks, the Vendor and the Owner**. The insurers, who are taking 19% of the construction risk and the Government, which is taking 56% will insist on this. Indeed they may well require the Vendor to take a substantially higher amount

[14] Retrospective premiums are commonplace in the nuclear insurance market: the US Government (as insurers of nuclear power stations) and the mutual insurers EMANI and NEIL use them in the insurance of both third party and material damage risks.

of risk under an EPC contract and I shall consider this in one of the other Financial Plans. The risk they take is that the stations will require extra FOAK money because, for example, there is an increase in FOAK costs, which it transpires, ***should have been foreseen***. Insurers will not pay it and so Government follows suit. As recompense for taking this share of the construction risk, the shareholders will require dividends, the banks will require loan interest, the Vendor will require profit on the EPC contract and the Owner will require profit on the electricity he eventually sells.

- **The remainder of the Construction R**isk is taken by the Fuel Supplier, who will lose profit if the stations are delayed or cancelled; and the Electricity Distributors who hoped to buy the electricity at a price below the market average and will not be able to do so if the plants are cancelled.

In this First Case, for the **<u>Operational Risks</u>**, all of which I provisionally believe will be acceptable to the parties:

- Government takes, as Governments do with all existing nuclear power stations, half the Operational Risk. It does this by agreeing to pay all costs, to Third Parties, of the most severe nuclear accidents. We do not expect any such accidents to occur, either because of machinery-breakdown, human fallibility, fire, earthquake, flood or terrorism &c. However the likelihood of severe accidents is estimated, by Probabilistic Risk Assessment[15], for all new (and most existing) nuclear power stations and when the PRA forecasts are used to estimate the magnitude of the Risk it transpires that Government is in fact taking a significant part of the Operating Risks by, in effect, providing Third Party insurance against the consequences of severe nuclear accidents. The Government charges a premium (which I have calculated under Contracts to both the UK and Canadian Governments) for covering the terrorist risk, but Government charges no premium for the other elements of the Third Party Risk.
- Most of the remaining Operational Risk is shared equally between Insurers, Shareholders, Banks, the Vendor and the Owner. As recompense for taking this share of the Risk,
  - *The insurers receive premiums,*
  - *The shareholders dividends, the Banks interest,*
  - *The Vendor receives the profit he made on constructing the stations and*
  - *The owner the profit he makes on selling electricity.*

Identifying the Risks.

The Risks presented by a Project that comprises the construction and operation of a nuclear power station by an Australian Sponsor are first analysed and expressed in terms of cost and probability. Each of these Risks is analysed and quantified in terms

[15] I produced the first PRA for Sizewell B and presented it as CEGB Proof of Evidence No 16 at the Sizewell Public Inquiry that preceded the construction of Sizewell B.

of financial provisions and probability: the most likely value and its statistical variance are estimated for the financial provision needed to cover each Risk.

The Risk that the Australian Safety Regulator will delay licensing the Plant and require costly design-changes;

The element of the FOAK cost that is the cost of obtaining regulatory approvals can be imagined to occur even if Australia chooses a reactor such as the KSNP of which several copies have already been constructed, albeit ***not in Australia***. Thus, a substantial part of the cost overrun for the UK's Sizewell B PWR was attributable to the fact that the UK HSE required far-reaching changes to the initial, Westinghouse, design. The US NRC would have accepted the Westinghouse design initially proffered for Sizewell B, but the UK's safety targets were different to those of the US NRC.

So the HSE delayed licensing Sizewell B and required costly design changes. Here we examine the possibilities of similar problems if a nuclear power station is built in Australia. The AP1000 is considered as an example of an advanced design that is likely to be offered and of which none has as yet been built. The KSNP is also considered: it is a less advanced design six of which are in operation and four more are planned or under construction.

AP 1000.

The Capital cost quoted by Westinghouse for the AP1000 comprises all construction costs, related manpower and materials together with the cost of financing the capital. ***It also includes the costs of obtaining regulatory approvals*** and of site-specific engineering work. The total FOAK cost element is forecast to reduce in line with the number of reactors in the programme series.

KSNP.

Six copies of the KSNP have already been built, in South Korea, and the fourth plant cost 23% less than the first, Figure 8. This is smaller than the reduction of 39% anticipated for the AP 1000, but the latter is more innovative than the KSNP and so we can expect the FOAK cost of the AP1000 to be greater than that which has actually occurred for the KSNP.

We do not know what proportion of the KSNP FOAK cost was due to the costs of obtaining regulatory approvals. However UK experience with Sizewell B would make the cautious finance-provider assume that the KSNP will effectively be the FOAK insofar as Australia is concerned and that the FOAK expenditure on obtaining regulatory approvals in South Korea will count for little or nothing in Australia.

FOAK Cost of Obtaining Regulatory Approvals.

So far as the FOAK cost of Australian regulatory approval is concerned, therefore, it would be prudent to assume, on the basis of experience with Sizewell B, that the KSNP would have no advantage over the AP1000: the FOAK costs of securing regulatory approval would to all intents and purposes be the same for the AP 1000 as for the KSNP.

We shall include the Risk associated with the FOAK cost of obtaining regulatory approvals in the total FOAK risk. This may be found in the section of this Report entitled: ***The Risk that the Vendor will not be able to deliver the Plant to the time-and-cost that he Guaranteed.***

The Risk that the Australian Safety Regulator will introduce delays to other Consents and in this way delay the Construction and the Operation of the station.

Delay or Cancellation due to lack of provision for Radioactive Wastes.

Framatome, in an analysis of the problems of building new nuclear power stations in the USA, identified delay or cancellation due to lack of provision for radioactive wastes as important concern. Here we argue that it is also important in the case of Australia***:***

However, spent fuel can be safely stored in dry casks for at least a century on the reactor site, making a new build programme independent of a long term solution to the problem of disposing of spent fuel.

It is concluded that a delay of up to 100 years in the provision of a final repository for the spent fuel from the new reactors can be catered for by dry cask storage.

The low level and intermediate level wastes present lesser problems. Repositories for such materials already exist in other countries and so it will be possible to copy the designs of those repositories in Australia.

The Risk that the Vendor will not be able to deliver the Plant to the time-and-cost that he Guaranteed.

This risk includes consideration of the likely financial strength of the risk-taker/vendor. A “Fixed Price EPC” Contract is assumed for this stage.

Modern nuclear power stations are designed to reduce the risk that the vendor will not be able to deliver the plant to the time and cost guaranteed. In this analysis two designs of plant will be used, to explore the financial risks of construction and operation; one is an advanced design that has not yet been built: the Westinghouse

AP1000. The other is a state-of-art reactor that has been built and is being built: the South Korean KSNP or “Korean Standard Nuclear Plant”.

The Westinghouse AP1000.

The AP1000 has not yet been built, Annex 2 However, The U.S. Export-Import Bank in February 2005 gave preliminary approval for up to $5 billion in loans to Westinghouse Electric Co. for the proposed construction of four AP1000 nuclear power plants in the country. San Francisco-based Bechtel Corp. is among the other U.S. suppliers involved in the Westinghouse proposal. The Chinese government is accepting bids for the plants, which are needed to meet the increased demand for power in the heavily industrialized region of the country, and the contracts will be awarded this year. If Westinghouse succeeds in its bid, then the first four AP1000 reactors will be built in China and some of the First Of A Kind problems will be resolved there for that reactor.

The AP1000 is an advanced 1117 to 1154 MWe nuclear power plant that uses the forces of nature and simplicity of design to enhance plant safety and operations, leading to major savings in plant costs and construction schedules. It can operate with a full core loading of MOX fuel.

The AP1000 utilizes modularisation technique for construction, which allows many construction activities to proceed in parallel. This technique reduces the plant construction calendar time, which saves the IDC (Interest During Construction) cost and reduces the risks associated with plant financing. The AP1000 has a site construction schedule of 36 months from first concrete to fuel loading.

The U.S. NRC agency has issued a standard Design Certification for the AP1000 .

The Korean Standard Nuclear Plant, KSNP.

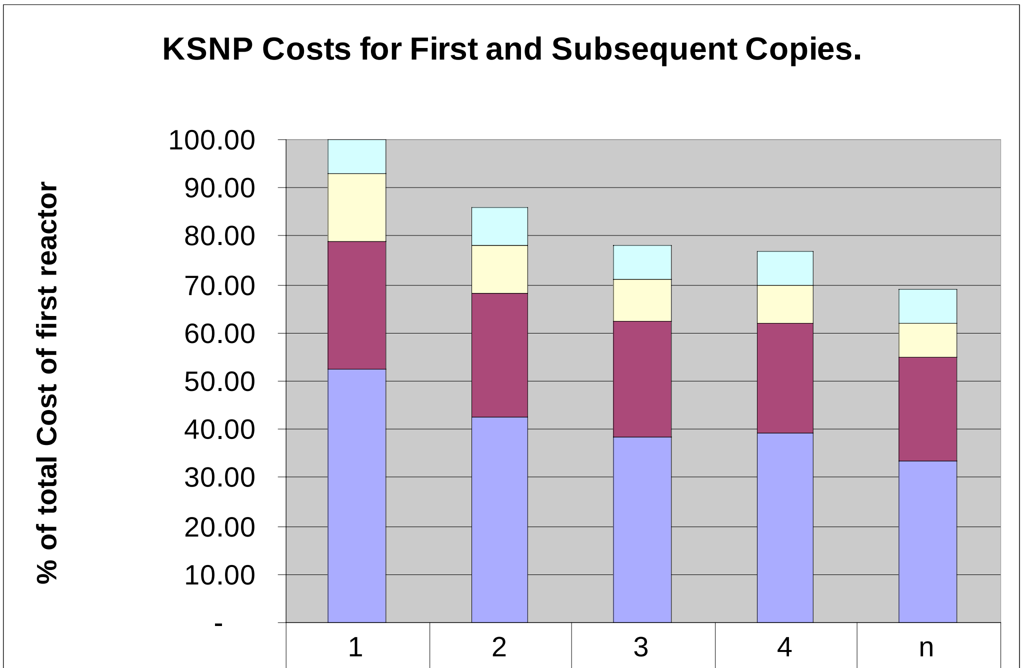
An important step in standardisation was the Korean Standard Nuclear Plant (KSNP), which was based on the CE System 80 and incorporated many of the US Advanced Light Water Reactor design requirements. Six are operating and four more will come on stream in the future.

First Of A Kind Risks for the KSNP.

Figure 8 shows how the cost of each copy of the Korean Standard Nuclear Plant, KSNP, has fallen. This design of reactor is not so innovative as the AP1000.

For comparison, Figure 9 shows some forecasts of the first, second, third etc for an AP1000.

Figure 8: Showing how Costs have fallen for copies of the Korean Standard Nuclear Plant. [16]



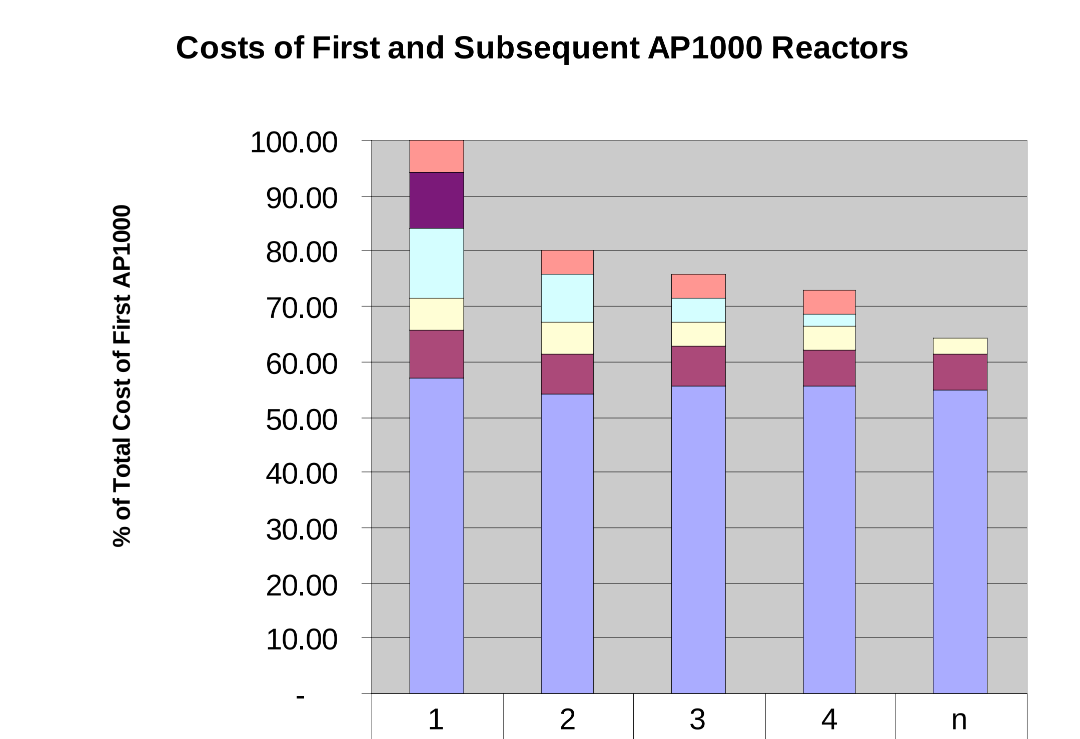
	1	2	3	4	n
Owner's Cost	7.09	7.80	7.09	7.09	7.09
A/E Cost	14.18	9.93	8.51	7.80	7.09
Constr Cost	26.24	25.53	24.11	22.70	21.28
Equip Cost	52.48	42.74	38.28	39.41	33.54

[16] Information from Korean Electric Power Company.

First Of A Kind Risks for the AP1000

Figure 9 shows, for the AP1000, built in the USA, how the cost may be expected to fall as copies are built.

Figure 9: Forecast Capital Costs of Early Orders of an AP1000: The FOAK Cost has all been allocated to the first plant, taken from Scully information.[17].



	1	2	3	4	n
Extra Finance	5.71	4.29	4.29	4.29	
FOAK Eng	10.00	-			-
Learning curve	12.86	8.57	4.29	2.00	-
Buyer's Contingency	5.71	5.71	4.29	4.43	2.86
Finance Cost	8.57	7.14	7.14	6.43	6.43
EPC	57.14	54.29	55.71	55.71	55.00

Insurance Possibilities.

It may be possible to insure, against the effects of accidents, the following items from Figure 8 and Figure 9:

[17] *Business Case for New Nuclear Power Plants: Bringing Public and Private Resources Together for Nuclear Energy: Mitigating Critical Risks on Early Orders for New Reactors. A Briefing for NERAC, October 1, 2002. Scully Capital, 1133 15th Street N.W, Suite 900, Washington, DC 20005*

1. A/E Cost
2. Construction cost
3. Equipment cost
4. Extra finance
5. FOAK Engineering
6. Learning Curve
7. Buyer's Contingency
8. Finance Cost
9. EPC.

Learning Curves.

Figure 10 shows the Cost of each of a series of 4 KSNP or AP1000 plants, together with the Wright Learning Curves, Annex 4, that best fit each set of points. The Wright Learning Coefficients are 92% for the KSNP and 91% for the AP1000. A learning coefficient of 94% for nuclear power in the OECD over 1975-93 has been calculated by McDonald et al. [18] . By contrast learning rates for most energy technologies lie in the range 15 – 20%, and those observed for wind energy and photovoltaics are in the 18 – 20% range. It is possible that increased standardization of products, globalization and privatization of the industry and a retreat from public sector reactor development programmes pursued in the national interest will serve to accelerate learning above the historic rate for nuclear power. Certainly the learning rate in South Korea has been significantly higher than in the OECD and the Westinghouse forecast for the AP1000 is in line with the Korean experience.

It is thought by EDF, that few significant further economies may be gained after seven or eight identical units. Individual components of nuclear power stations are subject to classic learning analysis in a straightforward way, but whole stations have been subject to long, complex and internationally variable regulatory and political processes. This has produced substantial increases in costs.

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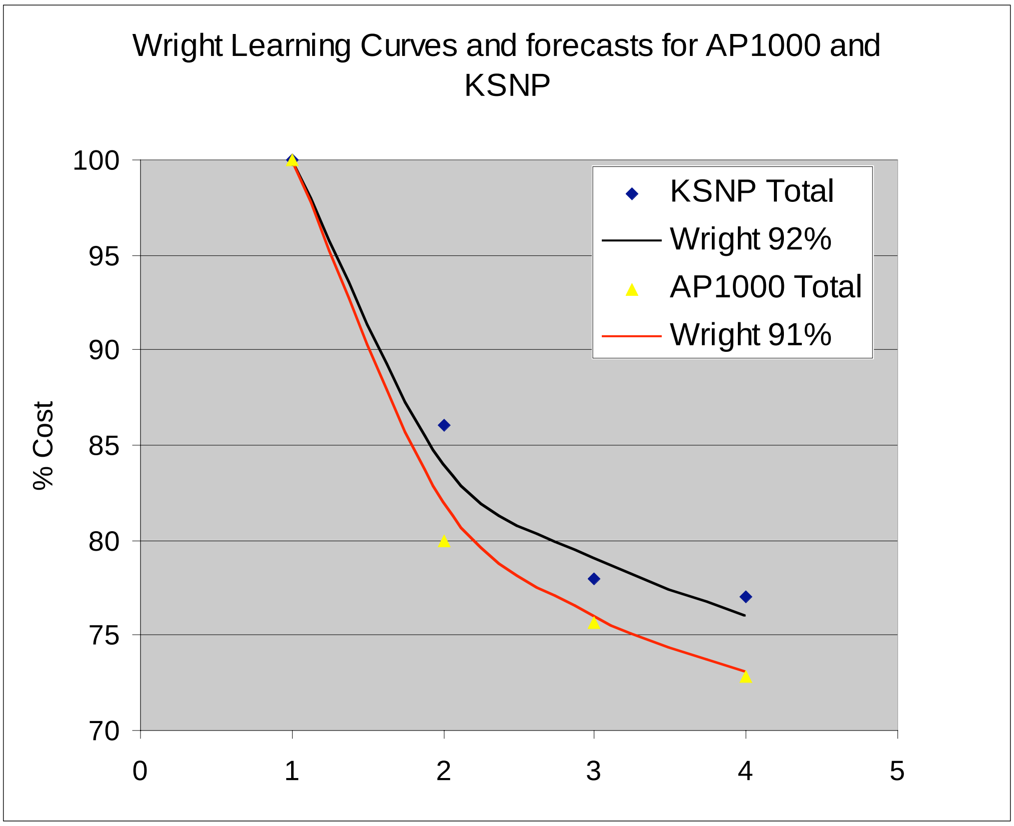
[18] *McDonald, A. & Schrattenholzer, L. (2001) 'Learning rates for energy technologies' Energy Policy 29, pp. 255-261.*

Figure 10: Wright Learning Curves for AP1000 and KSNP.



If the first two AP1000 plants are built in China (Bechtel and Westinghouse have bid to build two there) then the third, if it was built in China, would be built, we forecast, for 76% of the cost of the first. However the full benefit of learning may not transfer from China to Australia.

The industry's best estimates for the generating costs of new nuclear construction lie in the range 2.2p/kwh to 3p/kWh[19]. [20] Some sources of adverse movements in generating costs are shown in Figure 11. Where such adverse effects arise because of accidents it may be possible to insure against some of the costs so imposed.

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[19] *BNFL (2001) BNFL Submission to the Performance &Innovation Unit's Review of UK Energy Policy*

[20] *British Energy (2001) Replace Nuclear with Nuclear. British Energy's Submission to the Government's Review of UK Energy Policy*

Figure 11: Some Adverse Effects upon Generating Cost.[21]

Change	Resulting increase in generating cost
A. 10% escalation in construction cost	+ 0.18p/kWh
B. 20% escalation in construction cost	+ 0.35p/kWh
C. 1-year delay in construction	+ 0.15p.kWh
D. Impact of B and C combined	+ 0.5p/kWh
E. FOAK costs spread over 3 units	+ 0.18p/kWh
F. Operating performance lower by 8% (compared to BE expectation)	+ 0.2p/kWh

The total risk-related cost premium for early nuclear power plants using Generation III light water reactor (LWR) technology is substantial. For AP1000 reactors, the first four or five two-reactor plants are likely to contribute varying amounts to this premium, which is comprised of three large elements:

1. First-of-a-kind engineering (FOAKE) costs: ~US$200 – ~$350 million, based on the type of reactor and plant.
2. Learning-curve inefficiencies on construction costs: At least US$1 – $2 billion in total for the first four plants, on a base cost of US$14 – $15 billion for five plants (11,000 MWe) in the case of AP1000s.
3. Extra interest costs associated with the other elements: ~US$300 – 400 million.

Any government assistance would be negotiated, ideally with the government shaping the assistance to stimulate private investment and reward "first movers". These amounts do not include the cost of government efforts to address the three key barriers, which in the USA are seen as:

1. Waste disposal: Congress voted to proceed toward opening Yucca Mountain but its use is by no means certain.
2. Accident indemnification: This is meant to have been resolved by the re-authorized Price-Anderson Act to cover new plants.
3. Commissioning: NRC has not yet completed defining approval processes for new plants (e.g., ITAAC). The processes are not yet certain and finite.

US Industry and the financial community are capable of addressing—to varying degrees—most new plant development business risks. However, without the now-agreed US government participation, some USA risks and costs of new nuclear plants might have remained at unmanageable levels, particularly:

1. Regulatory risk not due to contractor fault that leads to delays during plant construction and commissioning.
2. First-of-a-kind engineering (FOAKE) costs for first new plants.
3. High capital costs for the first few nuclear plants, plus potential construction cost overruns for early plants using new designs.
4. Forecasting electricity demand and price levels for 2010 and beyond.

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[21] *PIU Energy Review Working Paper. The Economics of Nuclear Power. 2002*

5. Transmission availability and congestion, which vary widely by region.

The costs cover the following components:

- capital
- operation and maintenance
- fuel
- spent fuel and waste management
- decommissioning

Capital cost comprises all construction costs, related manpower and materials together with the cost of financing the capital. ***It also includes the costs of obtaining regulatory approvals, which are in part insurable if it had been impossible to foresee them*** and of site-specific engineering work. This cost element reduces in line with the number of reactors in the programme series.

Operation and Maintenance includes all the costs associated with routine operations (including staff costs, materials, and services) along with the labour costs of refueling, maintenance outages, and the management and ultimate disposal of intermediate and low level wastes. Miscellaneous costs such as grid connection charges are also covered here.

Fuel covers procurement of uranium and components, together with the costs of uranium and fuel services (conversion, enrichment, fuel fabrication).

Spent fuel management relates to storage at the reactor site, transport to interim storage, costs of interim storage, conditioning of the fuel for disposal, plus disposal of the associated high level waste and any other linked waste arisings.

Decommissioning is also provided for, to cover eventual decommissioning of the reactor, including care and maintenance prior to that final stage, the direct civil engineering costs and ultimate disposal of wastes arising from decommissioning. The decommissioning cost is £0.6/MWh.

EPC Contracts.

EPC Contracting is probably the most popular form of contract for major projects. Its main advantage lies in the fact that it designates one party responsible for both design and construction of the project. The contract has to address the allocation of the relevant risks among the parties involved, i.e. the EPC contractor and the owner. The EPC contractor usually retains the risk of loss, the exceptions being force majeure perils and specified cases for which the owner assumes responsibility.

In an EPC Contract, the contract price and design is ***fixed*** prior to Contract Award and:

1. An Integrated engineering/construction/operations team specifies constructability and operational requirements prior to the design freeze.

2. The process is Construction Driven to the Client's completion date with a Single Point of Contact.
3. The Contractor not the Client is accountable for all overruns.

Critical Steps within EPC Process are the following:

1. Early input of Client design and operational preferences together with benefits & constructability input into the design.
2. Early pricing of Engineered Equipment Items that constitute a significant portion of the overall cost.
3. Optimization of fabrication sites and labour costs.
4. Provision of solutions to mitigate risks associated with FOAK costs.
5. Freeze the Basis of Design prior to final fixed price costing.

Contractual Obligation.

An EPC Contract for a nuclear power station will stipulate that the EPC contractor is responsible towards the owner for any delay and/or under-performance of the project caused by technological failure or by any fault on the part of the EPC contractor or his sub-contractors.

The owner's loan agreement puts him under the strict obligation to service his debt. The owner will wish to pass as much of this risk as possible to other parties involved in the project. The contract should therefore contain a clause to the effect that if the project suffers any delay and/or under-performance and the EPC contractor is in default, then the EPC contractor is obliged to pay the owner adequate financial compensation, i.e. "liquidated damages". The amount payable to the owner in respect of liquidated damages generally corresponds to the project owner's financial obligations towards the party lending the money for the project. It does not contain any punitive and/or speculative element.

The Risk that Man-made Perils will Occur and the Harm so Caused.

These Perils include:

- *Events, incidents and accidents,*
- *Aircraft-crash,*
- *Machinery-breakdown*
- *etc.*

If one of these perils does occur then the harm so caused may:

- *Delay the Construction and Operation of the Plant*
- *Damage the operating plant,*
- *Harm third parties and*
- *Interrupt the generation and sale of electricity;*

There are two cases to consider:

1. During the construction of the nuclear power station and
2. During the operation of the nuclear power station.

Considering each of these in turn:

During Construction.

If one of these Perils occurs during the construction of the nuclear power station then it will add to the cost of the station. The commercial insurance market insures these risks. There is still a residual risk, which comprises part of the FOAK cost and which is not generally insurable; below we develop a scheme for dealing with this. (Section entitled: Government Insurance of FOAK Risk.)

During Operation.

Nuclear insurers cover all of these perils during the normal operation of the plant, see Annex 5. In the **UK**, the Energy Act 1983 brought legislation into line with revisions to the Paris/Brussels Conventions and set a limit of liability for particular installations. In 1994 this limit was increased to £140 million for each major installation, so that the operator is liable for claims up to this amount and must insure accordingly. This is covered through a pool comprising 13 insurance companies and 40 Lloyd's syndicates. Beyond £140 million, the Paris/Brussels system applies up to SDR 300 million.

In 2001, contracting parties to the Paris and Brussels Conventions agreed new limits on third party liability: Nuclear Operators (insured) € 700 million, Installation State (public funds) € 500 million, Collective state contribution (Brussels) € 300 million => total € 1500 M. This Protocol is expected to be ratified in 2007, as soon as states have enacted relevant legislation.

Beyond such provision there is at least a tacit acceptance that the installation state will make available funds to cover anything in excess of these provisions.

The Risk that Natural perils will Occur and the Harm so Caused.

These Perils include

- Storms,
- Fire,
- Flooding
- Earthquakes

If one of these perils does occur then the harm so caused may:

- *Delay the Construction and Operation of the Plant*
- *Damage the operating plant,*
- *Harm third parties and*
- *Interrupt the generation and sale of electricity;*

These are Force Majeure risks. They are insured by commercial insurers both during the construction and operation of the nuclear power station. However during construction these perils add to the FOAK costs in ways not currently fully insurable. Again, during operation, these perils can lead to Business Interruption and a loss of revenue that is not fully insurable.

A brief Analysis of the broad Risk of Terrorist Activity

Following the terrorist attack on the World Trade Centre, I was asked by the UK Government DTI and later(at their recommendation) by the equivalent department of the Canadian Government, to assess the numerical magnitude of the terrorist risks to nuclear installations, in the UK and later in Canada. This I did by

1. First determining that the original design intent had been that terrorist risks should not constitute the major risk: instead they should constitute no more than one tenth of the total risk presented by the nuclear installation.
2. Next the mean forecasts of relevant PRAs were used to calculate the numerical value, in pounds, of this original terrorist Third Party Risk.
3. Then the pessimistic view was taken, that the terrorists might equally have plunged a plane into a nuclear power station, instead of into the WTC. Using this assumption and the PRA forecasts Bayes theorem was used to revise the PRA forecasts upward: the fact that a terrorist strike on a nuclear power station had occurred would, it transpired, imply that the terrorist component of the risk had increased by a factor of six. The financial value of this revised risk then became the theoretical premium for insuring nuclear installations against modern terrorist attacks. Both Governments, having consulted other experts about these findings, accepted them and both charged the premiums that had been calculated: the commercial insurers were not at that time keen to insure the terrorist risk.

Now the commercial insurers are prepared to shoulder some if not all of the terrorist risk and the Governments take the remainder.

The Risk of Premature permanent Shutdown and Decommissioning because of new, more stringent Regulatory requirements or new Government policy;

It is difficult at present to insure the risk that new more stringent regulatory requirements or a new Government policy will lead to premature shutdown of a nuclear installation. In Germany and in Sweden, new Government policies have been introduced that will lead to premature shutdown of the nuclear power stations. If there is no compensation then the overall economics of nuclear generation is seriously affected. Some Force Majeure insurance contracts for things other than nuclear installations do cover the effects of unforeseen, more stringent regulatory requirements and it seems likely that similar policies could be obtained for a new Australian nuclear power station. Alternatively it may be possible to strike a deal with Government that reduces or eliminates the financial impact of this risk.

The Risk of Permanent shutdown following another "Chernobyl" overseas;

Annex 6 considers the likely effects of nuclear accidents upon the price of uranium. It is suggested that similar arguments may be applied to the effect of such accidents on the acceptability of nuclear power. The main point is this: there have been severe nuclear accidents, such as the Windscale fire, the Three Mile Island core damage accident, the Chernobyl core melt accident and the Tokai Mura criticality. None of these has led to the abandonment of nuclear power nor to the closure of any specific nuclear plant. The main reason for this is the fact that the world relies on nuclear power for 16% of its electricity: a country such as France that places total reliance on nuclear power cannot afford to switch off its nuclear power stations "just because of some accident overseas".

The Risk of Shutdown due to discovery by the Vendor of a "Class Fault" in all plants of this design, a fault that it would not be economic to remedy.

It is assessed that a new reactor, built in Australia, is unlikely to have to be shut down because of a "Class Fault" which renders its continued operation un-acceptable on safety grounds. No records of any such event exist in the 10,000 reactor.years of experience (frequency = 10^{-4}/reactor.year) and the probability is believed to be one tenth of this: 10^{-5} /reactor.year.

An example of a "Class Fault", albeit not one that was sufficiently serious to close down permanently all reactors of the same design is provided by the corrosion of RPV heads or "reactor lids", first detected at Davis Besse. On March 6, 2002, workers repairing a cracked control rod drive mechanism (CRDM) nozzle at the Davis-Besse Nuclear Power Station in Ohio discovered a substantial cavity in the reactor vessel head. It was due to corrosion by boron-containing primary coolant which had leaked through cracks in the Control Rod Drive Mechanism, CRDM.

The first such leakage has been detected by workers testing the integrity of the reactor vessel at France's Bugey Unit 3 PWR in September 1991. They found cracks extending completely through the wall of a control rod drive mechanism nozzle that permitted reactor cooling water to leak out. Subsequent examinations discovered cracks of up to two inches long.

Leakage has occurred in other reactors. In April 2001, the owner of Oconee Unit 3 in South Carolina reported finding through-wall leaks on nine of sixty-nine CRDM nozzles. Workers found the leaks after observing boron deposits at the base of the CRDM nozzle. Boron deposits are clear signs that borated reactor water is leaking out. The cracking extended nearly 45 percent of the way around the circumference of nozzle-to-vessel head welds on two CRDM nozzles.

In Japan, the three most susceptible vessel heads have already been replaced because of safety considerations, even though no cracks were found in the nozzles of these heads.

In France, EDF has found it economical to replace the vessel heads having defective nozzles; several heads have been replaced or are planned to be replaced.

In Sweden, replacement of the Ringhals 2 vessel head is planned.

Risk of changes in Market Trading arrangements: Political/Regulatory Risk;

These are significant risks: some measure of their importance is given by the attitude of commercial insurers, who are generally prepared to insure political risk, certainly in Australia where it is low, but are not keen on insuring Regulatory Risk. In the nuclear area, nuclear insurers are certainly not prepared to insure against the risk that the regulator will require a nuclear power station to shutdown or remain shutdown following repair of accidental damage.

It is recommended that the Australian Government be asked to take the Risk that the Regulator will unexpectedly require the shutdown of any new nuclear power station, built in Australia.

A brief analysis of the Risk that competing Generation Companies will price the plant out of the market.

The economics of nuclear power are laid out above.

Competing generation companies could price the nuclear plant out of the market because of

- *Falls in the capital cost of new gas-fired generating plant,*
- *Falls in the prices of other fuels,*
- *Increased subsidies to renewable sources of electricity or*
- *An order-of-magnitude rise in the price of uranium.*

Each of these possibilities is considered in the next four sections of this Report:

The Risk of a fall in the capital cost of new gas-fired generating plant.

The risk of an unexpected fall in the ***capital*** cost of new gas-fired generating plant that prices the new Australian nuclear reactor out of the market is insignificant: the gas generators are at the cutting edge of gas turbine technology, more advanced than aircraft gas turbines. They are unlikely to become significantly cheaper, either because of learning curve effects or because of technological innovations. Even a large reduction in capital cost would be reflected in a comparatively small fall in the price of electricity because capital charges are not the dominant feature of the price of electricity from gas-fired plant.

We assess this Risk at 10^{-2} per annum.

Some indication of the statistical significance of the advantage of nuclear generation is given a new study of the market in ***Croatia*** and therefore not ***numerically*** relevant to the Australian case, reveals that:

- The probability for a coal-fired plant to be more economical than a combined cycle gas-fired plant is 95%.
- The probability that electricity produced in a coal-fired plant will be less expensive than electricity produced in a nuclear plant is 15%.

These forecasts are based on the Settled-down capital cost of nuclear power. We have to deal with FOAK costs and the method that we have developed to deal with this risk is described in the section of this Report entitled Government Insurance of FOAK Risk.

The Risk of a fall in the prices of other fuels,

The above-mentioned, 2005 probabilistic analysis of comparative levelised power costs for new plants in Croatia[22] showed gas combined cycle 5.8 US c/kWh, coal 5.2 US c/kWh and nuclear 4.8 US c/kWh. The variability in the forecast levelised price of electricity is calculated and from this it can be seen that nuclear has a lower price and smaller uncertainty in price than coal or combined cycle gas.

The purpose was to assess the uncertainty of several key performance and cost parameters for electricity produced in coal-fired, gas-fired and nuclear power plants. In this was were developed probability distribution of the levelised price of electricity from different Power Plants and the probability distribution of cost difference between the technologies. The key parameters evaluated included:

- average rate of foreseen fuel price change during the plant lifetime.
- cost of produced electrical energy in US$/kWh
- overnight specific investment cost in US$/kW
- constant annual operational and maintenance cost in US$/kW year
- variable operational and maintenance cost in US$/kWh
- fuel cost in US$/GJ
- plant efficiency
- load factor
- years of loan repayment
- years of plant life
- discount rate
- average interest rate for loan repayment

The Risk of increased subsidies to renewable sources of electricity.

The risk of increased subsidies to renewable sources of electricity is a very real one. It is an element of the Political Risk that commercial insurers would be unwilling to cover, since current experience shows that these subsidies are susceptible to increases at any time.

Accordingly it is recommended that the Government be asked to provide cover for all or part of this Risk.

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[22] *Feretic D, & Tomsic Z, 2005 Probabilistic analysis of electrical energy costs, Energy Policy 33,1; Jan 2005.*

The Risk of an order-of-magnitude rise in the price of uranium.

Historically, in constant money terms, uranium prices have varied by an order of magnitude. Should that occur in future then it is forecast that the cost of electricity from a new Australian nuclear power station would increase by 45%. Even at this (very unlikely) level nuclear power would still have a price comparable to power produced from coal and gas.

Thus a detailed study of energy economics in **Finland** published in mid 2000 shows that nuclear energy would there be the least-cost option for new generating capacity[23]. The study compared nuclear, coal, gas turbine combined cycle and peat. Nuclear has very much higher capital costs than the others –Finland estimated it as Euro 1,749/kWe including initial fuel load, which is about three times the cost of the gas plant. But its fuel costs are much lower, and so at capacity factors above 64% it was the cheapest option.

Later estimates from Finland (April 2001) put nuclear costs at Euro 2.40 c/kWh, coal 3.18 c/kWh and natural gas at 3.21 c/kWh (on the basis of 91% capacity factor, 5% interest rate, 40 year plant life).

The Finnish study in 2000 also quantified fuel price sensitivity to electricity costs:

These show that a doubling of fuel prices would result in the electricity cost for nuclear rising about 9%, for coal rising 31% and for gas 66%. These are similar figures to those from a 1992 OECD report[24] and coupled with the forecasts of our Financial Model lead us to the above conclusion, that even if the price of uranium increased by an order of magnitude nuclear power could still compete.

The Risk that the financial provision that has been made and planned for decommissioning and waste management will be found inadequate.

Should the Government require an increase that eats into profits then this will make the Company less able to manage other risks. It is impossible to estimate this risk and accordingly the Government should be asked to cover it.

Default Frequencies for the Risk-Takers.

The various parties: Vendor, Contractors, Sponsor, Lenders, Partners and Insurers generally have high credit ratings.

Credit Ratings of the Parties to the Project.

[23] *Tarjanne & Rissanen, 2000, in Proceedings 25th International Symposium, Uranium Institute*
[24] OECD/IEA, 1992, *Electricity Supply in the OECD*

Figure 12 shows estimates of the credit rating of insurers and other major companies in several different countries.

Figure 12: Estimated Credit Ratings of Major Companies in different countries.[25]

	Credit Ratings
Belgian	AA
Brazilian	AA
Croation	AA
Czech	AA
French	AAA
German	AAA
Japanese	AAA
Korean	A
Mexican	A
NEIPROC	A
Nordic Nuclear	AA
Slovakian	A
Slovenian	A
Spanish	AAA
Swiss	AAA
UK	AAA
USA	AAA

Probability of Default for a Given Credit Rating[26].

In Figure 13 are given the probabilities, %, of default for a given credit rating.

Figure 13: Probability, %, of Default during a given year.

%Default	
0.0007	AAA
0.01	AA
0.04	A
0.22	BBB
0.98	BB
5.3	B
21.94	CCC
100	Default

The individual parties to the Project will, therefore, have no history of defaulting. It follows that they are unlikely to form a partnership with the sponsor, or undertake contracts for the Sponsor if they assess that they are likely to be involved in a default. Consider, therefore, what the US Congressional Budget Office has to say:

[25] These estimates were arrived at by one of us, Mr Michael Dawson, the active underwriter of Syndicate 1176.
[26]Deduced from http://www.riskglossary.com/articles/default_model.htm

…this project (to build a new nuclear power station in the USA) would have significant technical risk because it would be the first of a new generation of nuclear plants, as well as project delay and interruption risk due to licensing and regulatory proceedings. Because the cost of power from the first of the next generation of new nuclear power plants would likely be significantly above prevailing market rates, we would expect that ***the plant operators would default on the borrowing*** *that financed its capital costs."*

The solution to this problem is not for Government to award a grant or subsidy: this may prove inadequate. Instead the solution lies, as we shall show later, in an insurance scheme in which the Government plays a role.

Next, the organisations and other bodies that could in principle shoulder each of these Risks are examined.

Principal amongst these organisations is the Sponsor, since it would be the organisation that intended to profit from the venture.

Types of Financing

There are two different types of financing. The first uses '***on balance sheet***' methods. This means that whatever loans, credit or cash is used, this is shown on the purchasing company's balance sheets***, and the providers of the finance can claim against the assets of the purchasing company in the event of default on payment.***

The second type of financing is project finance, also known as limited recourse, non-recourse or 'off balance sheet' finance. Here financiers primarily rely on the cash flows generated from the project for repayment. While project assets are pledged as security for the loan, the assets are not readily available as a source of repayment. Also, the financing is 'limited recourse' in that the lender may not look to cash or assets outside the project as additional support for the loan unless these assets or cash are specifically dedicated as security for the project. An example of extra security would include a guarantee from a project sponsor, a performance warranty from the operator, or additional equity contributions from investors.

Project finance is often known as 'off-balance sheet' finance because the financing is arranged such that no one sponsor bears the majority of the project risk. If structured properly, the risk-sharing feature allows the project sponsors to avoid listing the project on any of their corporate balance sheets.

Types of Customer: Utilities, IPPs and MPPs.

The type of customer will also determine the type of financing. Large government-supported or privatised utilities can often finance 'on balance sheet' for purchasing both retrofit and new plant. This is not only because it relates to the core business of the utility, but also because these utilities can have the balance sheet strength to borrow directly for large capital expenditures. Independent Power Producers (IPPs) and Merchant Power Producers (MPPs), when purchasing new plant, will only finance by project finance because in most cases these companies would not have the balance sheet strength to raise finance by any other method.

One possible arrangement for a new Australian nuclear power station would be a BOT Contract with an IPP, who would build, operate and then transfer the station to the owner.

Lenders,

Debt is normally supplied in the form of a conventional commercial bank loan. Borrowers pay interest, ie the cost of the debt, and repay the principal, ie the loan amount. Lenders normally charge a pre-determined rate of interest that is set by adding an ‘interest margin’ to the bank’s standard inter-bank lending rate. The interest margin is generally expressed in ‘basis points’ representing the bank’s return on investment or income. Basis points are defined as one-hundredth of the interest margin as expressed in percentage points. For example, if the interest margin is 0.12%, then this would be 12 basis points. Interest payments on debt are usually tax deductible, which does not apply to equity, and this is one of the reasons debt is thought of as being ‘cheaper’ then equity.

For large infrastructure projects, the repayment period is often up to 15 years. Debt may also be provided by institutional investors, such as insurance companies.

The lender does not have a share in the project and therefore has no ‘upside’ potential. The ‘upside’ is that, if a project does well, there will be more profits for the equity investors. No matter how well the project does, a lender will never receive more than the interest and principal repayments. The downside risk is that the lender faces losing 100% of the loan to the project if the project does not perform. Lenders and banks have little or no opportunity to increase returns and face the possibility of losing entire investments. Thus they focus closely on all aspects of risk, and want to take the least risk of all parties involved.

Subordinated Debt.

Subordinated debt is debt that ranks below the main (senior) debt in terms of its priority of payment or in liquidation. The senior debt is usually bank debt, and there may be several layers of subordinated debt between the bank debt and equity. Subordinated debt principal and interest is paid only after the senior debt principal and interest is paid. In insolvency, subordinated debt holders receive payment only after the senior debt is paid in full.

Interest paid on subordinated debt is tax deductible. Subordinated debt may or may not be secured. It is flexible and can be tailored to be deeply subordinated to the senior debt; in this case it may almost take on the characteristics of equity. When calculating debt or equity ratios, often bankers will consider subordinated debt as ‘quasi-equity’ and include it as part of the ‘equity cushion’ that supports the senior bank debt. For example, a project with 70% debt, 10% subordinated debt and 20% equity sometimes may be viewed as a project having roughly 70% debt and 30% equity. Subordinated debt can be provided by companies involved in the particular power project, or can be from third parties. ‘Mezzanine finance’ is a general term used to describe various financings that rank below the senior debt. There is no one definition for mezzanine finance; it may or may not be from third parties, but in general is more likely to be so. It may also have certain features that allow the debt to be converted into equity.

Bonds

Bonds are interest-bearing instruments issued by companies, governments or other organisations, and sold to investors in order to raise capital. They are a type of debt. Bonds tend to be long-term obligations with fixed interest rates and repayment schedules. Bonds are usually issued and sold in the public bond markets, although increasingly some are sold directly to institutional investors, in which case the financing is known as a 'private placement.'

Grants

Grants are non-returnable payments that are provided to projects or exporters to cover capital costs. Bodies with an interest in seeing the projects developed use grants to encourage developers to consider projects that have high risks and uncertain returns. They often apply to FOAK or 'first of a kind' and demonstration plant. They can be used in order to reduce the risk exposure of the commercial lenders and investors, or to cover incremental capital costs. Grant programmes have to be operated carefully in ways that will not distort market forces or lead to market collapse on withdrawal.

Shareholders,

Equity represents the owners of the project, and usually equity investors are referred to as shareholders. Equity can come from individuals; companies involved in a project, such as project sponsors and equipment manufacturers, or sometimes from institutional investors like insurance companies or energy investment funds. Equity differs from debt in that it receives the profit from the project. If the project does well, the equity pay-out could be substantial. If the project under-performs or becomes bankrupt, however, equity investors are the last to be paid, after the banks and other claims on the project. Thus equity takes a higher risk and receives potentially higher returns to compensate.

Ownership

For independent power projects, which involve new power plant developed independent of the local or national utility, the legal control and ownership of the plant can be described by various acronyms.

BOO (build, own, operate) is used for straightforward projects that remain in the ownership of the project company that operates them to receive the revenues.

BOT (build, operate, transfer) is when the project company retains control for a time to receive profits from operational revenue, and then transfers ownership, often to the local public sector utility; similarly for BOOT (build, own, operate, transfer) where ownership actually resides with the project company for a time.

BOLT (build, own, lease, transfer) is when the company leases control to third parties, before transferring ownership.

Insurers: Insuring EPC Contracts.,

Whilst not a type of funding, insurance and loan guarantees are vital components in financing. For any project, a full insurance package must be in place before financing will be finalised. Due to the complexity of project insurance, the insurance package is arranged concurrently with the financing. Lenders will have specific insurance requirements, and insurance documents will be part of the overall financing documentation. Two general needs for insurance bear mentioning here: export insurance concerning the risks particular to doing business in other countries, and technology insurance concerning the risks particular to the performance of the technologies.

Export insurance for political and commercial risks is usually necessary for the market countries for nuclear power stations. A range of appropriate insurance covers is commonly provided by export insurers such as export credit agencies and their private sector counterparts. Loan guarantees are very important particularly for project financing. They provide the insurance cover for loans, guaranteeing the exporter payment from the loan and guaranteeing the financing bank the loan value in the event of default due to political or commercial risks. Loan guarantees are often a vital prerequisite for banks to be willing to lend to projects. They are available from export credit agencies on a bilateral basis and from the World Bank Multilateral Investment Guarantee Agency (MIGA) on a multilateral basis.

Technology insurance is very important for advanced nuclear power stations, being based upon advanced technologies. Lenders are wary of technological risk especially for new technologies or new applications of old technology. To cover the technological risk, manufacturers can provide performance guarantees or bonds. If the manufacturer is not a large creditworthy company, additional support may be required from commercial insurance policies or bank guarantees.

Engineering insurers are, in a limited number of cases, prepared to insure various types of contingency risk, such as the following:

1. Force Majeure (FM)
2. Liquidated Damages (LD)
3. Penalty.
4. Cost Overrun.
5. RAM (Reliability, availability, maintainability.)

The parties insured are:

1. Financiers (lenders and banks)
2. The owner or Sponsor in the terminology of the present Report.
3. The EPC Contractor, including Vendor(s) and Sub-contractors.

The construction of a nuclear power station contains, as this Report reveals, a variety of risks that are distributed among the parties involved. The matters that could lead to failure of the project are discussed and analysed in the present Report.

The Contract documents, that is to say the Loan Agreement and the EPC Contract for the nuclear station will need to set down which risk has to be borne by which party.

Here again, the present Report gives advice on this division of risk between the parties.

Guarantees.

The following are the basic guarantees involved in an EPC contract:

Quality.

The contractor is obliged to make good, during an agreed period, any defects resulting from faults in material or workmanship.

Performance.

The contractor should guarantee the performance of the nuclear power station in terms of its output, specific fuel consumption, availability etc. ***My discussions with Insurers and knowledge of the insurance market leads me to believe that it will be possible to insure the following things, which are not insurable at present, or rarely so:***

- The Contractor against the risk that a nuclear accident occurs at the station, making it impossible for him to honour his guarantee regarding its performance. The availability of this insurance will reduce the financial provision for such a risk that the Contractor will have to provide out of his own funds or borrowing.
- Lenders against the inability of the Sponsor to service the debt on account of an accident that impairs the performance of the nuclear station. Thus a Bank or Partner, that relies on revenue from the nuclear station for the payment of interest on a loan that it made, would be insured against the risk that an accident would result in the nuclear station being shut down, so that payment of interest might cease until it was restarted. The fact that this insurance may become available will be an incentive to banks and Partner-companies to lend money (loans and subordinate loans) for the construction of the new nuclear station.
- Trusts or other parties, against the fall in value of shares that they hold in the nuclear power station, occasioned by an accident that results in the station being temporarily or permanently shut down. The fact that this insurance may become available will be an incentive to parties to buy equity in the new nuclear station.
- The Sponsor against Business Interruption due to an accident or Machinery Breakdown at the nuclear station. This cover is already available for operating stations. It will be more limited during the first three years of a FOAK station, because of the increased likelihood of unforeseen problems during that period.

Delays.

The contractor should guarantee the date and time when he will have fulfilled the contractual obligations.

Reliability, Availability & Maintainability, RAM.

The contractor should be required to guarantee the Reliability, Availability and Maintainability of the nuclear power station.

Insurance of the Risks of not Meeting the Guarantees.

There is currently only limited scope for the transference, to the insurance industry, of the risks of not meeting the above EPC guarantees and no such insurance has been granted for nuclear power stations. The types of projects that have been insured or considered by underwriters to date do, however include projects that have technical similarities to nuclear power stations and which have capital costs that lie in the same order of magnitude. They include the following:

- Combined Cycle Power Plants.
- Co-generation plants.
- Thermal (coal or oil) Power Plants.
- Waste-to-energy plants.
- Hydropower plants.
- Geothermal Power Plants.

For some of the core entrepreneurial risks, certain limited forms of insurance have been available for some time. These include cover for defects in design, material, workmanship, for defects liability (maintenance cover) and machinery guarantees. Even so, with only few exceptions, the insurance industry has, to date, refrained from granting any coverage concerning delay and performance guarantees or for guarantees in respect of reliability, availability and maintainability.

Swiss Re Supplies Insurance Capacity to EPC Market.

Ever since the early eighties, the underwriting of this type of contingency cover has been the domain of one specialized broker who handled all market enquiries through his own facility. The capacity available to this single source has fluctuated considerably in the past and has been largely provided by ***Swiss Re***, albeit on a selective, facultative basis.

Division of Risk between Insurer and the Other Parties.

The insurer will provide cover, albeit at the moment limited cover. That cover and the other contributory factors in ***debt service payment*** are listed below:

1. Liquidated Damages, LD, cover for delays by default of the contractor which are not indemnifiable under Delay in Start Up (DSU) cover.
2. Force Majeure (FM) cover for delays caused by FM perils: owner's responsibility not indemnifiable under delay in start-up cover.
3. Delay in start up (DSU) cover for physical damage caused by FM perils.
4. Anticipated Revenues.

The obligation to pay the debt service lies with the owner. The "delay in start-up" cover) (DSU/ALOP) provides him with reasonably broad protection concerning delays which arise from physical damage- caused by perils of any kind, including "force majeure"- which is not excluded from the relevant material damage cover, i.e. builder's risk and/or marine. Neither the owner's force majeure cover, nor the contractor's delay/efficacy (LD) cover can replace the DSU cover. At the same time the integration of the FM and LD covers into the scope of the DSU cover is not feasible, either. All three covers are equally necessary, as each one serves its specific purpose.

Some risks must be borne by the contractor, while others remain with the owner. The transfer of these risks consequently necessitates two different types of insurance cover: i.e.

- Force majeure cover to the benefit of the owner and
- Liquidated damages for delay and efficacy to the benefit of the contractor.

Force Majeure Insurance.

Force Majeure includes lightning, earthquake, storms, flood, frost. Clauses of this kind are common in construction contracts since these are perils that may halt construction.

FM insurance is designed to cover the owner's debt service obligations towards the lending banks/financiers in the event of late completion or permanent abandonment of the project resulting from specified force majeure perils. Cover is limited to debt service and does not extend to full loss-of-profits cover.

The owner has the option of insuring a large part of the force majeure risk- i.e. delays caused by physical loss or damage resulting from force majeure perils- within the scope of the delay-in-start-up policy. This allows the FM cover to be reduced to a difference in conditions cover or DIC provided for delays arising from those force majeure perils that are not covered within the scope of the delay-in-start-up policy.

Efficacy and Limited Damages Insurance, LD.

Black's Law Dictionary defines Liquidated Damages in the following phrase:

"The sum to which party-to-contract agrees to pay if he breaks some promise and which, having been arrived at by good faith effort to estimate actual damage that will probably ensure from breach, is recoverable as agreed damages if breach occurs."

The provisions of the EPC contract for the nuclear power station will grant the owner protection against delays and/or underperformance of the project caused either by technological failure or by any fault on the part of the EPC contractor or his sub-contractors and suppliers. The relevant delay or under-performance must oblige ***the contractor to pay the owner*** liquidated damages equivalent to reasonable financial obligations of the owner to the project financiers.

The contractor can protect himself against such damages by taking out LD insurance. It will protect the contractor for the liability he assumes under the contract for any delay in completion and/or performance shortfall resulting from and error of the contractors or suppliers in connection with the work to be performed under the terms of the construction agreement. The tasks concerned could include engineering design, procurement, construction an commissioning and testing of the project.

These specialised forms of insurance offer more than pure cover against the financial loss incurred by the owner and the contractor. They also assure greater security for the lending institutions involved. Moreover, it has become common practice for the contractor to assume liquidated damages obligations in construction agreements. Consequently, if the contractor is involved in numerous projects at the same time, the resulting accumulation of such continent liabilities- whether on or off the balance sheet- could easily jeopardise the contractor's ability to meet his obligations under liquidated damages provisions.

Figure 14: Force Majeure and Liquidated Damage Insurance Covers.

Beneficiary of cover	Contractor	Contractor	Owner	Owner	Owner
Delay caused by:	Contractor's fault	Contractor's fault	Force Majeure Perils	Force Majeure Perils	Owner's fault.
	FM liability assumed under construction contract		Physical Damage.	Non-physical damage, i.e. -Strike -Changes of law -Other changes beyond the control of owner and contractor	Owner's required changes
Insurance Cover Available.	LD Delay/Efficacy.	LD Delay/Efficacy	Delay in start-up cover.	o FM o DIC o Delay in start-up	Not insured
Payable to:	Owner	Owner.	Payment of debt service to lenders.	Payment of debt service to lenders.	.

Details of the Insurance that could in Principle be made Available.

Force Majeure.

Force Majeure insurance is intended primarily for the owner of the project: the Sponsor of a project to build a nuclear power station. Perils that could be insured include:

1. Fire and allied perils occurring on or off site, including damage in transit and at the supplier's premises.
2. Strike, Lock-outs and/or labour disputes. Note that if these disputes are between insured parties and their employees then they are not insured.
3. Changes in legislation, i.e. the adoption, promulgation or modification, after the inception date of the subject policy, of any federal, state or municipal laws which establish requirements affecting the project to a greater extent than the most stringent requirements under the existing law. Laws relating to the licensing and licensability of the nuclear power station come in this category.
4. The order of any competent court enforcing a change of law.
5. Any other cause beyond the control of the insured owner or contractor and other project participants***, including for example nuclear fuel suppliers and electricity purchasers.***

Importantly, nuclear perils are excluded from Force Majeure, so delays due to contamination from some release of radioactivity from another nuclear reactor on the site would be excluded at present, although specialist nuclear insurers would consider insuring this peril on a facultative basis. Insolvency and/or financial default are also excluded.

Efficacy and Liquidated Damages.

The following forms of liquidated damages can, in principal, be covered:

1. Late completion payments for delays beyond the guaranteed completion date defined in the contract.
2. Performance shortfall payments if the contractor fails to achieve the contractually agreed performance criteria, such as electrical output, fuel consumption, thermal efficiency, heat rate or radioactive site-emission levels.

The following things will be required if insurance is to be granted:

1. The project must be insured against Force Majeure.
2. There must be 90 days or more between the dates of targeted and guaranteed completion.
3. The minimum deductible, payable by the insured should be make a claim, should be of the order of 30 times the maximum daily liquidated damages amount for delay.
4. The key triggers for liquidated damages must be clearly defined, e.g.
5. Substantial completion has occurred when certain agreed minimum performance criteria have been attained.
6. A Commissioning-Period must be agreed. It is the period allowed in which to achieve full plant performance criteria prior to performance LD's becoming due.

7. The maximum sum for which delay and performance LD's can be insured is at the moment of the order of £100 million. The amount of insurance available will not generally exceed 20% of the total contract value, TCV. This should generally be sufficient to cover either debt service obligations for at least 12 months or buy-down amounts for substantial performance shortfalls.
8. The design of the nuclear power station will have to be fully consistent with standard, proven engineering practice. It must not contain any experimental items of equipment, technology or method of construction.

Customers,

Customers take the risk that their business will be interrupted if there is failure of the electricity supplies. They can insure against this in the commercial insurance market. The diversity of electricity supplies that will be created if a new nuclear station is built in Australia to replace coal-fired ones will improve on the present levels of security-of-supply. Accordingly the risk of failure of electricity supplies will not rise and so the premiums charged for insuring businesses against interruption of electricity supplies will not rise.

The Vendor of the plant

The Vendor of the plant takes a substantial risk if he enters into an EPC Contract. We have already covered these risks in detail in the sections EPC Contracts. & Insurers: Insuring EPC Contracts.,

Contractors

Under the terms of an EPC contract the Contractors are engaged by the Vendor. We may therefore regard the risk to the project presented by the Contractors as being subsumed into that of the Vendor,

Government

It will be essential for the Government to take some of the Risk associated with this project to build new nuclear power station(s) in Australia. This is because of the indeterminate nature of the First of a Kind costs, FOAK(Australia). Below we present a new scheme for the joint insurance by private insurers and Government of the FOAK(Australia) risk.

Establishing which of the Risk-Takers could take each Risk.

The likelihood that each of these potential Risk-takers would be prepared to shoulder each of the various Risks is now examined, together with the financial charges that they may wish to make to compensate them for taking the Risk. Account will be taken of the fact that, where one risk-taker shoulders more than one risk, he will use Risk

Based Capital methodology to reduce the capital-provision and in this way reduce his costs.

As a focus for this allocation of Risks to Risk-takers, a Scenario will be first postulated and the roles of the Risk-takers in that Scenario will be defined.

The cost of this Scenario and various other reasonable Scenarios, each scenario comprising one of the logical allocations of the various Risks to the listed Risk-takers, will then be analysed.

Details of the Financial Plan.

Figure 15: Structure of EPC Project to build a Nuclear Power Station in Australia.

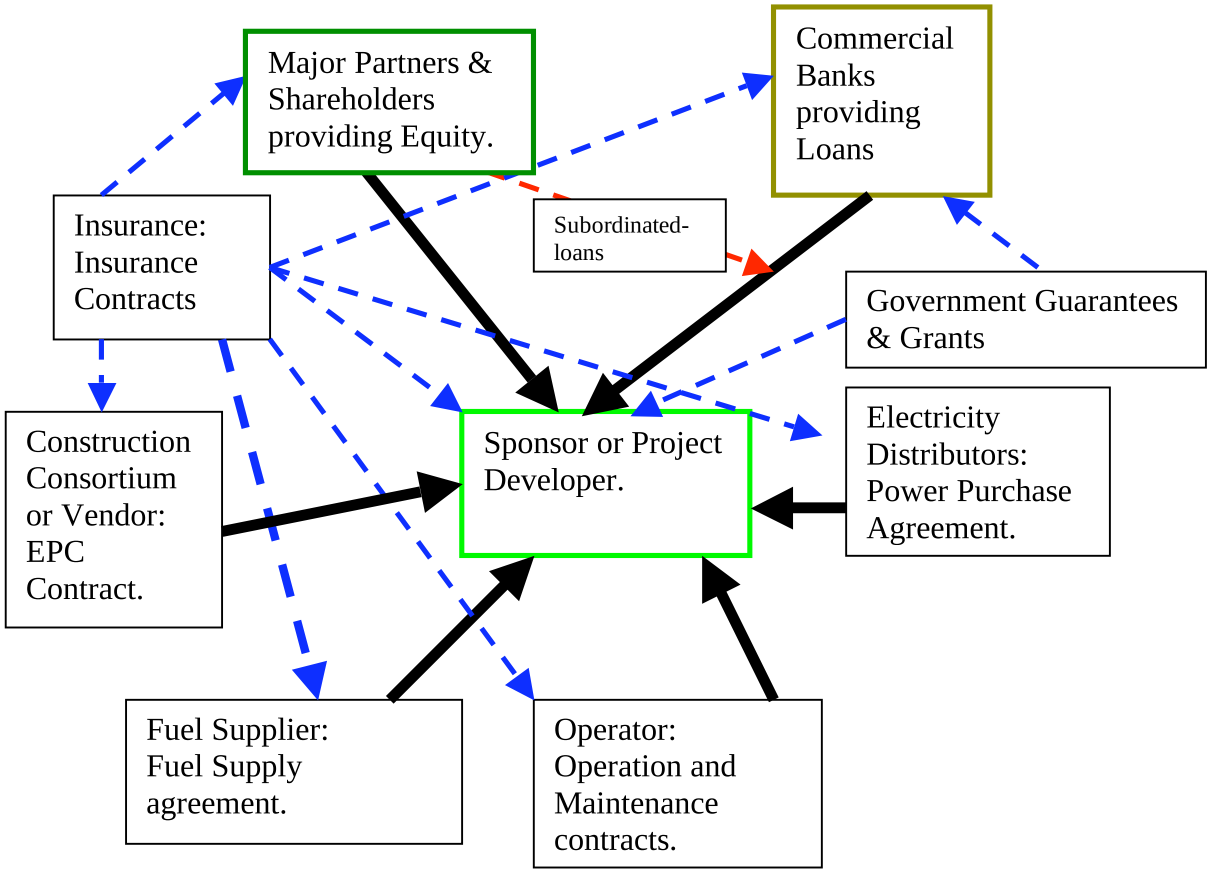


Figure 16: Sources of Money for the Australian Nuclear Power Station. This is Figure 15 with the details of Insurance deleted.

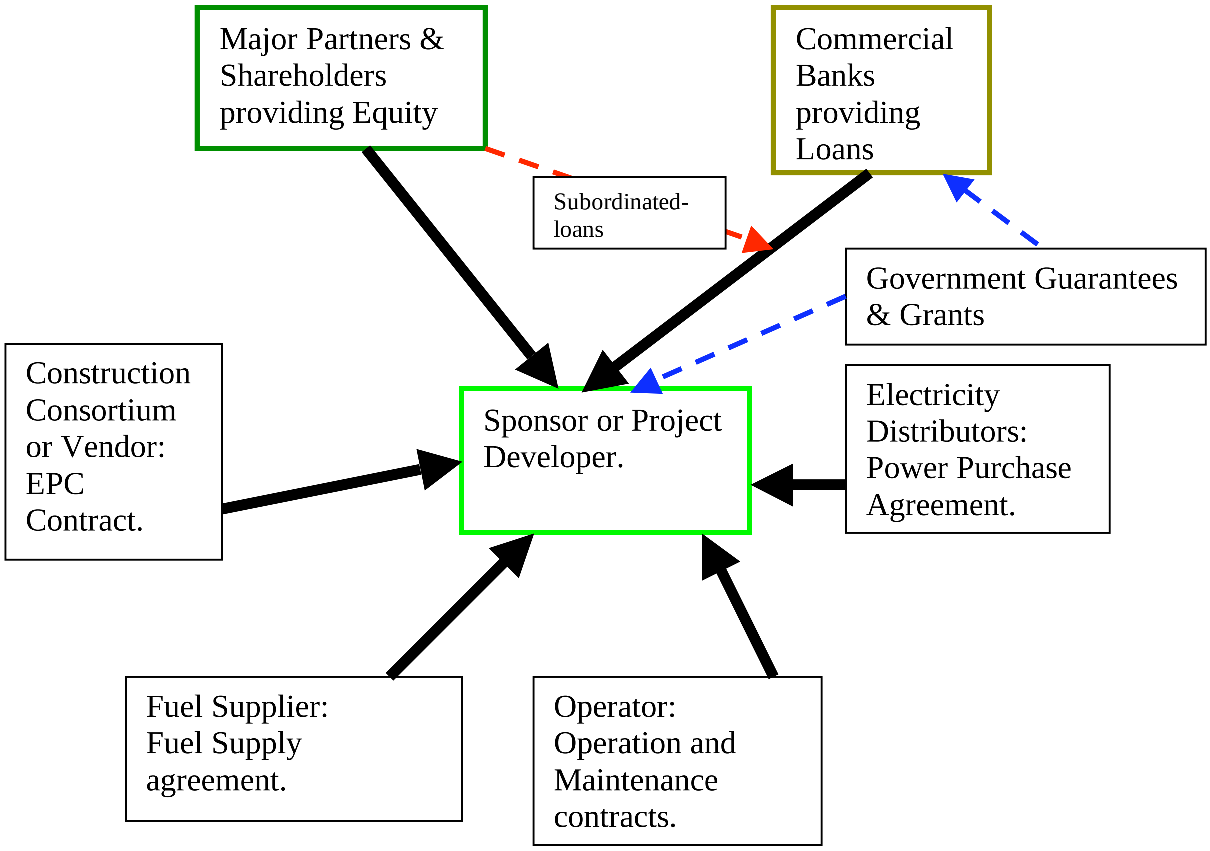
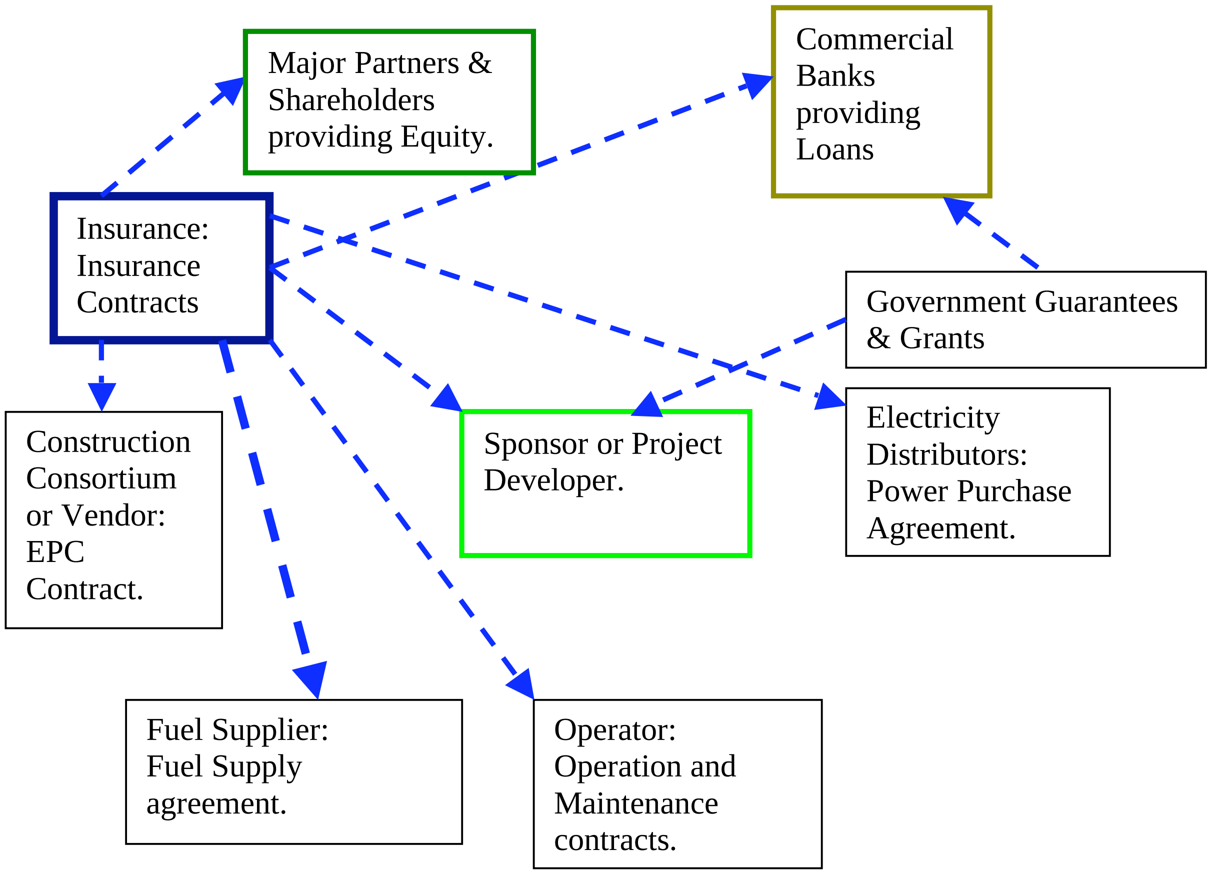


Figure 17: Insurance of Risks in EPC Project to build a Nuclear Power Station in Australia. This is Figure 15 with the funding details deleted.



A conceptual scheme for the construction and operation of a new nuclear power station in Australia is shown in Figure 15. Figure 16 is the same diagram with the insurance elements deleted.

The ***Sponsor or Project Developer***, in this conceptual scheme, is a company specifically set up to Sponsor the construction of the power plant.

Major Partners and Shareholders in The Sponsor Company would include all or some of the following:

- The Vendor.
- Other companies engaged in the construction of power stations,
- Companies that generate electricity,
- Electricity-distribution companies
- The firm that would eventually operate the station
- etc.

Partners and Shareholders would share the risk. They would provide ***Equity*** and ***Subordinated Loans***.

These companies would be both Australian companies and overseas companies.

The ***construction risks*** would be managed by an EPC Contract with a Vendor.

Having major companies directly involved - in the operation of the Sponsor Company, on the board of directors, on the steering and financial committees, and by their capital investment, would reduce the sponsor risk. These companies would be the Major Partners and Shareholders.

The ***supply risks*** would be managed by the fuel supply contracts.

The ***income*** risks would be managed by means of a Power Purchase Agreement or Agreements.

The ***operation and maintenance risks*** would be reduced by the direct involvement of major nuclear utility operating companies including the Operator and Sponsor and by a maintenance contract with the Construction Consortium or Vendor.

The ***technology risk*** is the most obvious one, since the nuclear power station will be an advanced design and even if copies have already been built in other countries, it will be the First of its Kind in Australia. From the lender's perspective, this risk would be reduced if there was

- Equity involvement of the major technology supplier(s),
- Sub-loans extended by the other shareholders,
- Government grants and Government risk-sharing. ***These grants and risk-sharing measures would represent a degree of market interventionism but are critical in reducing the risk perceptions to lenders, so that such FOAK plant can be built. Ideally, they need to cover***

- ***Interest-charges that accrue during delays occasioned by un-anticipated regulatory-requirements.***

- ***The financial risk that the project will cost more or even be abandoned because Government has not provided a final solution to the problem of disposing of radioactive wastes.***

The ***economic risk*** is relatively high, because the plant will be the First of its Kind in Australia. The plant availability in an Australian context would be seen, by lenders, as unproven, leading to a risk that it will not be able to produce the revenue needed to finance the borrowing. The supply of a Government grant and participation of the Government in the risk of low availability would help to reduce both borrowing and risk; it would in this way reduce the risk to the lenders and shareholders

The ***political and legal risks*** would not be insurmountable for this project as Australia is a developed country and has a stable legal system. Regional support should be forthcoming as a result of socio-economic impact assessments that would show considerable benefits for the local region.

A Finance Scheme.

Financing would be by '***On balance sheet***' methods. This means that whatever loans, credit or cash is used, this is shown on the purchasing company's balance sheets***, and the providers of the finance can claim against the assets of the purchasing company in the event of default on payment.***

Debt would be partly supplied in the form of commercial bank loans. Subordinated debt would be provided by companies involved in the building and eventual operation of the nuclear power stations and from third parties. A suitable division would be 70% debt, 10% subordinated debt and 20% equity; this could be viewed as a project having roughly 70% debt and 30% equity. Bonds could be sold as another source of debt.

The Insured FOAK Loan from Government.

It is believed that it will be possible to secure, from Government and Commercial Insurers, an "Insured FOAK Loan". This would take the form of a Government Loan to cover the foreseen FOAK costs of building, for example, five AP1000 reactors in Australia. The Government and the Insurers would cover the possibility that, because of accidents and related unforeseen events such as changes to Regulatory requirements, the FOAK would exceed the amount of the initially-computed Government Loan. A retrospective insurance premium payable to Government and Insurers would be agreed in advance. The Vendor or Construction Consortium would claim from Government any excess FOAK costs, over and above the initially-computed Government loan, that came within the terms of the insurance policy during the construction of the five nuclear power stations. The Operator would pay the premium, together with interest on the initially-computed loan, retrospectively, out of the revenue secured by operating the stations and selling the electricity that they produce.

Equity would come from individuals; companies involved in the project, such as the project Sponsor(s) and equipment manufacturers, plus institutional investors like insurance companies and energy investment funds.

Mitigation of Risk by Insurers.

Considering the interaction between insurers and the various parties, shown in Figure 15:

Provision of Debt by Insurers.

Insurance companies in their role as institutional investors may provide ***debt.*** Thus an insurance company has capital; saved to pay losses that may in a given year, exceed its premium-income. This capital is invested and the return so produced is an important component of the income of the insurance company. In principle an insurance company could supply some of the loan capital for an Australian nuclear power station.

The Sponsor's Insurance.

Delay in Start-up.

The obligation to pay the debt service lies with the owner. The "delay in start-up" cover) (DSU/ALOP) provides him with reasonably broad protection concerning delays which arise from physical damage- caused by perils of any kind, including "force majeure"- which is not excluded from the relevant material damage cover, i.e. builder's risk and/or marine. Neither the owner's force majeure (FM) cover (see next section), nor the contractor's delay/efficacy (LD) cover (see below) can replace the DSU cover. At the same time the integration of the FM and LD covers, into the scope of the DSU cover, is not feasible, either. All three covers are equally necessary, as each one serves its specific purpose.

Force Majeure.

Force Majeure insurance is intended primarily for the Sponsor of a project to build a nuclear power station

Force Majeure includes lightning, earthquake, storms, flood, and frost. Clauses of this kind are common in construction contracts since these are perils that may halt construction.

FM insurance is designed to cover the owner's debt service obligations towards the lending banks/financiers in the event of late completion or permanent abandonment of the project resulting from specified force majeure perils. Cover is limited to debt service and does not extend to full loss-of-profits cover.

The Sponsor has the option of insuring a large part of the force majeure risk- i.e. delays caused by physical loss or damage resulting from force majeure perils- within the scope of the delay-in-start-up policy. This allows the FM cover to be reduced to a difference in conditions cover or DIC provided for delays arising from those force majeure perils that are not covered within the scope of the delay-in-start-up policy.

Perils that could be insured include:

1. Fire and allied perils occurring on or off site, including damage in transit and at the supplier's premises.
2. Strike, Lock-outs and/or labour disputes. Note that if these disputes are between insured parties and their employees then they are not insured.
3. Changes in legislation, i.e. the adoption, promulgation or modification, after the inception date of the subject policy, of any federal, state or municipal laws that establish requirements affecting the project to a greater extent than the most stringent requirements under the existing law. Laws relating to the licensing and licensability of the nuclear power station come in this category.
4. The order of any competent court enforcing a change of law.
5. Any other cause beyond the control of the insured owner or contractor and other project participants***, including for example nuclear fuel suppliers and electricity purchasers.***

Importantly, nuclear perils are excluded from Force Majeure, so delays due to contamination from some release of radioactivity from another nuclear reactor on the site would be excluded at present, although specialist nuclear insurers would consider insuring this peril on a facultative basis. Insolvency and/or financial default are also excluded.

Business Interruption.

When the nuclear power station is operating, part of the revenue stream derived from sales of electricity will serve to service the debt and pay dividends to the shareholders. Should an accident occur that causes the station to shut down then the revenue would cease. Insurers will cover part of this loss. Typically the insurance market will cover the actual revenue lost for a period of from 60 days to one year after the accident or Machinery Breakdown that led to the reactor shutting down.

Nuclear Accidents: insurable to Seven times the current Limit.

Insurers will cover the cost of losses due to nuclear accidents that occur whilst the station is operating. This cover is given to current nuclear power stations and identical cover would be given to the Australian one, with one important difference: ***the nuclear insurers say that they would be prepared to insure liability up to a limit of Aus $ 2.4bn,*** which is substantially greater than the current limit of Aus $ 330m (shortly to be increased, but only to Aus $1bn). Insurers are prepared to offer this higher limit because their independent assessment has convinced them that reactors such as the AP1000 present substantially lower risks than current plant.

The confidence of the nuclear insurers, expressed in this higher limit, will raise the confidence of all the other parties: the sponsor, lenders, shareholders and Government. It will strengthen the sponsor's resolve to buy a new nuclear station and make lenders, including the Government, more willing to help finance the project.

Shareholders.

In principle, insurers would be prepared to cover part of the risk, of a fall in the market value of shares in the project, should that fall be due to:

- Accidents during construction.
- An overseas or domestic nuclear accident equal to INES 5 or greater, which reduced investor confidence and resulted in a fall in the market value of shares in nuclear ventures generally.

Similar cover could be provided for ***shares***, held by the Sponsor, in uranium mines, fuel manufacture or back-end services.

Commercial Banks.

As the Australian nuclear power station would be purchased from a ***foreign*** Vendor, export insurance may be important; it is concerned with the risks particular to doing business in other countries.

Export insurers such as export credit agencies and their private sector counterparts provide a range of appropriate insurance covers. Loan guarantees are very important particularly for project financing. They provide the insurance cover for loans, guaranteeing the exporter payment from the loan and guaranteeing the financing bank the loan value in the event of default due to political or commercial risks. Loan guarantees are often a vital prerequisite for banks to be willing to lend to projects. They are available from export credit agencies on a bilateral basis and from the World Bank Multilateral Investment Guarantee Agency (MIGA) on a multilateral basis.

Lenders, whether Banks or Partners providing subordinated loans, may also be able to insure themselves against accidents that damage the Sponsor's ability to service the debt. This can arise in one of the following ways:

1. An accident may delay completion of the plant, increasing the amount of debt required.
2. An accident may cause the operating station to shut down.
3. An overseas nuclear accident may lead the sponsor to conclude that he should shut the station down. Or it may lead the Regulator to instruct him to shut it down.

These things are not insured at present, but insurers are prepared in principle to insure them for the new nuclear power station. This will raise the confidence of lenders and shareholders alike.

Government.

We are not here concerned with Insurance that might be purchased ***by*** the Government. However, Governments do present Political Risks to the Project, and some of these can be insured.

As mentioned elsewhere, Loan guarantees are very important particularly for project financing. They provide the insurance cover for loans, guaranteeing the exporter payment from the loan and guaranteeing the financing bank the loan value in the event of default due to ***political*** or commercial risks. Loan guarantees are often a vital prerequisite for banks to be willing to lend to projects. They are available from export credit agencies on a bilateral basis and from the World Bank Multilateral Investment Guarantee Agency (MIGA) on a multilateral.

The Sponsor can obtain Force Majeure insurance against Changes of law that may occur and cause financial harm to the Project. He can insure against changes in legislation, i.e. the adoption, promulgation or modification, after the inception date of the subject policy, of any national, federal, state or municipal laws, which establish requirements affecting the project to a greater extent than the most stringent requirements under the existing law. ***Laws relating to the licensing and licensability of the nuclear power station come in this category.***

The Government will have an important role as a Risk Taker. If Government can mitigate the FOAK risk, either by means of an insured FOAK loan, a grant or a Guarantee, then lenders and shareholders will be encouraged to put money into the project. Certainly in the USA it has been recognized that Government participation will be essential if new nuclear power stations are to be built. Now many of the measures that are presented in this Report have not been considered in the US analyses, but these additional measures seem unlikely to succeed in themselves unless Government can take some of the FOAK risk. Below we show how this may be accomplished, using the methodology of the insurance market in a manner that has succeeded in the case of the insurance, by the UK and Canadian Governments, of terrorist threats to nuclear power stations[27].

Government Insurance of FOAK Risk.

Studies of the variability in energy prices suggest a method devising a scheme whereby Government and Insurers could jointly take some of the FOAK risks.

We might imagine that if enough copies of a particular design of nuclear power station had already been built overseas for the “settled-down-cost” to be reached, then there would be no FOAK cost if one was to be built in Australia. This however would be to ignore the experience of the UK’s Sizewell B, where the intention had been to build a standard US PWR, just as the French had done 20 years earlier. The FOAK for Sizewell B, however, was considerable.

Nevertheless, we can reasonably expect that FOAK costs in Australia will be reduced if we chose to build a design of nuclear power station, several copies of which have been built overseas. It seems likely that several copies of the AP1000 will have been started, and some put into service, before any decision can be made to build a new nuclear power station in Australia. Similarly there are other modern designs of

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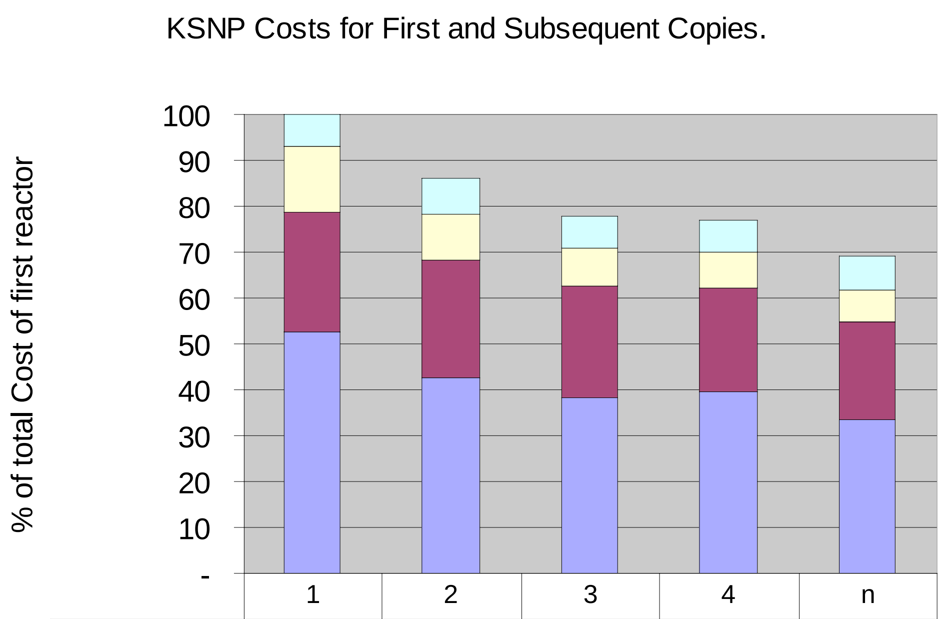
[27] Professor Gittus, under Contract to the UK Government and the Canadian Government, in 2002, 2003 and 2004 calculated the Terrorist Risk to the nuclear installations in those countries and the premiums that the nuclear utilities should pay to Government for insuring those risks, following “9/11”. Both Governments accepted the advice he gave and both charged the premiums that he recommended.

reactor, series of which are currently being built overseas (such as the KSNP) copies of which Australia might well decide to build.

If Australia’s FOAK is the world’s fifth or tenth copy of that particular plant, what will be Australia’s FOAK costs? There is a certain probability that, if five have been built overseas, Australia will only incur the sixth of a kind cost, for the first that it builds, the seventh of a kind for the second and so on. It would indeed be incautious to assume that this is likely, but it is possible. The sixth to be built would indeed incur only the sixth of a kind cost if it were built in the country where the other five had been built and the same Vendor would no doubt take responsibility for an Australian Contract.

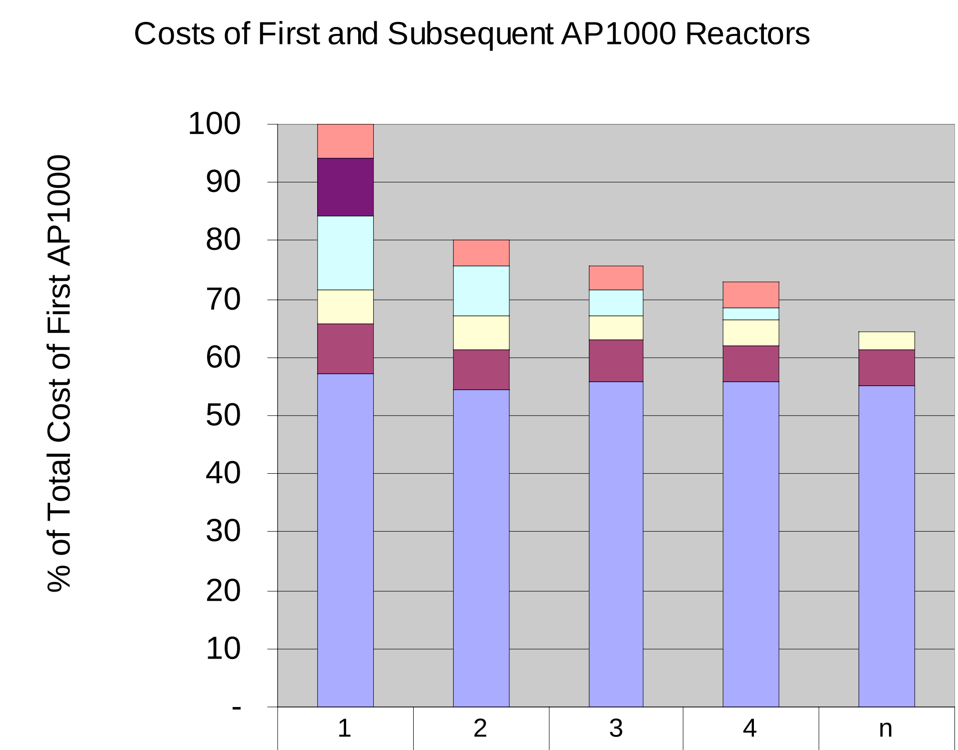
Figure 18 shows the costs that were actually incurred, in South Korea, for the first four copies of the Korean Standard Nuclear Plant, KSNP. Also shown are the forecast settled down costs for the “nth” copy. Figure 19 is a similar diagram, this time comprising forecasts for the AP1000, which unsurprisingly are quite comparable with the actual experience for the KSNP. Figure 20 shows the total costs, taken from the two previous figures and compares them with what would be expected if the Wright Learning Curve applies. Clearly it does and it provides us therefore with a method of forecasting the FOAK and NOAK (Next Of A Kind)costs of five AP1000’s built in Australia.

Figure 18: Korean Standard Nuclear Plant: Costs for the first four copies and forecast of settled-down cost of the "nth" copy.



	1	2	3	4	n
Owner's Cost	7.09	7.80	7.09	7.09	7.09
A/E Cost	14.18	9.93	8.51	7.80	7.09
Constr Cost	26.24	25.53	24.11	22.70	21.28
Equip Cost	52.48	42.74	38.28	39.41	33.54

Figure 19: AP 1000: Costs for the first four copies and forecast of settled-down cost of the "nth" copy.



	1	2	3	4	n
Extra Finance	5.71	4.29	4.29	4.29	
FOAK Eng	10.00	-			-
Learning curve	12.86	8.57	4.29	2.00	-
Buyer's Contingency	5.71	5.71	4.29	4.43	2.86
Finance Cost	8.57	7.14	7.14	6.43	6.43
EPC	57.14	54.29	55.71	55.71	55.00

Figure 20: Wright Learning Curves for KSNP and AP1000 Compared with Totals of Figure 18 and Figure 19.

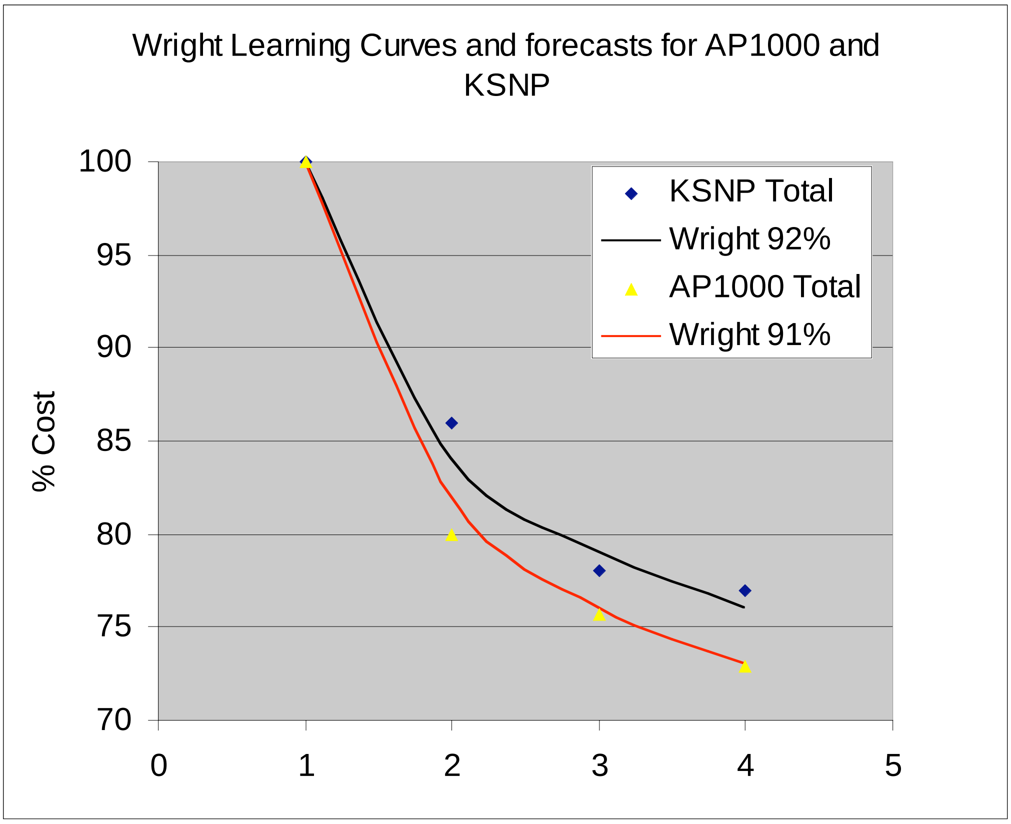


Figure 21 shows the difference between the actual capital cost of reactor number 5 (for example) and the settled-down cost. It is expressed as a percentage of the settled down cost. If the world's 5th AP1000 is Australia's first AP1000, then the suggestion is that this sum is advanced as a loan by Government and then repaid out of electricity revenues when the station is producing electricity. The loan would total 18% of the settled down cost of a single nuclear power station. The repayment would be 1.8% of the revenue from electricity, payable for 12 years.

This would have a negligible effect upon the price of electricity from the Australian nuclear power station.

FOAK Insurance Premium: the Overseas Learning Curve Risk.

There would obviously be a chance that the FOAK costs would exceed the forecast loan. In that case, provided that various conditions recognized by the commercial insurers (accident, unforeseen events, etc) were met, Government and the insurers would advance more FOAK funds, but the retrospective premiums would not increase or would not increase by an amount sufficient to repay this added FOAK funding. That is the nature of insurance; the insurer takes some or all of the agreed Risk away from the insured party. Insurers would take the view that there was a certain probability that Australia would not fully profit from overseas learning curve experience. There are various models, based on experience that allow insurers to do this and the Government would be invited to follow suit.

Figure 22 shows that the FOAK costs would be less if Australia built a later reactor and more if she built an earlier one.

Figure 21: Capital Sums (Expressed as a percentage of the Settled-down Capital Cost) Advanced for AP1000 reactors 5 through 9, assuming them to be built in Australia. It is envisaged that Australia would build one of these reactors.

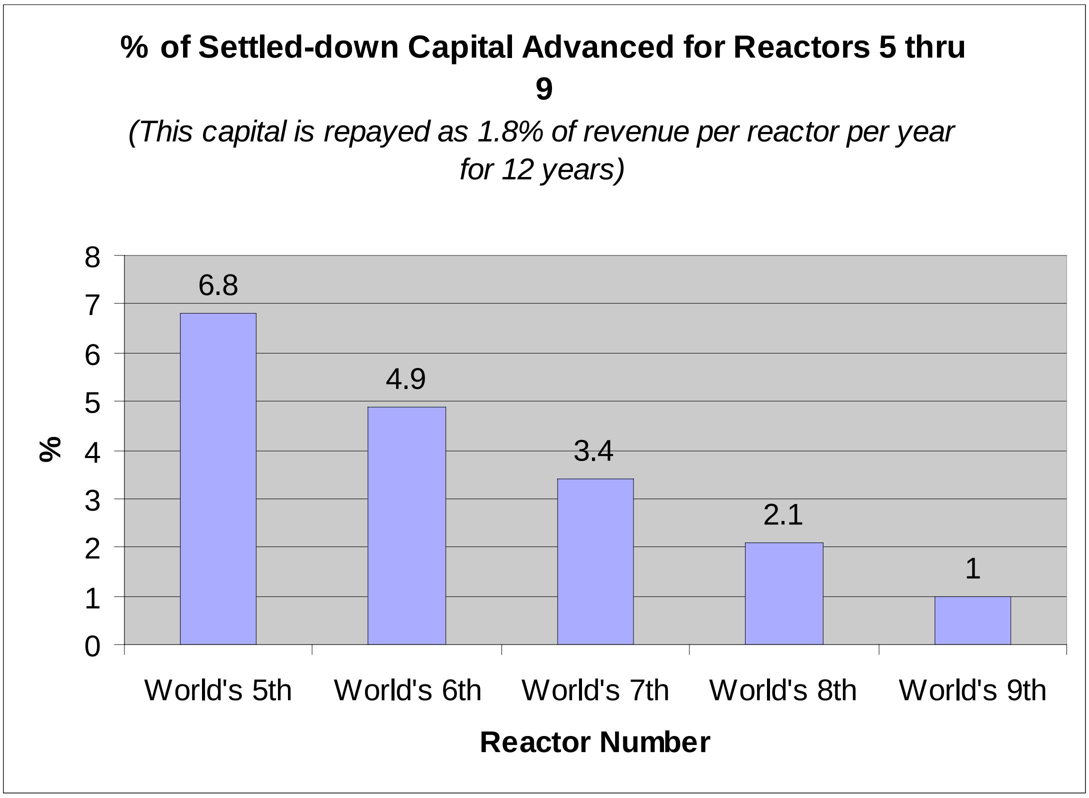
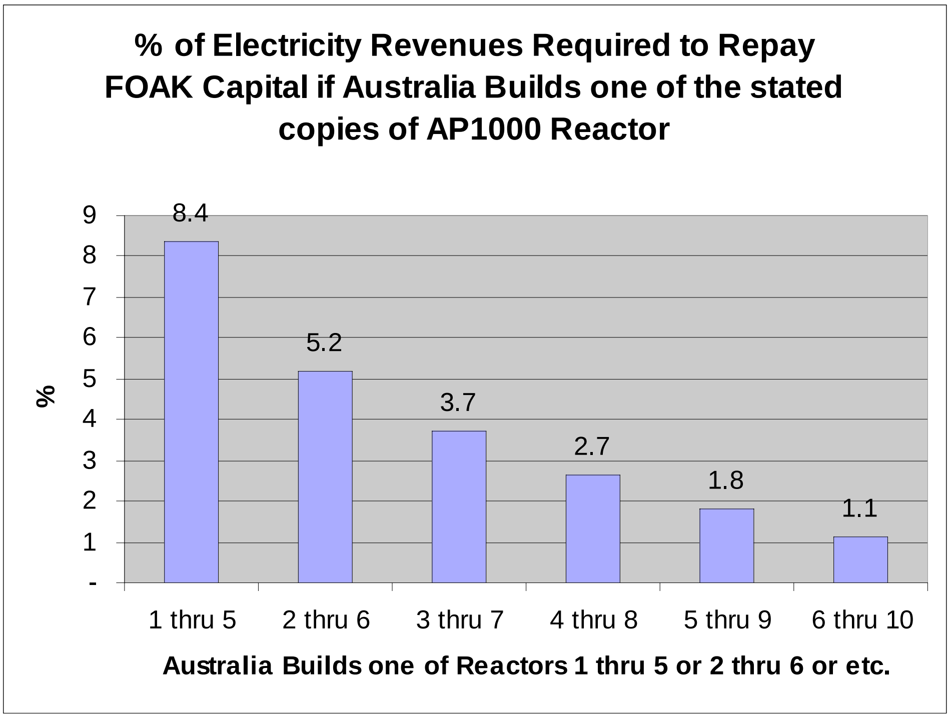


Figure 22: Capital sums are repaid out of the revenue that the operating reactors earn from electricity sales.



The risk, taken by Government and private insurers, would be that the capital sums required would be greater than here estimated. To limit these risks there would need to be trigger-points that release more capital: these would typically be accidents and other unforeseeable occurrences of a type agreed between the parties. Insurers would guide this process, based on their commercial experience. Those elements of the Sum Insured that insurers will be prepared to cover include Force Majeure and the risks of accidents, both nuclear and non-nuclear, during construction and during operation.

The remainder of the Sum Insured should be covered by Government, which would receive the remaining 80% of the premium. As the risks faced by the Treasury (the insurer in this case) are many and diverse we do not expect it to apply a factor to the net premium here calculated. This is the policy that we recommended when calculating, for the Treasury, the premium that it should charge for insuring UK nuclear installations against terrorism, following “9/11”, and the Treasury followed that advice, charging exactly the premiums that I had calculated. Subsequently I did identical work for the Canadian Government and they, too, based the premiums that they charge on the calculations that I had made.

The insurance market would require each reactor to pay the premium retrospectively for a period of 12 years in order to insure these FOAK(Australia) costs. I recommend that the Australian Government be invited to follow suit.

The five reactors would share both the capital repayment and the premium.. Note that we have assumed that the Government would not require interest on the FOAK costs that it had paid before starting to collect the repayments.

Electricity Distributors and other Purchasers of Electricity from the Station.

The Electricity Distributors will have there own insurance and we are not concerned with that in this Report.

The Sponsor can obtain Force Majeure insurance against any cause beyond the Sponsor's control, or beyond the control of the Vendor and other project participants**, *including causes that originate with electricity purchasers, including the electricity distributors and others of his clients. Failure to honour PPAs due to certain agreed events come in this category.***

Operator.

Natural and Man-made Perils.

The Operator will insure the operating plant against the following Perils whether man-made or due to natural causes:

- *Events, incidents and accidents,*
- *Aircraft-crash,*
- *Machinery-breakdown*
- *Terrorist acts: part of this cover is provided by Government, the remainder by commercial insurers*
- *etc.*

If one of these perils does occur then the harm so caused may:

- *Delay the Construction and Operation of the Plant*
- *Damage the operating plant,*
- *Harm third parties. Part of this is insured by Government and the rest by commercial insurers: the latter are prepared to increase six-fold the cover that they give to an AP1000*
- *Interrupt the generation and sale of electricity;*

New Health and Safety Regulations.

Some Force Majeure insurance contracts for things other than nuclear installations do cover the effects of unforeseen, more stringent Health and Safety Regulations and it seems likely that similar policies could be obtained for an Australian nuclear power station. Alternatively it may be possible to strike a deal with Government that reduces or eliminates the financial impact of this risk.

The Risk of Permanent shutdown following another "Chernobyl" overseas;

This is not a significant risk:

There have been severe nuclear accidents, such as the Windscale fire, the Three Mile Island core damage accident, the Chernobyl core melt accident and the Tokai Mura criticality. None of these has led to the abandonment of nuclear power nor to the closure of any specific nuclear plant. The main reason for this is the fact that the world relies on nuclear power for 16% of its electricity: a country such as France that places total reliance on nuclear power cannot afford to switch off its nuclear power stations "just because of some accident overseas".

The Risk of Shutdown due to discovery by the Vendor of a "Class Fault" in all plants of this design, a fault that it would not be economic to remedy.

It is assessed that a new reactor, built in Australia is unlikely to have to be shut down because of a "Class Fault" which renders its continued operation un-acceptable on safety grounds. No records of any such event exist in the 10,000 reactor.years of experience (frequency = 10^{-4}/reactor.year) and the probability is believed to be one tenth of this: 10^{-5} /reactor.year.

The Risk that competing Generation Companies will price the plant out of the market.

We have made an assessment of the cost of nuclear electricity in Australia in this Report and conclude that it would be competitive. There is nevertheless a risk that companies that generate electricity from coal or gas will undercut the nuclear plant and that customers will not buy all of the electricity that it is capable of producing. A new probabilistic assessment of the cost of electricity shows that, in Croatia, the price of nuclear electricity is lower and more certain than the price of electricity from competing sources. It is recommended that this analysis is repeated for Australia.

The Risk of increased subsidies to renewable sources of electricity.

This is an element of the Political Risk that commercial insurers would be unwilling to cover. It is recommended that the Government be asked to provide cover for all or part of this Risk.

The Risk of an order-of-magnitude rise in the price of uranium.

Historically, in constant money terms, uranium prices have varied by an order of magnitude. Should that occur in future then it is forecast that the cost of electricity from an Australian nuclear power station would double. Such an increase in the price of uranium is extremely unlikely and it would almost certainly be driven by comparable increases in the prices of coal, oil and gas, since this is how the Energy Market works. In that event, nuclear power would still be competitive. Part of this risk is, recently, commercially insurable.

Waste Management.

The risk of delay or cancellation by the Government Regulator, due to lack of provision for radioactive wastes is negligible: certainly less than 1%. This is because the provision that has to be made for radioactive wastes would have to be agreed, with Government, before Government would give permission for construction to commence. It is envisaged that LLW will be placed in a surface repository similar to the USA's Barnwell repository or the UK's Drigg repository. ILW will, it is suggested, be stored in concrete blocks on the surface, as at Sellafield in the UK. Spent fuel will be stored in ponds at the nuclear power station for up to 20 years and will then be stored in Dry Casks on the surface. Later an underground repository will be built to accommodate the spent fuel and ILW.

Fuel Supplier.

The Nuclear Fuel Suppliers will have there own insurance and we are not concerned with that in this Report.

The Sponsor can obtain Force Majeure insurance against any cause beyond the Sponsor's control, or beyond the control of the Vendor and other project participants, ***including causes that originate with Nuclear Fuel Suppliers. Failure to honour fuel supply contracts due to certain agreed events come in this category.***

Should the supply of fuel be interrupted and the Sponsor therefore be unable to service the loans for a period, then insurers would, within agreed limits, help to bridge the gap.

Vendor.

The Vendor or EPC Contractor responsible for the construction of the nuclear power station:

- Is obliged to make good, during an agreed period, any defects resulting from faults in material or workmanship.
- Must guarantee the performance of the nuclear power station in terms of its output, specific fuel consumption, availability etc.
- Must guarantee the date and time when he will have fulfilled the contractual obligations.
- Must guarantee the Reliability, Availability and Maintainability (RAM)of the nuclear power station.

The Capital cost quoted by Westinghouse, vendor of the AP1000 comprises all construction costs, related manpower and materials together with the cost of financing the capital. ***It also includes the costs of obtaining regulatory approvals and the EPC Contract would be drawn so that this Risk remains with the Vendor.***

There is currently only limited scope for the transference, to the insurance industry, of the risks of not meeting the above guarantees and no such insurance has been granted for nuclear power stations. The types of projects that have been insured or considered by underwriters to date do, however include projects that have technical similarities to nuclear power stations and which have capital costs that lie in the same order of magnitude. They include the following:

- Combined Cycle Power Plants.
- Co-generation plants.
- Thermal (coal or oil) Power Plants.
- Waste-to-energy plants.
- Hydropower plants.
- Geothermal Power Plants.

For some of the core entrepreneurial risks, certain limited forms of insurance have been available for some time. These include cover for defects in design, material, workmanship, for defects liability (maintenance cover) and machinery guarantees.

Even so, with only few exceptions, the insurance industry has, to date, refrained from granting any coverage concerning delay and performance guarantees or for guarantees in respect of reliability, availability and maintainability.

Efficacy and Liquidated Damages.

The provisions of the EPC contract for the nuclear power station will grant the owner protection against delays and/or underperformance of the project caused either by technological failure or by any fault on the part of the EPC contractor or his sub-contractors and suppliers. The relevant delay or under-performance must oblige ***the contractor to pay the owner*** liquidated damages equivalent to reasonable financial obligations of the owner to the project financiers.

The contractor can protect himself against such damages by taking out LD insurance. It will protect the contractor for the liability he assumes under the contract for any delay in completion and/or performance shortfall resulting from and error of the contractors or suppliers in connection with the work to be performed under the terms of the construction agreement. The tasks concerned could include engineering design, procurement, construction an commissioning and testing of the project.

The following forms of liquidated damages can, in principal, be covered Figure 23:

1. Late completion payments for delays beyond the guaranteed completion date defined in the contract.
2. Performance shortfall payments if the contractor fails to achieve the contractually agreed performance criteria, such as electrical output, fuel consumption, thermal efficiency, heat rate or radioactive site-emission levels.

The following things will be required if insurance is to be granted:

1. The project must be insured against Force Majeure.
2. There must be 90 days or more between the dates of targeted and guaranteed completion.
3. The minimum deductible, payable by the insured should be make a claim, should be of the order of 30 times the maximum daily liquidated damages amount for delay.
4. The key triggers for liquidated damages must be clearly defined, e.g.
5. Substantial completion has occurred when certain agreed minimum performance criteria have been attained.
6. A Commissioning-Period must be agreed. It is the period allowed in which to achieve full plant performance criteria prior to performance LD's becoming due.
7. The maximum sum for which delay and performance LD's can be insured is at the moment of the order of £100 million. The amount of insurance available will not generally exceed 20% of the total contract value, TCV. This should generally be sufficient to cover either debt service obligations for at least 12 months or buy-down amounts for substantial performance shortfalls.
8. The design of the nuclear power station will have to be fully consistent with standard, proven engineering practice. It must not contain any experimental items of equipment, technology or method of construction.

Figure 23: Force Majeure and Liquidated Damage Insurance Covers.

Beneficiary of cover	Contractor	Contractor	Owner	Owner	Owner
Delay caused by:	Contractor's fault	Contractor's fault	Force Majeure Perils	Force Majeure Perils	Owner's fault.
	FM liability assumed under construction contract		Physical Damage.	Non-physical damage, i.e. -Strike -Changes of law -Other changes beyond the control of owner and contractor	Owner's required changes
Insurance Cover Available.	LD Delay/Efficacy.	LD Delay/Efficacy	Delay in start-up cover.	o FM o DIC o Delay in start-up	Not insured
Payable to:	Owner	Owner.	Payment of debt service to lenders.	Payment of debt service to lenders.	.

New Insurances for the Construction Consortium/Vendor and other Parties.

The contractor should guarantee the performance of the nuclear power station in terms of its output, specific fuel consumption, availability etc. ***My discussions with Insurers and knowledge of the insurance market leads me to believe that it will be possible to insure the following things, which are not insurable at present, or rarely so:***

- ***The Contractor*** against the risk that a nuclear accident occurs at the station, making it impossible for him to honour his guarantee regarding its performance. The availability of this insurance will reduce the financial provision for such a risk that the Contractor will have to provide out of his own funds or borrowing.
- ***Lenders*** against the inability of the Sponsor to service the debt on account of an accident that impairs the performance of the nuclear station. Thus a Bank or Partner, that relies on revenue from the nuclear station for the payment of interest on a loan that it made, would be insured against the risk that an accident would result in the nuclear station being shut down, so that payment

of interest might cease until it was restarted. The fact that this insurance may become available will be an incentive to banks and Partner-companies to lend money (loans and subordinate loans) for the construction of the new nuclear station.

- ***Trusts*** or other parties, against the fall in value of shares that they hold in the nuclear power station, occasioned by an accident that results in the station being temporarily or permanently shut down. The fact that this insurance may become available will be an incentive to parties to buy equity in the new nuclear station.
- ***The Sponsor*** against Business Interruption due to an accident or Machinery Breakdown at the nuclear station. This cover is already available for operating stations. It will be more limited during the first three years of a FOAK station, because of the increased likelihood of unforeseen problems during that period.

The Risk of default by any of the Risk-takers

The Risk-takers, where they are commercial concerns, will all have credit ratings that imply a very low risk of default: below one chance in 10,000. They are unlikely to undertake to participate in a project to build a nuclear power station if they believe that they will be caused to default or become bankrupt as a result.

The Magnitudes of the Risks.

I have analysed the Risks presented by a Project that comprises the construction and operation of a nuclear power station or stations by an Australian Sponsor and expressed them in terms of cost and probability.

I have made these calculations for the case in which Australia builds one of the world's 5th, 6th, 7th, 8th and 9th AP1000 reactors and Figure 25, which is explained below, refers to that case. For comparison, in Figure 26 we show the case in which Australia builds the world's first AP1000. These two Figures deal only with the EPC insurance, by Government and commercial insurers, of a Government loan to cover FOAK costs. However the Government and insurers are not the only Risk-takers, as we have shown above and in the following example we spell out the type and share of each Risk taken by the Vendor, Owner and all the other main parties. A summary of these findings is as follows:

Figure 24: Probabilities of exceeding the FOAK value by the stated amount and the associated risks.

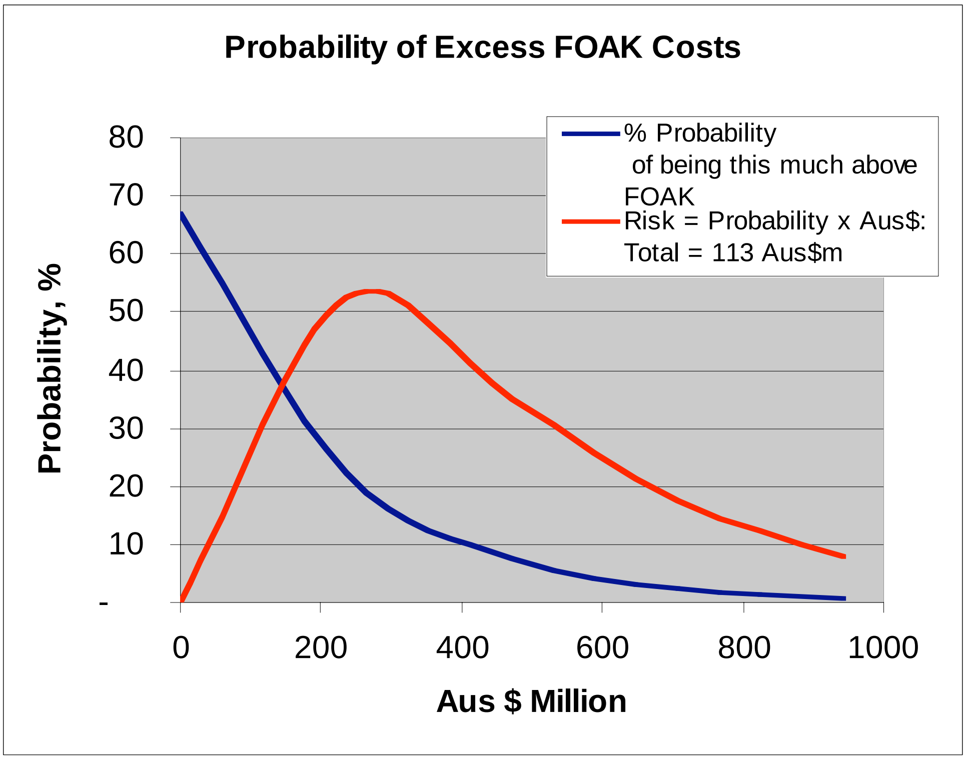


Figure 25: AP1000 Reactors numbers 5,6,7,8 & 9: Retrospective FOAK Payments out of Electricity Sales, per Reactor per year for 12 years.: Loan Capital and FOAK Insurance Premium to Government; FOAK Insurance Premium to Insurers.

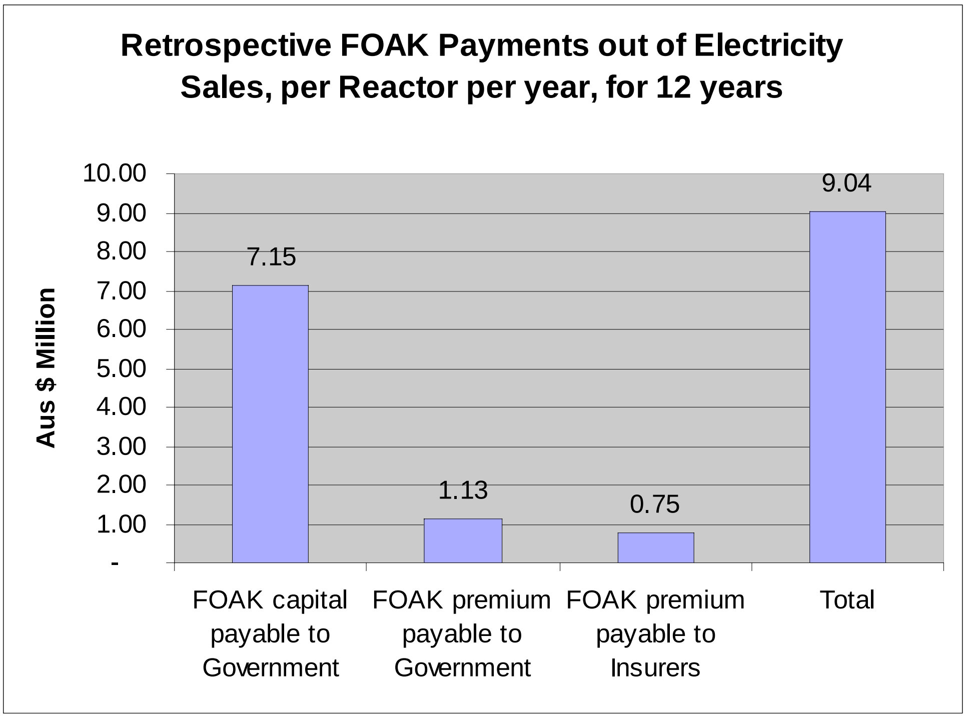
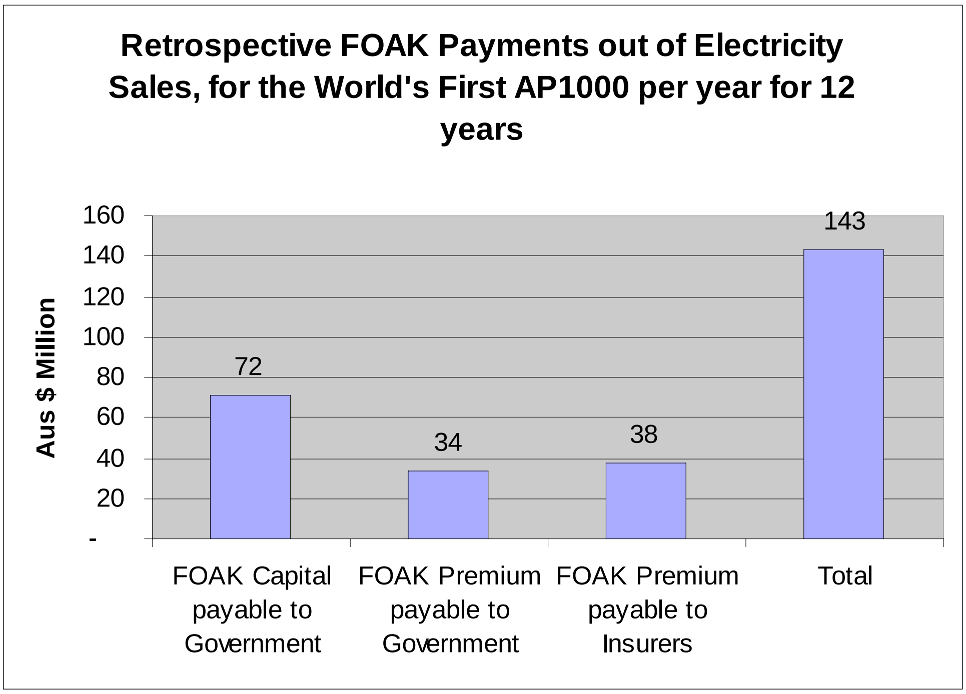


Figure 26: AP1000 Reactor number 1: Retrospective FOAK Payments out of Electricity Sales, per Reactor per year for 12 years.: Loan Capital and FOAK Insurance Premium to Government; FOAK Insurance Premium to Insurers.



- **EPC, including Licensing and obtaining Consents**: The Risk that the Government Safety Regulator will delay licensing the Plant or refuse Consents and require costly design-changes is a FOAK cost and will be covered by an insured FOAK grant and/or loan. This is part of the Risk that the Vendor will not be able to deliver the Plant to the time-and-cost that he guaranteed. A "Fixed Price EPC" Contract is assumed for this stage. The Risk Takers are the Government, commercial insurers, the Vendor and the lenders. Figure 24 shows Insurers' first estimates of the probability that the FOAK costs for five AP1000's will exceed expectation by various amounts. There is a 22% probability that the FOAK will be one and a half times the amount that we have estimated from the learning curve of Figure 20. There is a 7% chance that it will be twice that amount. The total Risk (sum of probability times consequences) is Aus $ 113m. Insurers would be prepared to cover 20% of this Risk providing that the Vendor or Construction Consortium took 20%. This would leave 60% of the Aus $ 113m, which we recommend Government to take. The Owner would repay this as a retrospective premium of Aus $1.13m per reactor per year of electricity generation, Figure 25. The Electricity Distributors will suffer as a result of the delay in delivery of the plant since it is designed to deliver electricity at a low price- lower than that of many of the existing. Power stations: if it is delayed 12 months then the distributors will have to pay say an average of 5% more for their electricity, reducing their profits when they sell it on. If they pass 2% of this 5% to their customers then they will suffer a reduction in revenue of Aus $ 14m. It is estimated that there is a one in ten chance of this, giving a Risk of Aus $ 1.4m to the distributors. The fuel suppliers will also suffer: if start-up is delayed for say 12 months then their contract may mean that they will receive no payment for fuel for that period of 12 months since none will be burned-up in the reactor. They will pay interest charges of say 10% on fuel worth Aus \$ 47m with a probability of 1/10. That is a financial risk of . Aus \$ 0.47m. The owner will have lost say 12 months' output, worth Aus \$ 470m, on which he would have made a profit of, say, 15%, with a probability of 10%. This is a risk of 0.1*0.15* Aus \$ 470m = Aus \$ 7m. In what follows, we calculate the main risks and apportion fractions of these figures to the other Risk-Takers in the same proportion as for the Licensing, Consents and EPC Risks dealt with in this section.

- **Accidents**: The Risk that ***Man-made*** perils such as the following will occur, with the stated results: this risk is partly covered by Government (which typically shoulders all Third Party Liability above Aus \$ 330 million) and partly by commercial insurers. The insurers bear a risk (integral of frequency times consequences) of order AUS \$ 2.36m/reactor.year. The Government share amounts to Aus \$ 11.8m/reactor.year. The same sharing of this Risk will occur to the new nuclear power stations.
    - *Events, incidents and accidents,*
    - *Aircraft-crash,*
    - *Machinery-breakdown*
    - *etc.*

  will occur and will consequently
    - *damage the operating plant,*
    - *harm third parties and*
    - *interrupt the generation and sale of electricity;*
- **Force Majeure**: Also the Risk that Natural perils, such as storms, fire, flooding and earthquakes will damage the plant, harm third parties and interrupt generation; this is partly covered by Government (which shoulders all Third Party Liability above Aus \$ 330m) and partly be commercial insurers. The same sharing of this Risk will occur to the new nuclear power stations.
- **Terrorism**: The broad Risk of terrorist activity; this, my analysis for the UK and the Canadian Governments indicates is of the order of the Risk of man-made nuclear accidents. It is partly covered by Governments (which is why they contracted me to determine its magnitude) and partly by commercial insurers. The Australian Government should be advised to take a share of this risk for an Australian nuclear power station.
- **New Government Policy**: Premature permanent shutdown and decommissioning because of new Government policy; we shall have to ask Government to take most of this risk. In Sweden, Germany and Belgium, Government policy requires the premature shutdown of the nuclear power stations and so the same thing could happen late in the life of an Australian nuclear power station. We should have to ask Government to indemnify this risk. We estimate the probability as 10^{-2} and the loss is equal to the cost of replacing the power station at half its life, say Aus \$ 2.36bn. The Risk is then Aus \$ 470 m per reactor year.
- **More stringent Government Safety Regulator requirements**. These may well require the owner to make improvements and he may have to shut the reactor down for a time to do this. The Government Safety Regulators overseas have never, however, closed down nuclear stations permanently because of revisions to their perception of the Risk that they present and are less likely to do so in future so the probability of this is 10^{-5}/year. The probability that the Government Safety Regulator would have requirements that would necessitate closing a station for a year is greater: perhaps 10^{-3}/year with a loss of

generation worth Aus $ 470 m. The Risk (frequency times consequences) is therefore Aus $470,000/reactor.year.

- **Public Opinion**: Permanent shutdown following another “Chernobyl” overseas; This did not happen following Chernobyl, just as it had not happened following TMI, Mihama or Tokai Mura (three big accidents at nuclear installations). It is therefore unlikely to happen in future. We assess the probability at 10^{-4} per year or 50 * 10^{-4} for a reactor lifetime. The nuclear power station would have to be replaced by another, costing say Aus $ 2.35bn and so the annual risk is 10^{-4} * Aus $ 2.35bn = £235,000/reactor.year.
- **Class Fault**: Shutdown due to discovery by the Vendor of a “Class Fault” in all plants of this design, a fault that it would not be economic to remedy. This has never occurred in 10,000 reactor.years of commercial nuclear power station operation. It is less likely in future than in the past because of improvements to nuclear technology. We assess the risk as 10^{-4} per reactor.year, giving a financial risk of Aus $ 235,000/reactor.year.
- **Market Regulation**: Risk of changes in market trading arrangements: Political/Regulatory Risk: It is not possible for the Owner to take this risk on board and so we should have to persuade Government to take it. We estimate that it amounts to a Risk of 10^{-3} or Aus $ 2.3m/reactor.year.
- **Economics**: A brief analysis has been made of the Risk that competing Generation Companies will temporarily price the plant out of the market. The total Risk is Aus $ 3.3m/year to be born by the Owner and Aus $ 2.3m/reactor.year by Government. The elements of this Risk are:
    - *Falls in the capital cost of new gas-fired generating plant; We estimate that the risk that, as a result, electricity from gas will cost 20% less than nuclear for up to five years is* 10^{-2} *leading to a Risk of 10% of say Aus $ 2.3bn ** 10^{-2} *= Aus $ 2.3m/reactor.year*
    - *Temporary falls in the prices of other fuels, We estimate that the risk that electricity from gas will cost 20% less than nuclear for up to a year is* 10^{-2} *leading to a Risk of 20% of say Aus $ 4.72m ** 10^{-2} *= Aus $ 943,000/reactor.year.*
    - *Increased subsidies to renewable sources of electricity: these are possible, and Government will have to be asked to take this Risk off the shoulders of the Owner of the new nuclear power station(s). We estimate this Risk at Aus $ 2.35m/reactor.year*
    - *A temporary, order-of-magnitude rise in the price of uranium: this has occurred historically and uranium prices have doubled in the last 12 months. We estimate that it has a probability of* 10^{-2} *and if it occurred it would not reduce the competitiveness of nuclear electricity. No loss of revenue from the new nuclear station would result.*
- **Decommissioning**: The Risk that the financial provision that would have to be made and agreed with Government for decommissioning and waste management will be found inadequate so that Government requires an increase that eats into profits, making the Company less able to manage other risks: a 10^{-2}/reactor.year chance of having to provide another 5% of the revenue stream for half the life of the reactor, to pay for decommissioning. This equals, per reactor.year, 0.05*Aus $ 470m*10^{-2} = Aus $ 235,000/reactor.year, with the Owner.
- **Defaul**t: The Risk of default by any of the Risk-takers: 10^{-3} to 10^{-4} per year of the Project, subject to the provision, by Government and possibly by

Commercial Insurers of “Insured FOAK Finance” as described in this Contract Report. The residual risk is estimated at 10^{-4}/year.

Figure 27 brings together the above estimates of financial risks. Approximately half of these risks are borne by Government. If the Government was not prepared to take this proportion of the financial risks then it is judged that the Market would not be prepared to finance the construction of a new nuclear power station in Australia. Of the remaining half of the risk, about 6% is taken by each of the owner, shareholders and banks. Insurers take about 18%. The Electricity Distributors and the Fuel Suppliers share the balance. Figure 28 shows the magnitudes of the individual Risks.

Figure 27: Financial Risks taken by the Parties, for an Australian Nuclear Power Station.

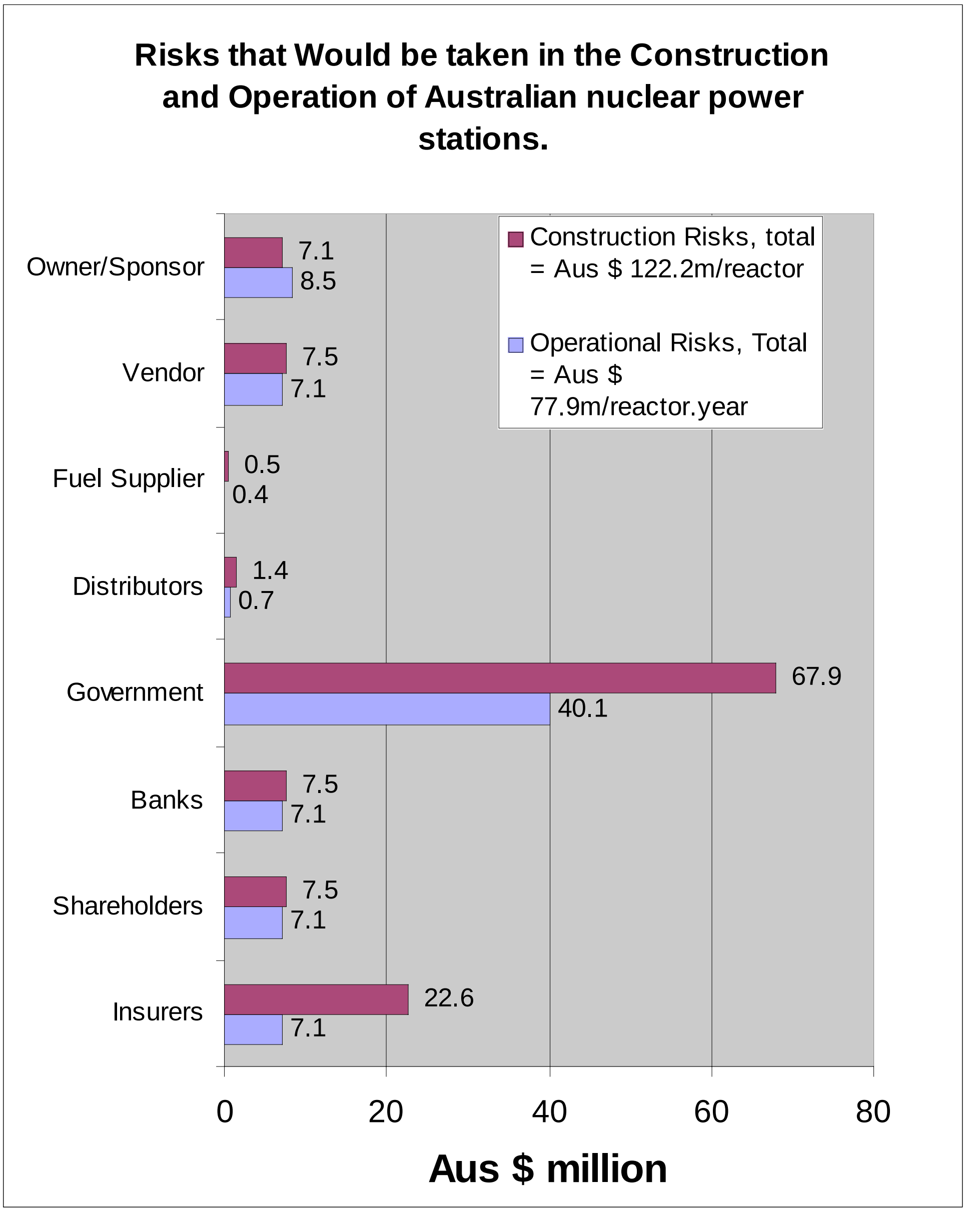
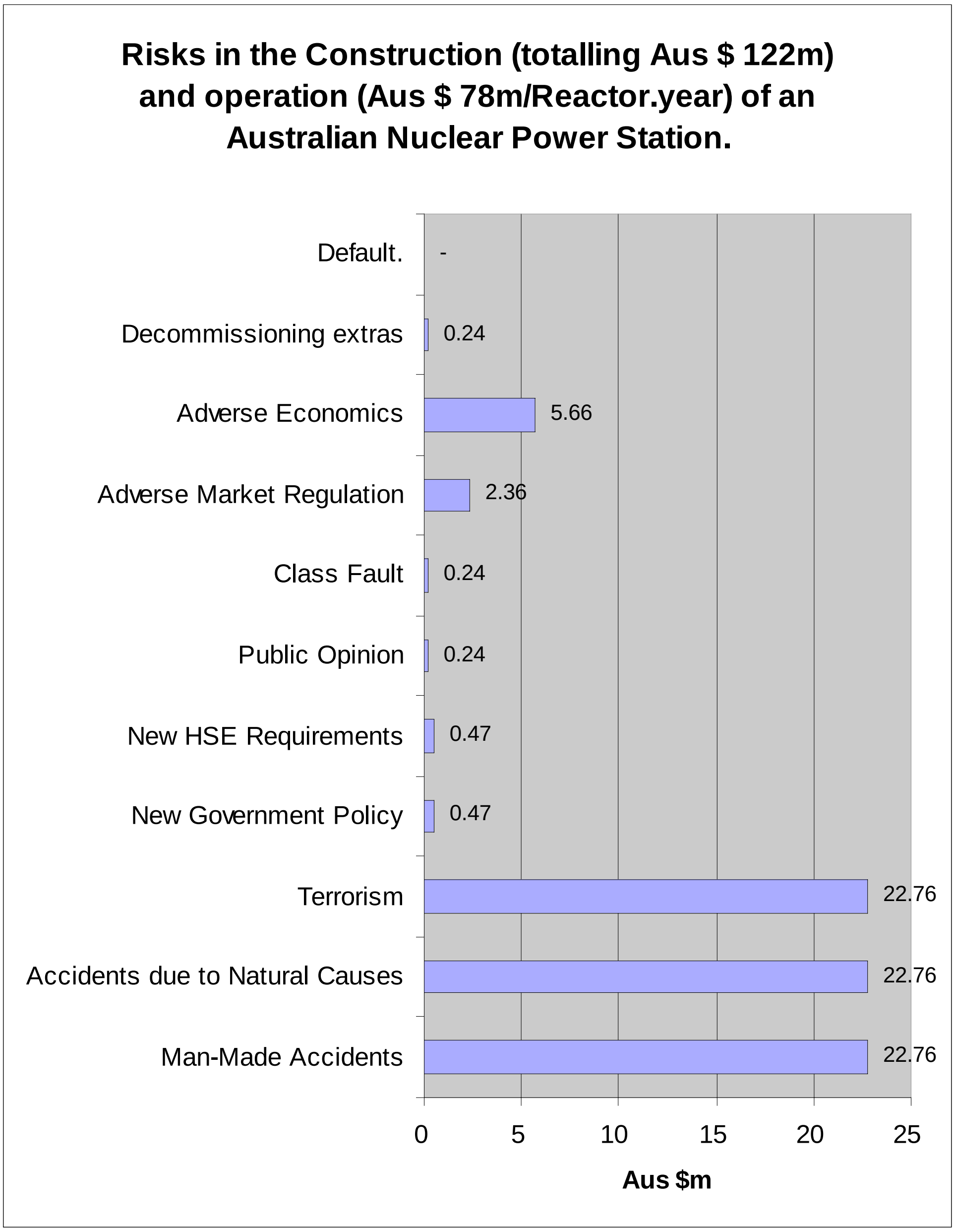


Figure 28: Risks, Aus $ m, for an Australian Nuclear Power Station.



Comparative Costs of Electricity from Australian Nuclear Power Station.

For the Case where the Financial Risks are Shared by the Stakeholders.

We are now in a position to make a comparison between our Reference cost of electricity, from an Australian nuclear power station and the cost that includes allowance for the risks of building and operating it.

Figure 29: Cost of Electricity from Australian nuclear power station showing the advantages of the Financial Plan presented in this Report.

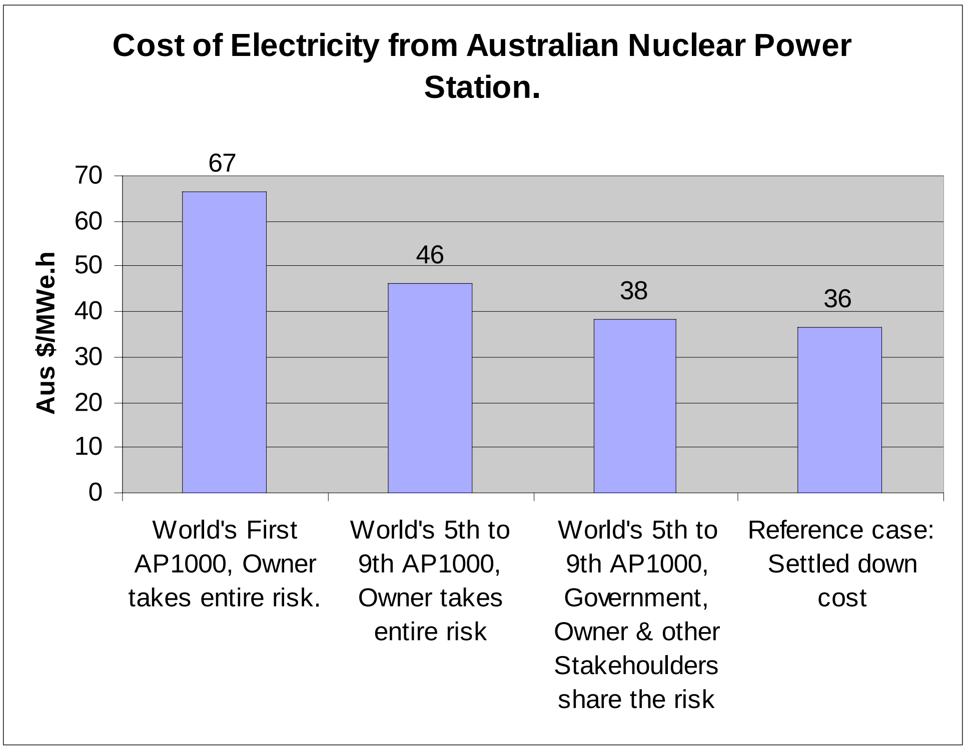


Figure 29 shows this comparison for the financial model that we have developed in this section of this Report and from it the following conclusions may be drawn:

6. The settled-down cost of electricity, which we calculated using the Financial Model developed earlier in this Report, is shown: it is 36 Aus $/MWe.h.
7. If Australia builds the world’s first AP1000 (just as Finland is currently building the world’s first EPR) then the cost of electricity that we forecast is virtually double the reference case: 67 Aus $/MWe.h. This is due to the FOAK costs forecast by Westinghouse and shown in Figure 19. To these costs we have added the financial values of the two risks, which are:
    a. The Construction Risk which is the risk that the FOAK costs will be higher than Westinghouse has forecast, Figure 24; and

    b. The Operating Risk that we calculated above.

8. We have assumed that the owner shoulders the financial value of these two risks, a and b. He would clearly go into liquidation in this case since, in the Australian Energy Marketplace, no one would pay 67 Aus $/MWe.h for electricity when he can buy it for half that price from established coal-fired power stations. This problem has caused the US Government to offer to pay half the capital cost of the first 6 new nuclear power stations to be built in that country and to subsidize the electricity that they produce.
9. If Australia builds either the 5th, 6th, 7th, 8th or 9th AP1000 then if the owner takes all of the financial risks the cost of the electricity will be 46 Aus $/MWe.h. This is not a competitive cost, either. It is nearly a third higher than our Reference Cost.
10. Finally, if our Financial Plan is implemented and the risk of the 5th-9th AP 1000 is shared between the Owner, Government and the other Stakeholders, the cost of electricity from Australia's nuclear power station is 38 Aus $/MWe.h, as compared with 36 Aus $/MWe.h for our reference case which is for the nth copy of the reactor. This is an economic cost. The electricity will be competitively priced and saleable in Australia. Unlike the American scheme, ours does not involve a Government subsidy: the Government is asked to be a source of debt and to act as the reinsurer of the FOAK costs. The loan is repaid with commercial interest rates and in addition the Government receives commercial insurance premiums for doing this.

The Government Subsidy that would be needed if our Risk-Sharing Finance Plan is not Adopted.

In Figure 29 we showed the costs of electricity from an Australian nuclear power station in which all of the financial risks are shared between the stakeholders. That is the scheme that we have developed above. The Government takes most of the financial risk but it is paid an insurance premium for doing so out of the revenue received from the sale of electricity when once the plant is operating. The Government also loans the FOAK costs, but again this loan is repaid, plus interest, out of the revenue produced by the station. So there is no Government subsidy, although the Government, like the other stakeholders, does take the risk that more capital will be needed: it is for being ready to supply its share of that extra capital that the Government is paid an insurance premium.

An alternative scheme is one in which Government ***subsidizes*** the nuclear power plant. This is what the US Government has undertaken to do, for the first 6 new nuclear stations built in the USA[28]. Figure 30 shows such a scheme, derived from the finance model of the present Report, applied either to the World's first AP1000 or the World's fifth to ninth AP1000. In the latter case, the Australian Government would give a Grant of 14.31% of the "NOAK" capital cost. For example if this is the

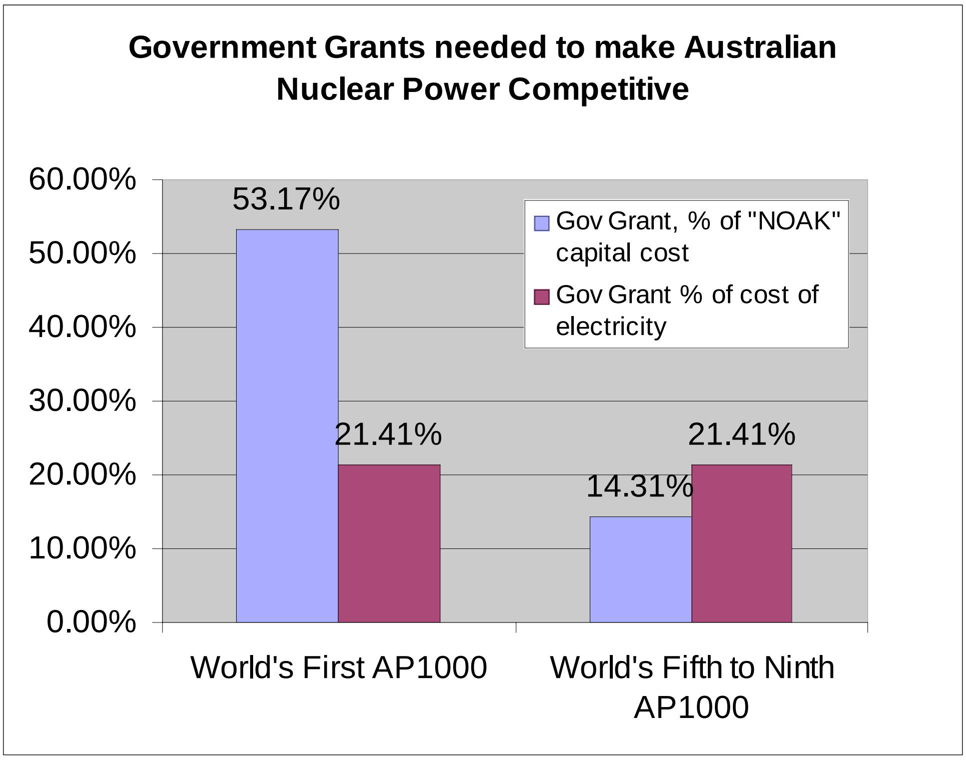
[28] The 2005 USA energy bill offers new plant investment protection in the form of "standby support" to offset the financial impact of delays beyond industry's control that may occur during construction and during the initial phases of plant startup for the first six new reactors. The bill provides for 100 percent coverage of the cost of delays for the first two new plants, up to $500 million each, and 50 percent of the cost of delays, up to $250 million each, for plants three through six.

World's fifth AP1000 then our best estimate would be that it would have the "5th of a Kind" capital cost, which can be extrapolated from Figure 19. However the values given in Figure 19 are the ***best estimates*** of the NOAK costs and Figure 24 shows the probabilities that the actual NOAK cost will exceed the best estimate by the stated percentage. Clearly if Government is to subsidize the station then it will have to give a sum that has a good chance of being adequate: how much should that be? An answer is suggested by the requirements of the Government bodies that regulate the world's finance markets. In the UK the Financial Services Authority, FSA, requires insurers to have enough capital to suffice for needs that arise at the 0.5% level of probability. This then is the level that we take here: the Australian Government should give a subsidy such that there is only a 0.5% chance that it will prove inadequate. Of course if less is needed then less must be given and financial management tools will have to be put in place to avoid, to the extent possible, intentional overspends.

So a Government grant of 14.31% of the "NOAK" cost of the fifth to ninth AP1000 would have a 0.5% chance of being inadequate. The risk of excessive operating costs would also be taken off the books of the Utility by Government, which would pay a subsidy of 21.41% of the cost of the electricity produced by the station, for the first 12 years of its operation. Such a subsidy is to be paid by the US Government for the first 6 new nuclear reactors built in the USA. The USA legislation provides a production tax credit of 1.8 cents per kilowatt-hour for 6,000 megawatts (MW) of capacity from new nuclear power plants for the first eight years of operation.

This forecast of the need for a subsidy of "only" 14.31% on the capital cost of the station seems at first sight to be much smaller than the 50% subsidy offered by the US Government. However the latter is for the first six copies of a new nuclear reactor and in fact the estimate arrived at from the present financial model for the World's first AP1000 is virtually identical: it is 53.17% for the World's first AP1000, Figure 30. There is also the 21.41% Government subsidy on the cost of electricity produced when the power station is in operation.

Figure 30: Government Grants needed to make Australian Nuclear Power competitive.


Government Grants needed to make Australian Nuclear Power Competitive
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
53.17%
21.41%
14.31%
21.41%
Gov Grant, % of "NOAK" capital cost
Gov Grant % of cost of electricity
World's First AP1000
World's Fifth to Ninth AP1000

HOW DO YOU ACCOUNT FOR THE WHOLE FUEL CYCLE COST?

The costs of the whole fuel cycle for nuclear electricity comprise the following components:

6. ➢ capital
7. ➢ operation and maintenance
8. ➢ fuel
9. ➢ spent fuel and waste management
10. ➢ decommissioning

Of these five items, all except numbers 4 and 5 are costed into our reference cost of electricity generated from an Australian nuclear power station. Dealing with each of these items in turn:

Capital cost

The capital cost comprises all construction costs, related manpower and materials together with the cost of financing the capital. It also includes the costs of obtaining regulatory approvals, which are in part insurable if it had been impossible to foresee them and of site-specific engineering work. This cost element reduces in line with the number of reactors in the programme series.

Operation and Maintenance

Operation and Maintenance includes all the costs associated with routine operations (including staff costs, materials, and services) along with the labour costs of refueling, maintenance outages, and the management and ultimate disposal of intermediate and low level wastes. Miscellaneous costs such as grid connection charges are also covered here.

Fuel.

Fuel covers procurement of uranium and components, together with the costs of uranium and fuel services (conversion, enrichment, fuel fabrication).

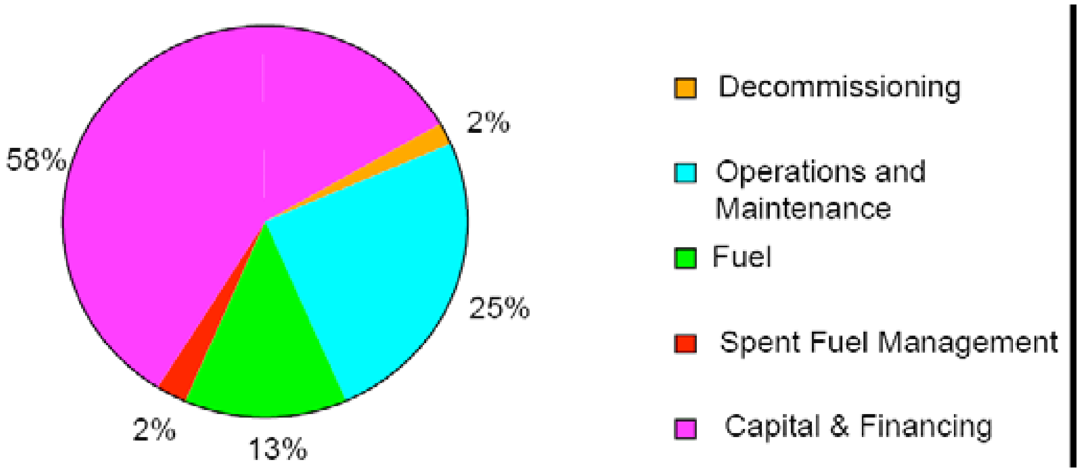
Spent fuel management.

Spent Fuel Management relates to storage at the reactor site, transport to interim storage, costs of interim storage, conditioning of the fuel for disposal, plus disposal of the associated high level waste and any other linked waste arisings. The back-end of the fuel cycle, including spent fuel storage or disposal in a waste repository, contributes up to 10% to the overall costs per kWh, - less if there is direct disposal of spent fuel rather than reprocessing, the situation that we expect to exist in Australia. The $18 billion US spent fuel program is funded by a 0.1 cent/kWh levy which is 4% of our Reference Cost of electricity from an Australian nuclear power station. We take a figure of 2% of the Reference Cost as the provision for spent fuel management for the AP1000 in this Report, Figure 31.

Decommissioning

Decommissioning is also provided for, to cover eventual decommissioning of the reactor, including care and maintenance prior to that final stage, the direct civil engineering costs and ultimate disposal of wastes arising from decommissioning. Decommissioning costs, when they become payable, are estimated at 9-15% of the initial capital cost of a nuclear power plant. When discounted, they contribute only a few percent to the investment cost and even less to the generation cost. In calculations made by British Energy, the decommissioning cost is Aus $ 1.414/MWh which is 3.89% of our Reference Cost of electricity from an Australian nuclear power station. In the USA they account for 0.1-0.2 cent/kWh, which is between 4% and 8% of our Reference Cost of electricity from an Australian nuclear power plant. We take a figure of 2% of the Reference Cost as the provision for decommissioning the AP 1000 in this Report, Figure 31.

Figure 31: Proportion of Cost of Electricity from AP1000 due to Fuel Cycle and other Elements.[29]



[29] Westinghouse data provided by Dr Richard Mayson, Technical Director for Reactor Systems, BNFL, 2006.

WASTE.

In this Report we assume that the provisions that Australia would make for management of the radioactive waste from its nuclear power station would be the same as in most parts of the world currently. That is to say:

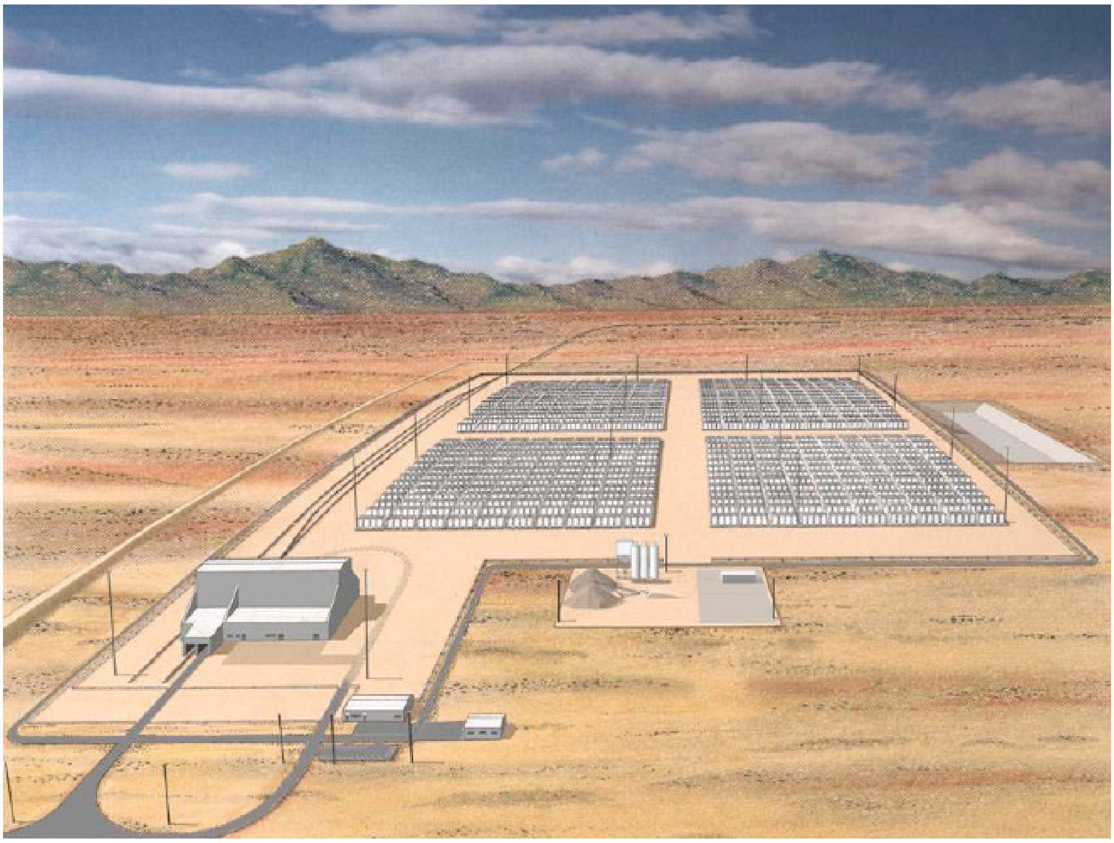
Spent Fuel.

It is assumed that the spent fuel would remain in the reactor pond for 20 years so that the level of radioactivity could decay substantially. This occurs with all LWR nuclear power stations. Then the fuel will, it is assumed, be placed in dry casks and stored for up to a century in a building on the surface awaiting the construction of an ultimate repository. Storage of spent fuel in dry casks has become the norm in Europe and the USA.

- Dry cask storage is environmentally benign.
- Thick shielding makes radioactivity harmless to human health during accidents and natural disasters.
- Extremely heavy cask construction makes release of radioactive material extremely unlikely.
- Casks can safely withstand earthquakes, tornados, floods, fires, and lightning.
- The US NRC has stated that dry cask storage remains safe for at least one hundred years.

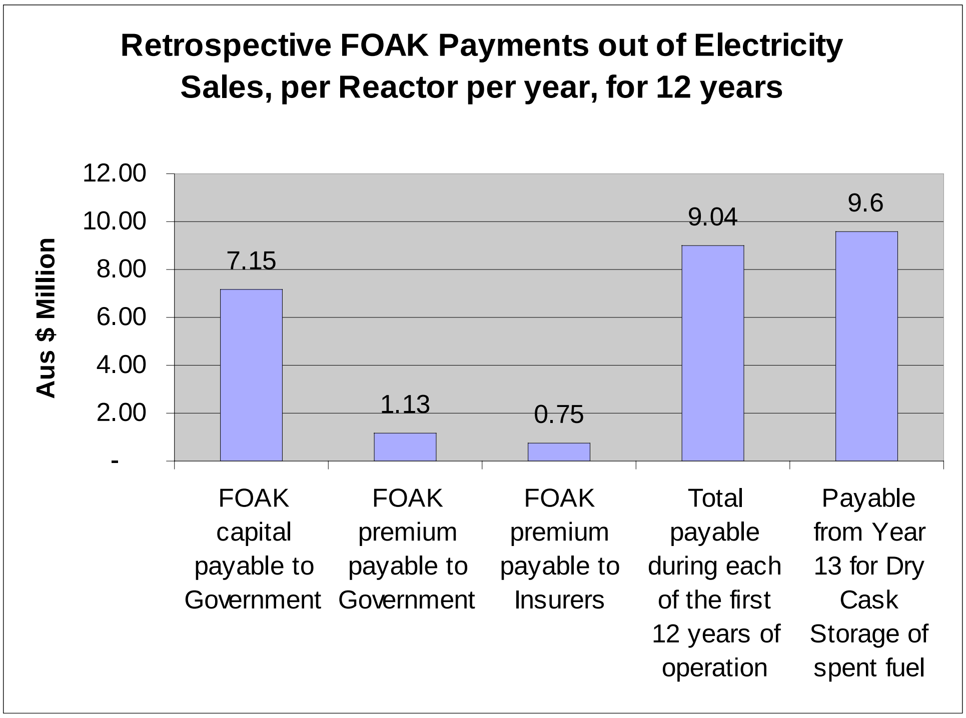
The spent fuel will finally be placed in this repository, which may be underground. It is believed that the spent fuel will not be reprocessed since this is amore expensive option.

Figure 32: Artist's Impression of a Dry Cask Store for Spent Nuclear Fuel.



Building dry storage at a plant site requires an initial investment of Aus $13.6 million to Aus $27 million. Once operational, it costs about Aus $6.8 million to Aus $9.6 million a year to maintain the facility and add containers as storage needs grow. These costs will arise after the period of 12 years during which, in our Financial Plan, retrospective repayment of the FOAK loan and associated insurance premiums takes place. These payments total Aus $ 9.04m/year and when they cease we shall have to pay almost the same sum—Aus $ 9.6m, to manage the storage of spent fuel in dry casks in the dry cask store, Figure 33.

Figure 33: Annual Cost of Aus $ 9.6m/year for spent fuel storage takes over from Aus $ 9.04m/year that was paid for FOAK Capital and Insurance.



As for the capital cost of the Dry Store: this comprises an addition, that we have already made, of Aus $ 5m to the Capital Cost of the Nuclear Power Station. This provides the sum of Aus $ 27m needed 20 years after the reactor starts-up, to pay the capital cost of the Dry Cask store.

Intermediate Level Waste, ILW.

It is assumed that the Intermediate Level Waste from the Australian Nuclear Power Station will be consolidated into concrete blocks, which will be kept in a shielded store on the surface until an ultimate repository is constructed. This is what is done with ILW in the UK.

Low Level Waste, LLW.

It is assumed that Low Level Waste will be permanently disposed to a surface repository similar to Drigg in the UK and Barnwell in the USA.

Figure 34: Relative cost, in five countries, of disposing of LLW

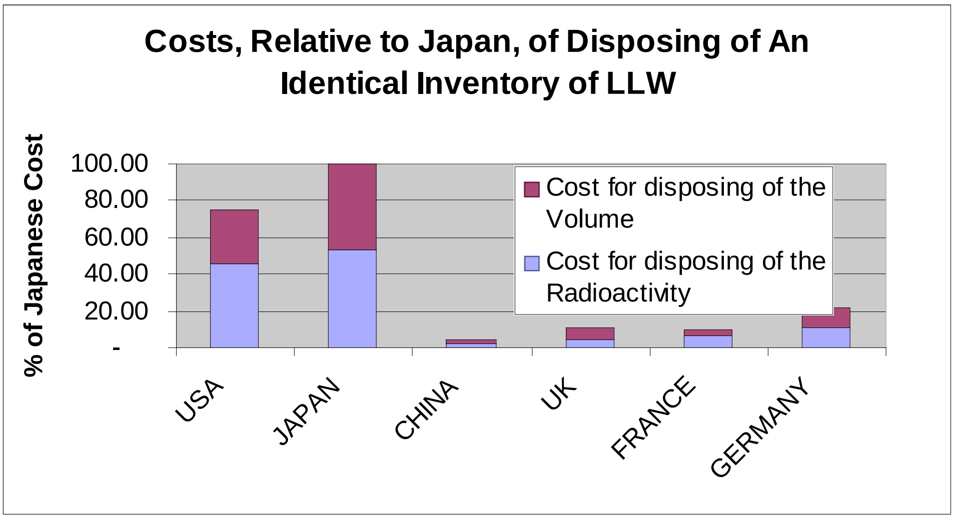


Figure 34 shows that the cost of disposing of LLW varies by a factor of more than ten between five countries, including the UK and the USA.

Figure 35: The Drigg LLW Disposal Site, UK.

In recent years all suitable LLW has been supercompacted before disposal to Drigg, Figure 35. In this process drums or boxes of waste are compacted under high pressure of up to 2,000 tonnes per square metre. Waste is placed in large metal containers, which are then filled with cement. These containers are then placed in concrete lined vaults.

We assume that storage of the ILW and LLW from the Australian nuclear power station will cost the same annual sum, Aus $ 9.6m/year (which is Aus $ 0.96/MWe.h or 3% of the cost of generation), as will the management and storage in a Dry cask store, of the spent fuel. We have included in the capital cost of the power station the sum of Aus $ 20 m as a contribution towards the capital cost of these stores, which will, like the Dry Cask Store, be needed some years after the construction and initial operation of the power station.

FUEL SUPPLIES.

The following Table shows the amount of natural uranium required by each country in 2006.

Table 14:Natural Uranium that will be required for the World's Nuclear Power stations in 2006.[30]

	NUCLEAR ELECTRICITY[31] 2006		REACTORS OPERABLE Mar-06		REACTORS under CONSTRUCTION Mar 2006		REACTORS PLANNED Mar-06		REACTORS PROPOSED Mar-06		URANIUM REQUIRED 2006
	billion kWh	% e	No.	MWe	No.	MWe	No.	MWe	No.	MWe	tonnes U
Argentina	5.4	7.2	2	935	0	0	1	692			140
Armenia	2.1	41	1	376	0	0	0	0			54
Belgium	44.7	57	7	5728	0	0	0	0			1163
Brazil	13.8	4	2	1901	0	0	1	1245			303
Bulgaria	20.2	47	4	2722	0	0	0	0	1	1000	340
Canada*	71	12	17	12054	1	515	2	1030			1692
China**	57.4	**	15	11471	4	4500	4	3800	22	18000	2127
Czech Republic	18.7	25	6	3472	0	0	0	0			474
Egypt									1	600	
Finland	21.4	30	4	2656	0	0	1	1600			542
France	415.5	78	59	63473	0	0	0	0			10181
Germany	162.3	30	18	20643	0	0	0	0			3704
Hungary	12.8	36	4	1755	0	0	0	0			271
India	17.8	3.7	14	2493	9	4128	0	0	24	13160	299
Indonesia									2	2000	
Iran	0	0	0	0	1	950	1	950	3	2850	125
Japan	313.8	39	53	44141	3	3707	13	16810			7661
Korea DPR (North)	0	0	0	0	1	950	1	950			0
Korea RO (South)	113.1	39	19	15880	1	960	8	9200			2819
Lithuania	12.9	80	2	2370	0	0	0	0			290
Mexico	9.4	4.1	2	1310	0	0	0	0			233

30

Sources:

Reactor data: WNA to 25/3/04 (revised & checked then).

IAEA- for nuclear electricity production & percentage of elelctrcity (% e).

WNA: Global Nuclear Fuel Market (reference scenario) - for U. Operating = Connected to the grid

Building/Construction = first concrete for reactor poured, or major refurbishment under way

Planned = Approvals and funding in place, Proposed = still without funding and/or approvals.

TWh = Terawatt-hours (billion kilowatt-hours), MWe = Megawatt net (electrical as distinct from thermal), kWh = kilowatt-hour

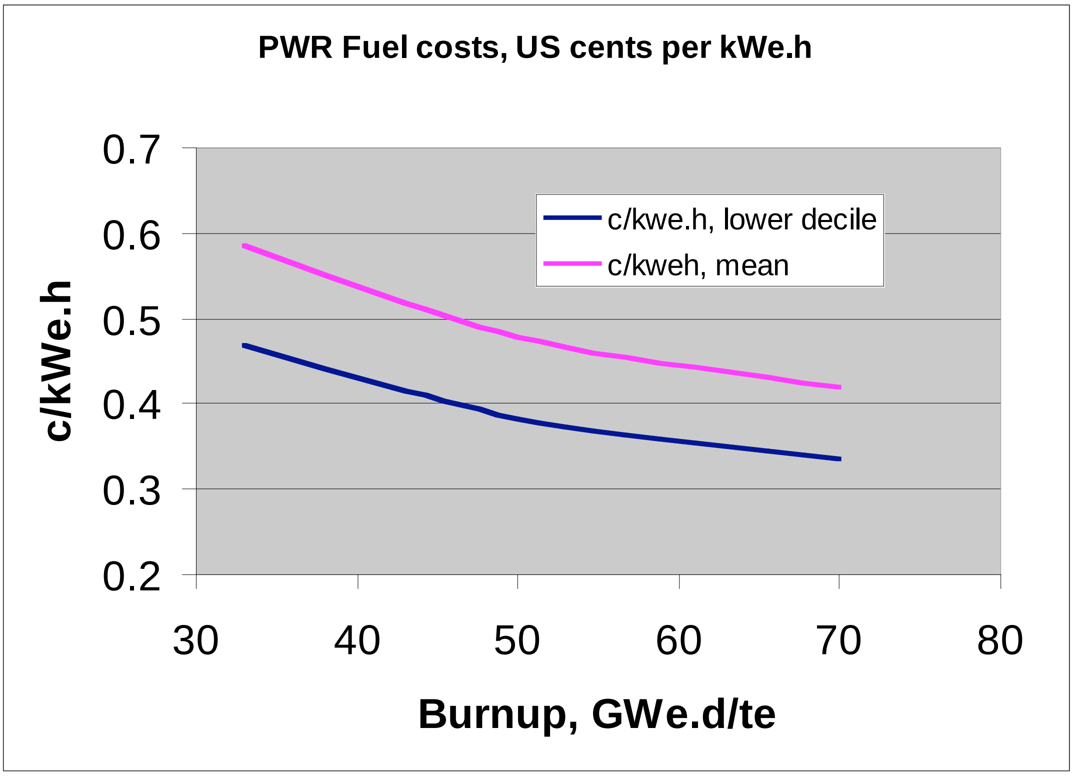
31 Estimate

Netherlands	3.7	4	1	452	0	0	0	0			112
Pakistan	1.8	2.5	2	425	0	0	1	300			57
Romania	5.1	10	1	655	1	655	0	0	3	1995	90
Russia	130	16	30	20793	6	5475	0	0	8	9375	3013
Slovakia	18	65	6	2472	0	0	0	0	2	840	370
Slovenia	5.3	41	1	676	0	0	0	0			128
South Africa	12	5.9	2	1842	0	0	0	0	1	125	356
Spain	60.3	26	9	7584	0	0	0	0			1629
Sweden	65.6	46	11	9429	0	0	0	0			1536
Switzerland	25.7	40	5	3220	0	0	0	0			596
Ukraine	73.4	46	13	11268	2	1900	0	0			1512
United Kingdom	81.1	22	27	12048	0	0	0	0			2488
USA	780.1	20	103	97452	1	1065	0	0			22353
Vietnam									2	2000	
WORLD	**2574**	**16**	**440**	**361,696**	**30**	**24,805**	**33**	**36,577**	**69**	**52,000**	**66,658**
	billion kWh	% e	No.	MWe	No.	MWe	No.	MWe	No.	MWe	tonnes U
	NUCLEAR ELECTRICITY GENERATION 2006		**REACTORS OPERATING**		**REACTORS BUILDING**		**ON ORDER or PLANNED**		**PROPOSED**		**URANIUM REQUIRED**

Late in the 1990s, there was a large scale merging in the nuclear fuel manufacturing industry. BNFL purchased the nuclear businesses of Westinghouse and ABB_CE. Toshiba has since purchased them. Merging the nuclear activities of Framatome and Siemens-KWU formed Framatome ANP Company. Westinghouse and Framatome ANP are producing and supplying BWR and PWR fuels. Annual production capacity of the two companies is over 3,000 MTU. Both are experiencing keen competition. Westinghouse is focusing its activities on opening up the Western and Eastern Europe market while maintaining its dominant position in the USA market. Framatome ANP is concentrating its efforts on finding a USA market while protecting its European market.

The market prices for fuel fabrication vary over a wide range, by a factor of about three. The extremes of this range occur in the USA and Japan. This explains the present tendency of falling prices in Japan and to some extent in Europe. However, recent low price levels in the USA, due to fierce competition, cannot be equalled by Framatome ANP without abandoning much of the R&D that underpins innovations such as the drive to higher burnups, Figure 36. This will drive fuel manufacturers to combine, as a way of reducing the R&D overhead.

Figure 36: Forecasts, for 2005 to 2010, of the cost of PWR fuel per kWe.h generated. The lower decile represents the lowest values for the US market.



Fuel fabrication for the bulk of installed LWR nuclear capacity is now open to full competition. This includes

- Westinghouse, Framatome, and Mitsubishi Heavy Industries (MHI) reactor types (comprising 57% of all LWR capacity),
- General Electric (GE) types (including Hitachi and Toshiba) (23%), and Siemens reactors (9%).

For BWR fuel, competition is among
GE, Siemens and Westinghouse/ABB,

and for PWR fuel type among
Framatome/Siemens,
BNFL/ABB/Westinghouse and its licensees.

The market share of Western LWR fuel fabricators is:

Fragema/Framatome Cogema Fuels: 26%,
General Electric/JNF: 21%,
Westinghouse/MHI: 21%,
ABB/Combustion Engineering: 11%,
Siemens: 19%,
Others: 2%.

The maximum turnover of the nuclear fuel business of Westinghouse/ABB is $1bn and the R&D effort is of the order of 17% of turnover, which is quite a high figure and requires very high margins.

Table 15:: Light Water Reactor Fuel Fabrication Competitors.

Country	Owner/Controller	Plant Name/Location	Capacity [MTU/year]
Belgium	FBFC (49% COGEMA 51% Framatome	Dessel	750
Brazil	FEC (INB	Resende	100
China	CNNC	Yibin	100
France	FBFC (49% COGEMA 51% Framatome	Romans-sur-Isère [ISSUES]	820
	SICN (100% COGEMA	Veurey-Voroise [ISSUES]	150
Germany	Advanced Nuclear Fuels (66% Areva 34% Siemens	Lingen	650
India	Nuclear Fuel Complex	Hyderabad [ISSUES]	25
Japan	Japan Nuclear Fuel Co., Ltd.	Yokosuka City	750
	Mitsubishi Nuclear Fuel	Tokai-Mura	440
	Nuclear Fuels Industries	Kumatori	284
		Tokai-Mura	200
Kazakhstan	Ulba Metallurgical Co	Kamenogorsk [ISSUES]	2,000
South Korea	KEPCO Nuclear Fuel Co., Ltd. (KNFC)	Taejon	400
Pakistan	Pakistan Atomic Energy Commission (PAEC)	Kundian	?
Russia	JSC TVEL	Elektrostal [ISSUES]	1,020
		Novosibirsk	1,000
Spain	ENUSA	Juzbado	300

Sweden	ToshibaWestinghouse	Västerås	600
United Kingdom	British Nuclear Group Ltd.	Springfields, Lancashire [ISSUES]	330
	Framatome ANP, Inc.	Lynchburg, Virginia [ISSUES]	400
	Toshiba (Westinghouse)	Hematite, Missouri (closed) [ISSUES, OLD ISSUES]	450
		Columbia, S. Carolina	1,150
	Framatome ANP (66% Areva 34% Siemens	Richland, Washington [ISSUES]	700
United States	Global Nuclear Fuel - Americas, L.L.C.	Wilmington, N. Carolina	1,200
Total			*13,819*

Table 16: Manufacturers of MOX

Country	**Owner/Controller**	**Plant Name/Location**	**Capacity [a)] [MTIHM/year]**
Belgium	Belgonucléaire SA	Dessel	37
	COGEMA	Cadarache	40
France	MELOX (50% COGEMA , 50% Framatome)	Marcoule	195
India	DAE	Tarapur	50
Japan	JNC	Tokai-Mura	10
United Kingdom	British Nuclear Group, Ltd.	Sellafield, Plant not yet	128

		commissioned.	
Total			*460*

[a] Nominal capacity, MTU = metric tonnes of uranium. MTIHM = metric tonnes of initial heavy metal.

Table 17: Details of the main manufacturers of nuclear fuel.

Country
Company/Description

Brazil

Indústrias Nucleares do Brasil S.A. (INB) - INB is the company in charge of promoting in Brazil uranium exploitation, from mining and primary processing up to its placement in the fuel elements which activate nuclear power reactors in the plants.

France

AREVA [English] - The AREVA group makes its début as a world class leader in each of its business areas through the merger of all CEA-Industrie, COGEMA, FRAMATOME ANP and FCI operations. In the nuclear sector, AREVA provides services for every aspect of power generation. From uranium mining through site clean-up and decommissioning, for power plant construction or fuel fabrication, our experience is backed by unequaled expertise.

Framatome ANP - Framatome ANP (Advanced Nuclear Power) merges the complementary strengths of two global nuclear industry leaders - Framatome and Siemens - offering clients the best technological solutions for safe, reliable and economical plant performance. Framatome ANP Nuclear Fuel designs for both PWR and BWR plants provide innovative features and world-leading performance. Close association with Cogema further enhances our support for the entire fuel cycle. An AREVA and Siemens company.

MOX Fuel - This web site is dedicated to the industry education for the use of MOX fuel. It is sponsored by BNFL, COGEMA and ORC.

Germany

Advanced Nuclear Fuels, GmbH (ANF) Site in German only. - ANF is a subsidary of Siemens Nuclear Power GmbH (SNP). ANF manufactures fuel elements on behalf of SNP for the German and Western European market.

Framatome ANP GmbH [English] - Framatome ANP GmbH, based in Germany, has manufactured both PWR and BWR NSSSs since the 1950s. As a major nuclear plant vendor, Framatome ANP GmbH has also developed and maintains a full range of services, fuel, design engineering, and decontamination capabilities. An AREVA and Siemens company.

India

Nuclear Fuel Complex, Hyderabad - Nuclear Fuel Complex, Hyderabad produces fuel bundles for both BWR and PHWR type reactors. The plant has facilities to manufacture coolant and calandria tubes for nuclear reactors. It also fabricates seamless stainless tubes.

Japan

Japan Nuclear Cycle Development Institute (JNC) [English] - JNC was formed in-October 1998; its mission is to perform the development of the advanced technology required to establish the complete nuclear fuel cycle. Key projects include: the fast breeder reactor (FBR), advanced reprocessing, plutonium fuel fabrication and the disposal of high-level radioactive waste.

Mitsubishi Nuclear Fuel Co., Ltd. (MNF) [English] - MNF is in the light water reactor fuel fabrication business.

Nuclear Fuel Industries, Ltd. (NFI) Site in Japanese only. [Some English] - NFI is a company jointly formed in July 1972 by the Furukawa Electric Company, Ltd. and Sumitomo Electric Industries, Ltd. The parent companies transferred to NFI all of their facilities, technology and personnel in their nuclear fuel operations. NFI has developed its own technology over the years, also applying technology introduced from abroad, to become an integrated nuclear fuel manufacturer independent of any reactor vendor.

Kazakhstan

Ulba Metallurgical Plant [English] - This company is the largest facility in CIS for fabrication of nuclear fuel for power plants. It also produces hydrofluoric acid, other materials, and is approved for the production of products from uranium compounds including reprocessed uranium for nuclear reactors and power plants and processing of different uranium compounds to produce products of different degree of readiness.

Korea, South

KEPCO Nuclear Fuel Company, Ltd. (KNFC) [English] - KNFC is Korea's sole nuclear fuel company. It has self-reliant manufacturing technology for PWR and PHWR fuels. Carrying out conversion, nuclear fuel design and fabrication scope currently in the nuclear fuel cycle, KNFC has a long-term plan, aiming to be highly competitive in the world nuclear fuel cycle business early in the 21st century.

Netherlands

WISE: World Nuclear Fuel Processing Facilities - WISE Uranium Project page listing information on various nuclear fuel processing facilities.

Russia

JSC Chepetsky Mechanical Plant (JSC CMP) [English] - JSC Chepetsky Mechanical Plant, which is the part of the Russian Federation nuclear-power complex (Join-Stock Company "TVEL"), is the biggest producer of zirconium alloy products, natural and depleted uranium, calcium metal and its compounds in Russia. It occupies one of the key positions in Russia in the technological process of nuclear fuel manufacturing on the basis of natural uranium. Natural uranium products are manufactured as uranium metal powder, uranium oxide and uranium tetrafluoride.

TVEL - The activities of JSC TVEL are based on the integration of enterprises of the nuclear fuel cycle in one technological multi-link chain for production of nuclear fuel and its components.

Spain

ENUSA Industrias Avanzadas, S.A. (ENUSA) [English] - ENUSA is engaged in activities related to the first part of the nuclear fuel cycle. These consist fundamentally of: Management of enriched uranium supplies for Spanish nuclear power plants, Production of uranium concentrates - a residual production activity complementary to the closing-down works of its Mining Centre at Saelices-Ciudad Rodrigo (Salamanca), Manufacture of PWR and BWR fuel elements, as well as the engineering associated to this activity, and other services related to nuclear power stations. At present, ENUSA has direct supply contracts with the nuclear power stations of Almaraz I and II, Ascó I and II, Vandellós II and José Cabrera (Zorita).

Nuclear Energy in Spain (via Foro Nuclear) [English] - Spain has a total of eleven nuclear facilities located on the peninsula, including seven nuclear plants - Almaraz I & II, Ascó I & II, Cofrentes, José Cabrera, Sta. María de Garoña, Trillo 1 and Vandellós II - which contain a total of nine nuclear units. Vandellós I is currently in the process of being dismantled. The country also has a nuclear fuel factory, Juzbado, and a low- and medium-level radwaste repository, El Cabril.

Sweden

Westinghouse Atom - Westinghouse Atom provides nuclear fuel services, nuclear components and design, and automation services. A vital part of the Nuclear Fuel Operations is the Nuclear Fuel Factory situated in the city of Västerås, Sweden. The Fuel Factory manufactures LWR fuel, BWR Channels and BWR Control Rods.

United States

Amer Industrial Technologies, Inc. (AIT) - AIT designs, engineers, and manufactures steel components for Nuclear Applications. 25 Years of Experience, Quality, and Project Management. Think Amer for Nuclear!

COGEMA, Inc. - Since its inception in 1982, COGEMA, Inc. has been offering total nuclear fuel cycle services to support the U.S. nuclear community. The COGEMA Group is proud to count the majority of the United States nuclear utilities amoung our valued customers and is present at a number of Department of Energy sites.

Duke Cogema Stone & Webster LLC - Duke Cogema Stone & Webster LLC is comprised of three partner companies -- DE&S, COGEMA, Inc. and Stone & Webster -- and a number of respected subcontractor firms. The consortium provides full-scope services required by DOE, including design, construction and licensing of a mixed oxide fuel fabrication facility; the fabrication of mixed oxide fuel; and the irradiation of that fuel in commercial nuclear reactors.

Framatome ANP, Inc. - As part of a worldwide team, Framatome ANP, Inc. designs and fabricates nuclear fuel, control components, and incore detectors. It also provides fuel-related engineering and analysis services associated with the nuclear fuel cycle, and field services for inspection and repair of fuel and related components. It is also actively involved in the back end of the fuel cycle in a number of areas, including spent fuel storage and disposal. An AREVA and Siemens company.

GlobalEnergyJobs - GlobalEnergyJobs is focused on the world's energy industry including: oil and gas exploration & production, refining & marketing; power & utility; pipeline transportation; engineering & construction; service & equipment; chemicals & petrochemicals; geothermal; alternative energy; fuel cells; solar; wind; nuclear; cogeneration; mining; professional services; energy banking and information technology.

Savanna River Site (SRS) - SRS was constructed during the early 1950s to produce the basic materials used in the fabrication of nuclear weapons, primarily tritium and plutonium-239. In 1989, SRS began lifting the veil of secrecy under which the site had traditionally operated. SRS focuses on three mission areas associated with products and services essential to achieving the Department of Energy's (DOE) goals: Nuclear Weapons Stockpile Stewardship, Nuclear Materials Stewardship, and Environmental Stewardship

Thorium Power, Inc. (TPI) - Radkowsky Thorium Fuels (RTF) and the Plutonium Burning Fuels, which are the only known means of preventing commercial nuclear power plants from producing nuclear weapons usable plutonium, are the most effective method to permanently dispose of existing stockpiles of weapons usable plutonium and produce electricity. Thorium Power owns the patent rights to these fuels.

Westinghouse Electric Company, LLC - Westinghouse, part of the BNFL Group, provides nuclear services, nuclear fuel, and nuclear systems & projects.

Table 18 shows that, with the original burnups attained by nuclear fuel, the world's nuclear power stations would in 2006 require 13,677 tons of fuel. Table 15 showed that, at 13,819.tons/year, the world's nuclear fuel manufacturers have the capacity to produce this fuel. However the burnups now achieved are in many cases substantially higher than the original values and, conservatively, reduce the estimated weight of fuel required for 2006 to 9,863 tons. This is 74% of the global manufacturing capacity and as burnups continue to rise, the fuel required will be less than 74% of the capacity of the world's nuclear fuel manufacturers.

Table 18:The World's Power Reactors and the Weight of Nuclear Fuel they require, tons per year.[32]

	Operational		Under Construction					
Type	**No. of Units**	**Total MW(e)**	**No. of Units**	**Total MW(e)**	**MWth.d/ton**	**ton/y**	**Original MWth.d/ton**	**ton/y with original burnups**
ABWR	2	2630	4	5329	50000	45	50000	45
AGR	14	8380	0	0	20000	358	18000	398
BWR	90	78005	1	1067	40000	1668	27500	2426
FBR	3	1039	0	0	80000	11	80000	11
GCR	12	2484	0	0	6000	354	4000	531
LWGR	17	12589	1	925	15000	718	17000	633
PHWR	39	19987	8	3135	8000	2136	7500	2279
PWR	213	203447	5	4721	45000	3866	27500	6326
WWER	50	33040	12	10310	40000	706	27500	1027
Total:	**440**	**361601**	**31**	**25487**		9863		13,677

It is concluded that there will be competition between fuel manufacturers to supply Australia with the fuel for a new nuclear power station, should one be built.

[32] Information on reactors from IAEA PRIS April 2004. Information on fuel burnups from various sources.

SECURITY.

Nuclear Power.

In this section we show that nuclear power is demonstrably the safest way of generating electricity and that it is an excellent source of secure supplies, little affected by accidental or political interruption. Its price is little affected by the price of uranium and so will remain stable even when the price of gas rises steeply, as it has recently risen.

Nuclear Accidents

The Paul Scherrer Institute in Switzerland has for many years maintained a data base of accidents. In this section we use a recent review of that data base to compare the risk of nuclear accidents with the risks of accidents in the gas, coal, oil and hydro energy sectors.[33]

It was in 1998 that the Paul Scherrer Institute (PSI) established ENSAD, a highly comprehensive database on severe accidents with emphasis on the energy sector. The historical experience represented in this database was supplemented by probabilistic analyses for the nuclear energy, so as to carry out a detailed comparison of severe accident risks in the energy sector [34]. The database allows one to perform comprehensive analyses of accident risks, which are not limited to power plants but cover full energy chains, including exploration, extraction, processing, storage, transports and waste management.

The ENSAD database and the analysis have now been much extended, not only in terms of the data as such but also what concerns the scope of applications. This work has been mainly undertaken within the NewExt EC DG Research Project on "New Elements for the Assessment of External Costs from Energy Technologies", which apart from the issue of accidents within non-nuclear energy chains [35] also addressed other unresolved issues in the context of energy externalities. We make use of the findings and methodology of NewExt elsewhere in this Report.

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[33] Burgherr P., Hirschberg S., Hunt A. and Ortiz R. A. Accidents in the Energy Sector: Damage Indicators and External Costs. PSI Report, Paul Scherrer Institute, Wuerenlingen and Villigen, Switzerland, to be published 2005.

[34] Hirschberg S., Spiekerman G., Dones R. Severe accidents in the energy sector. First edition, PSI Report No. 98-16, Paul Scherrer Institute, Wuerenlingen and Villigen, Switzerland, 1998.

[35] Burgherr P., Hirschberg S., Hunt A., Ortiz RA. Severe accidents in the energy sector. PSI Report prepared for European Commission within Project NewExt on New Elements for the Assessment of External Costs from Energy Technologies, Paul Scherrer Institute, Wuerenlingen and Villigen, Switzerland, 200

The main objectives of the work here summarized were:

- to carry out comparative assessment of severe accidents in the energy sector,
- to assess the external costs associated with severe accidents within the various energy chains.

Thus, the results can support policy decisions and serve as an essential input to the evaluation of sustainability of specific energy systems. Lack of estimates of external costs of non-nuclear accidents was earlier identified as one of the major limitations of the state-of-the-art of externality assessment.

Figure 37: Severe Accidents with at least five fatalities.

	OECD		EU-15		Non-OECD	
Energy chain	Accidents	Fatalities	Accidents	Fatalities	Accidents	Fatalities
Coal	75	2259	11	234	102 1044 (a)	4831 18'017 (a)
Oil	165	3789	58	1141	232	16'494
Natural Gas	80	978	24	229	45	1000
LPG	59	1905	19	515	46	2016
Hydro	1	14	0	0	10	29'924 (b)
Nuclear	-	-	-	-	1	31 (c)

(a) First line: Coal non-OECD w/o China; second line: Coal China
(b) Banqiao and Shimantan dam failures together caused 26'000 fatalities
(c) Latent fatalities treated separately

Source: Burgherr et al., 2004

Figure 37 shows that there have been accidents in the coal, oil, natural gas, LPG and hydro sectors that dwarf Chernobyl, the only nuclear accident to have caused more than 5 fatalities. The latter was in any case irrelevant to the safety of Western designs of nuclear power station since the RBMK design of reactor used at Chernobyl is intrinsically unstable and incapable of operating to acceptable safety levels [36]. The original purpose of the RBMK was not the generation of electricity but the provision of military-grade plutonium for nuclear weapons and it was hurriedly designed for that express purpose, without proper attention to its safety.

[36] The Chernobyl Accident and its Consequences. J H Gittus et al. Foreword by Lord Marshall of Goring. ISBN 085356216-4. London, HMSO.

Figure 38: Number of Severe Accidents and Aggregated Rates: Coal, Oil, Gas, Hydro and Nuclear.

Energy Chain	Number of severe accidents world-wide with fatalities # accidents / # fatalities	Number of immediate fatalities per $GW_e yr$				
		Worldwide	No allocation		With allocation	
			OECD	Non-OECD	OECD	Non-OECD
Coal (1)	1221 / 25'107 177 / 7090	0.876 0.690	0.157	1.605 0.597	0.185	1.576 0.589
Oil	397 / 20'283	0.436	0.135	0.897	0.392	0.502
Natural Gas	125 / 1978	0.093	0.080	0.111	0.091	0.096
Hydro (2)	11 / 29'938 10 / 3938	4.265 0.561	0.003	10.285 1.349	0.003	10.285 1.349
Nuclear	1 / 31	0.006	0	0.048	0	0.048

(1) Second line: China excluded
(2) Second line: Banqiao/Shimantan dam accident excluded

Source: Burgherr et al., 2004

Figure 38 relates the accident statistics to the amount of electricity produced. Now we see that there have been 0.006 fatalities per GWe.year of nuclear electricity, fifteen times as many fatalities per GWe.year for natural gas and one thousand times as many fatalities per GWe.year for coal, oil and hydropower.

Figure 39 is a form of diagram often used to display forecasts, from Probabilistic Risk Assessment (PRA) or Probabilistic Safety Analysis (PSA) of the frequency with which increasing numbers of fatalities will occur. Such a forecast, for nuclear accidents, is shown in this Figure. For comparison actual results are shown for LPG, oil, coal, natural gas and hydro. LPG has produced a given number of fatalities ten times more frequently than oil, coal or natural gas in OECD countries. These latter, in their turn, have been ten times more dangerous than hydro, in the OECD. Nuclear is forecast to be ten times safer than hydro.

The nuclear line in Figure 41 is a forecast from Probabilistic Risk Assessments, since there have been no fatalities in OECD countries to plot on this Figure. However the records of commercial nuclear insurers show a good correlation between the financial losses that they have had to pay and the forecasts of Probabilistic Risk Assessments for the world's nuclear installations, Figure 40. This raises our confidence in PRA.

Figure 39: Frequency-consequence curves for severe accidents in various energy chains. OECD, 1969-2004.

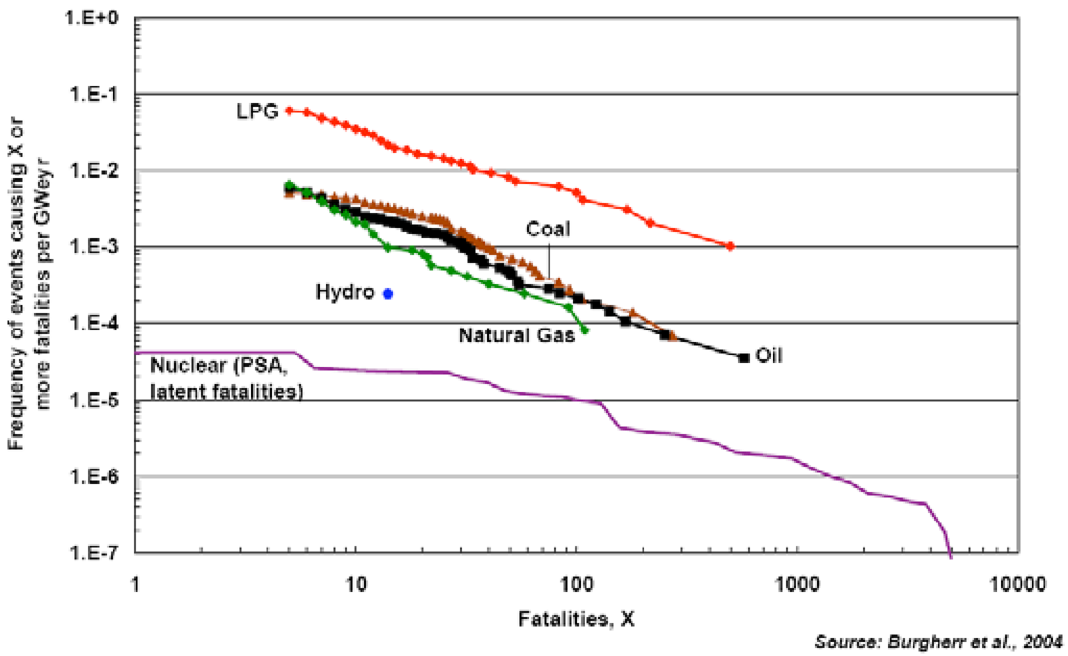


Figure 40: Showing the losses forecast from Probabilistic Risk Assessments are comparable to those actually incurred over the period of the World's nuclear power programme.

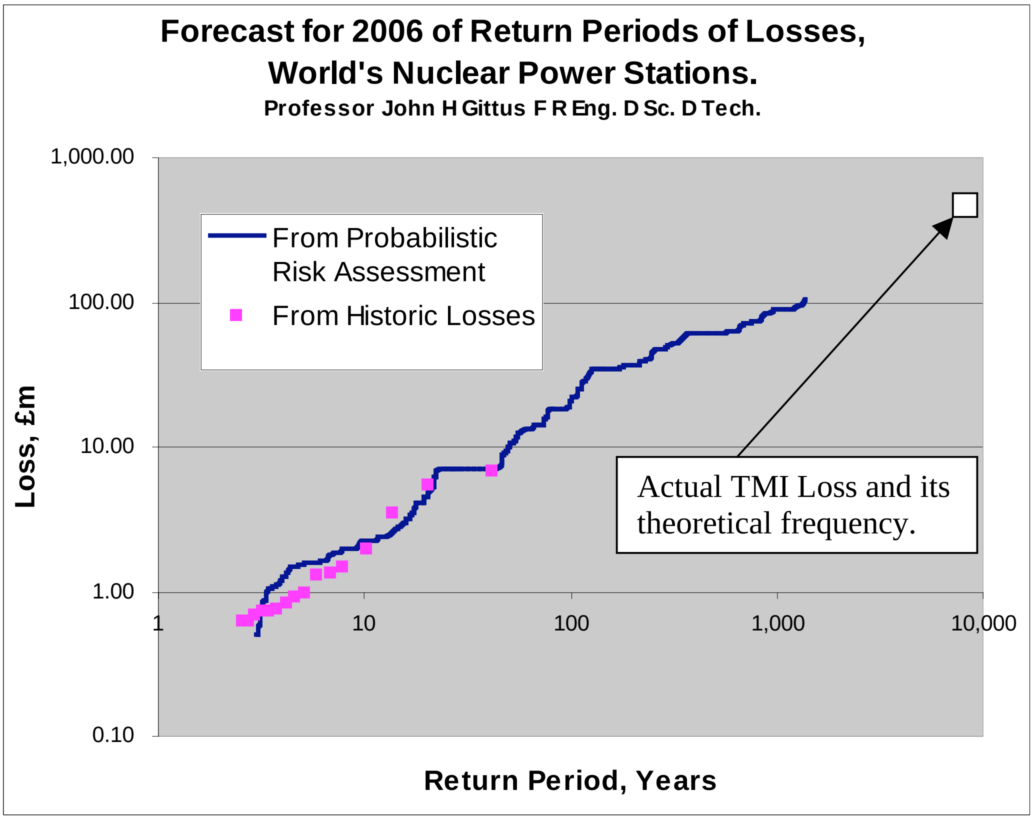


Figure 41: Frequency-consequence curves for severe accidents in various energy chains, non-OECD, 1969-2004

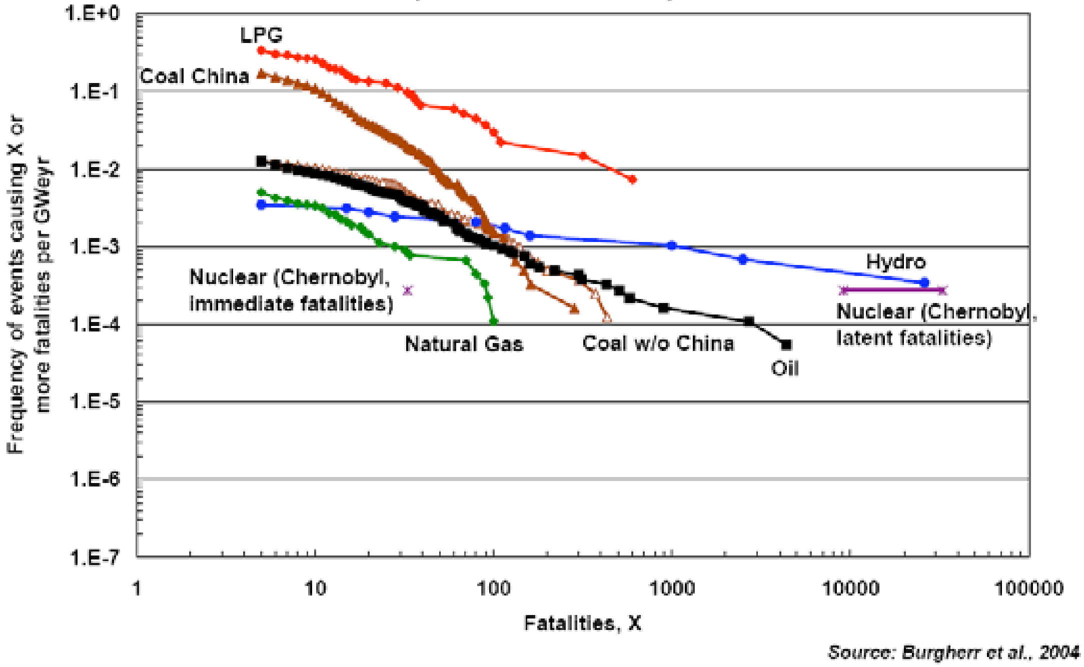


Figure 41 is a corresponding figure for non-OECD countries: now it has been possible to plot the data for the Chernobyl accident, which have the lowest severity of all the data plotted in the diagram. The Chernobyl data include forecasts for fatalities that have, or will, occur after the accident and these lie below the frequency of immediate fatalities due to hydro accidents. No data for such "latent fatalities" are available for any of the other sources of electricity and so a comparison is impossible.

The overall conclusions drawn by the workers at the Paul Scherrer Institute are as follows:

1. Expected fatality rates are lowest for western hydropower and nuclear power plants. This results in low associated external costs. However, the maximum credible consequences are very large. The corresponding risk valuation is subject to stakeholder value judgments and can be pursued in multi-criteria decision analysis.
2. Comprehensive historical experience of energy-related severe accidents is available and can be used as a basis for quantifying the corresponding damages and external costs.
3. Small accidents are strongly underreported but their contribution to external costs appears to be quite small.
4. Energy-related accident risks in non-OECD countries are distinctly higher than in OECD countries.
5. Hydro power in non-OECD countries and upstream stages within fossil energy chains are most accident-prone.
6. The damages caused by severe accidents in the energy sector are substantial but quite small compared to those caused by natural disasters. External costs

associated with severe accidents are rather insignificant when compared to the external costs of air pollution.

Table 19 shows events that would result in outages at an Australian nuclear power station. They are due to accidents, terrorist attack or political intervention in Australia or overseas. The analysis that underpins these forecasts derives from the Probabilistic Risk Assessments that have been done for modern designs of nuclear power station and from the analysis of political risks and from the experience of nuclear insurers.

By summing the products of likelihood and duration we arrive at a figure of 1 day per year as the average outage duration and this could be used to derive the effect on the cost of electricity: it is a small reduction in the number of days per year that is used in our Reference Model calculation. However the losses due to interruptions lasting between 90 days and one year are insurable, as are the material damage and third party liability losses. Accordingly these losses are not additional to the cost of electricity. The insurance premiums are additional costs, however.

Table 19: Events that would result in outages at an Australian Nuclear Power Station.

	Source of Interruption.	Days: Duration of Consequent Interruption	Per Year: Likelihood
	Licensing event	*180*	*8.33E-05*
Internal event	*Cold zone*	*123*	*8.60E-04*
	Design basis	*180*	*7.98E-05*
	Core damage	*360*	*7.98E-06*
	core damage and containment leakage.	*720*	*7.98E-07*
	Core damage and containment failure.	*1,800*	*7.98E-08*
External and shutdown events	*Cold zone*	*123*	*6.02E-03*
	design basis	*180*	*5.59E-04*
	Core damage	*360*	*5.59E-05*
	Core damage and containment leakage.	*720*	*5.59E-06*
	Core damage and containment failure.	*1800*	*5.59E-07*
	core damage, internally initiated	*360*	*1.02E-05*
	core damage and containment leakage, internally initiated.	*720*	*1.02E-06*
	core damage and containment failure, externally initiated. Political decision to defuel the reactor	*1800*	*1.02E-07*
Nuclear Fuel Supplies Cease	*Overseas fuel suppliers stop sending nuclear fuel to Australia*	*180*	*1.00E-06*
	Refuelling maintenance etc	*15*	*1*

Figure 42: Frequency of an outage lasting for the stated number of days or longer at an Australian Nuclear Power Station, due to accidents or the interruption of nuclear fuel supplies.

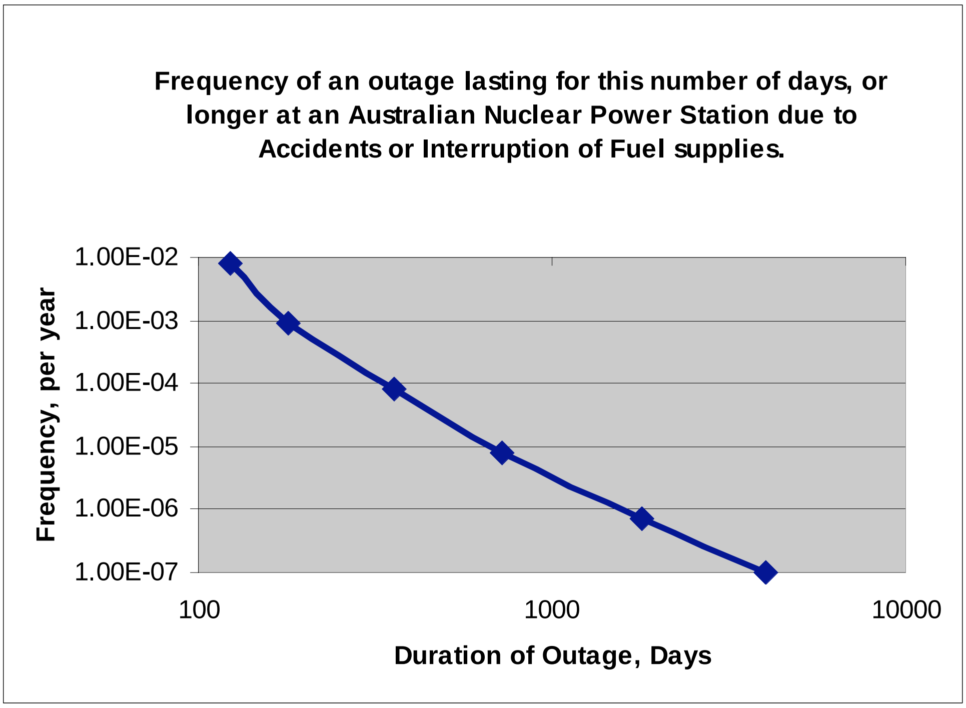


Figure 42 has been plotted using the forecasts of Table 19. It shows the way in which the duration of the outage increases as the frequency of the outage diminishes. It is with the catastrophic events that we are most concerned since they lead to long or even indefinite outages. What these forecasts reveal is that very long outages of the kind that jeopardize security of supply are very infrequent for nuclear power, making it a very reliable source of electricity.

In particular, there is little risk of politically inspired interruptions to the supply of nuclear fuel from foreign suppliers. The main reason for this is the fact that the country from which Australia will buy its nuclear fuel would almost certainly be one to which Australia would export uranium. Another reason is the fact that there are a dozen suppliers of nuclear fuel, in different countries, competing for orders.

Nuclear Events included in this Analysis.

The forecasts in Table 19 involve a number of events that may happen at an Australian nuclear power station. Some background is as follows:

Licensing Event.

If the Australian Nuclear Safety Authority were to find that a number of nuclear power stations round the world, similar to the one built in Australia, had a similar fault, prejudicial to safety, then they might order the Australian plant to be shut down until the fault had been corrected.

Faults that could have led to such shutdowns have occurred in the USA and in France. In the USA, pressure vessel lids on some reactors have suffered from boric acid corrosion. The USNRC determined that this did not prejudice safety and so the reactors have been allowed to continue operation, although the lids are to be replaced shortly. Clearly such an occurrence could have been safety related and if it had been then all such reactors, in whatever country they happened to be, would have been shutdown until the lids were replaced.

Similarly, storms in December 1999 led to the flooding and forced shutdown of the four Blayais reactors in France. Sixteen other French reactors were then deemed not to meet the flood criteria of the French nuclear safety authority and it could have ordered them to shutdown until they had been improved. In the event that was not deemed necessary and they continued to operate whilst improvements were made.

The most pessimistic assumption is that, although no such licensing event has occurred in the world one will occur tomorrow. This would be the first such event in 12,000 reactor years, giving a frequency of 1/12000 = 8.33E-05.

It is not possible to insure against a Licensing Event.

Accidents.

Accidents could lead to the shut down of Australia's nuclear power station. This would interrupt the supply of electricity from the station. xxx gives a comprehensive list of the nuclear accidents that have occurred and Professor Gittus has used both accident statistics and theory to arrive at the resultant impact on security of supply.

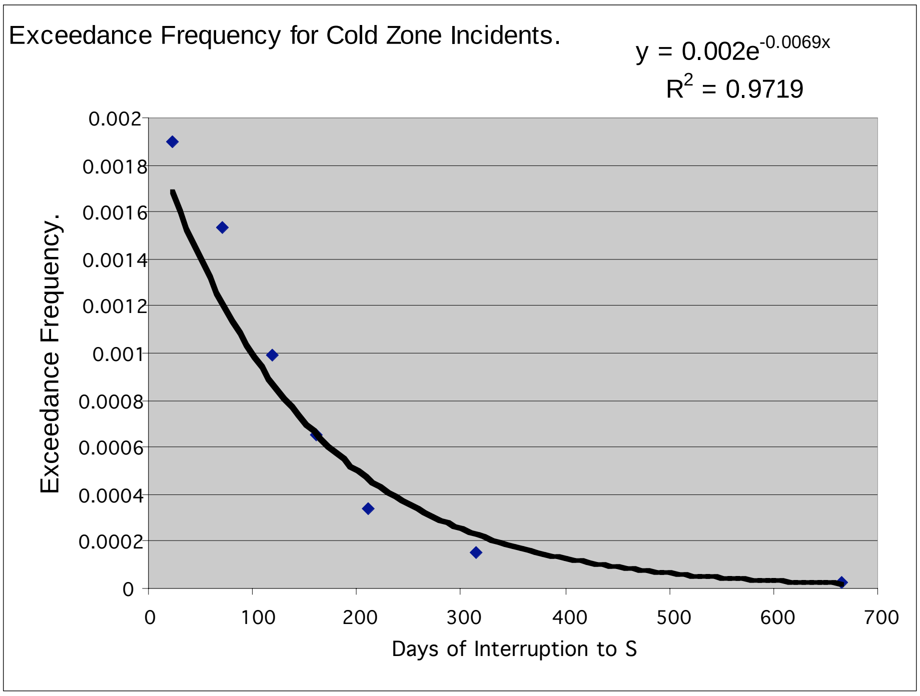
Cold Zone Accidents.

A nuclear power station, like a thermal power station, has steam turbines, generators, condensers, pumps, valves, electronic controls, transformers, switching gear and all the plant associated with these, the "cold zone" items. The "hot zone" items are what distinguish a nuclear from a thermal power station. These hot zone items are the nuclear reactor and all of the plant that controls it and takes away heat from it.

Likelihood.

Cold zone accidents happen in both nuclear and thermal power stations. The insurance industry has data bases for the cold zone accidents that have happened in both nuclear and thermal power stations. From these data bases, Figure 43 has been prepared. It shows, for a notional 1 GWe of electric power, the frequency with which the output of electricity is interrupted. These are Exceedance frequencies. So, for example, the frequency with which electric power of 1 GWe ceases to flow for 161 days or more ***because of a cold zone incident*** is 0.0007 per year. Note that there will be other occasions when the plant is shut down, most of them intentional for maintenance and refueling or because of hot zone incidents.

Figure 43: Exceedance Frequency for Cold Zone Incidents.



Duration of Consequent Interruption.

Figure 43 shows that the interruption to supply can last for many weeks. The mean period is 123 days for which the frequency is 0.00086/GWe.y. These are the figures used in the present analysis, Table 19.

The frequencies are low and so there is little likelihood that, in a given year, there will be two cold zone interruptions to anuclear power station, each of which leads to a loss of 123 days of generation.

Nuclear Accidents.

To extend the model to cover nuclear or hot zone accidents we have adapted analyses from four sources:

- Work done as part of the ExternE project, [37],
- From the associated Joule study [38],
- From the Sizewell B public inquiry, [39]

[37] CEPN (1995) DG XII, EXTERNE Project

[38] "Joule Study": Dreicer, M, Fort V. and Manen, P. "Nuclear Fuel Cycle: Estimation of Physical impacts and monetary valuation for priority pathways" Report Number 234. Centre D'Etude sur L'evaluation de la protection dans le domaine nucleaire, CEPN. February 1995. Prepared for DG 12 of the CEC in the framework of the EsternE project.

- And from the work of a joint Royal Society/Royal Academy of Engineers working party of which Professor Gittus was a member [40].

The Joule study considers the physical impact of the entire fuel cycle for nuclear power for the entire world and for up to 100,000 years into the future. It shows that the dominant source of risk derives from the nuclear power stations themselves.

The NAPAG study considers the effects on the UK. Where it discusses future effects of present day releases of radioactivity it looks 500 years into the future (page 57 of the NAPAG study).

The Prospect of Terrorist Attack on Australian Nuclear Installations.

Since the attack on the World Trade Centre there have been worries that a similar "Kamikaze" terrorist attack could be made on a nuclear power station, reprocessing plant, waste store, truck or other similar target. There is also the possibility that terrorists will steal or buy radioactive isotopes, fissile materials or even nuclear weapons and use them to contaminate or destroy people and property. Thus Greenpeace have recently stated that plutonium being transported across France could be stolen by terrorists. Cargoes of plutonium oxide are taken by road at least once a month from nuclear plants at La Hague in the north to Marcoule in the south to make fuel for French reactors. Similar criticisms are made of the transport, or planned transport, of radioactive waste in Australia.

Immediately after the attack on the World Trade Centre commercial insurers all over the world determined that it was no longer practicable for them to continue insuring nuclear installations against terrorist attack. Accordingly Governments stepped in and took over this aspect of nuclear insurance. With the passage of time, however, commercial insurers have gained confidence and now insure a large part of the terrorist risk to nuclear installations. There mounting confidence is based on a sober interpretation of the true nature of the risk and stems in part from analyses that have been made of its magnitude.

Magnitude of the risk of Terrorist Attack on Nuclear Installations.

Professor John H Gittus was commissioned, first by the UK Government and then by the Canadian and Japanese Governments to assess the magnitude of the risk of terrorist attacks to nuclear installations in the UK, Japan and Canada.[41]. He made use of two independent methods to analyze the terrorist risk to nuclear power stations:

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[39] Sizewell B data are derived from my own work (J H Gittus), quoted by Sir Frank Layfield, (1987) Sizewell B Public Inquiry, HMSO ISBN 011 411 575 3.

[40] NAPAG Report "Energy and the Environment in the 21 st Century" The Royal Society and the Royal Academy of Engineers, London, 1996.

41 Professor John H Gittus. November 2004. Review of the Premium for Government Reinsurance of Terrorist Coverage under the Canadian Nuclear Liability Act, (NLA). © PROPERTY OF Dr John H Gittus; PERMITTED GOVERNMENT USE DEFINED UNDER NRCAN CONTRACT N° NRCan-04-0525.

One method involved the analysis of a number of scenarios, for incidents of varying severity that have actually occurred accidentally in different parts of the world and which could be caused, instead by terrorists. Most nuclear accidents have their origin in human fallibility. What a well-intentioned person does by error, a terrorist can, in principle, do on purpose.

The second, independent method involved use of forecasts arrived at in the EU Externe Study, or "**Joule** Study" and in an equivalent study by the Royal Society and the Royal Academy of Engineers[42]. Each of these studies was concerned with the detrimental impact, on health, crops and the environment, of nuclear power generation. They are used elsewhere in this Report as a method of assessing the external costs of electricity-generation. The forecasts presented in these two studies were used to arrive at estimates of the risks to workers and the community, presented by nuclear power generation, expressed in monetary terms.

Use of Bayes' Theorem.

In order to deduce the likelihood of a terrorist strike on a nuclear installation, given the WTC air strike, Professor Gittus made use of Bayes' theorem. This theorem is in widespread use for such purposes. It enables us to use sparse data (air strikes on two targets) to logically-modify our prior belief about the likelihood, in future, of such terrorist acts. A simple explanation of Bayes' theorem is given on the Internet.[43].

The two studies lead to similar values for this risk. Bayes' theorem was then used to estimate the current share of risk that is attributable to terrorism. In the UK, the design requirement of the NII is that no single class of event should contribute more than 10% of the risk due to a nuclear installation. The Canadian regulator, the CNSC takes a similar view: it specifies that no single class of events shall contribute more than 10% of the risk due to Class 5 accidents, for example. We shall take as our prior estimate of the financial loss due to terrorism, therefore, one tenth of the total risk, calculated by the Joule approach and by the Scenario approach.

Now that the attack on the WTC has taken place, we can use Bayes theorem to update our Prior Distribution estimate, and that has been done in Figure 44. The case for this is simply that instead of demolishing the WTC the terrorist might have struck a nuclear power station. It is precisely because commercial insurers take this view that Governments have had to insure part of the risk of terrorist attack for the world's nuclear power stations.

The ***Posterior*** Distribution so obtained has a peak at a monetary risk that is six times higher than that of the ***Prior***: That is to say the terrorist component of the risk presented by the nuclear power station has increased six fold. It was formerly at most one tenth of the total risk; if the total risk was 100 units then the terrorist element was less than 10

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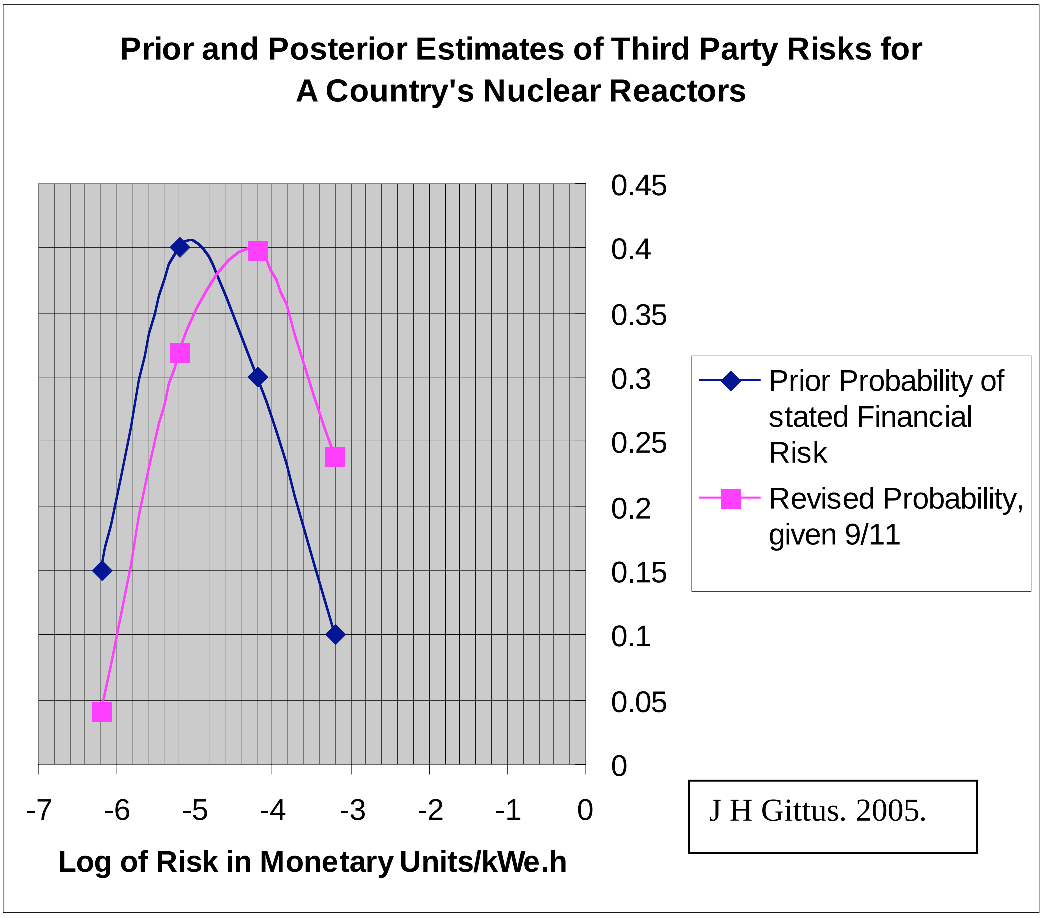
[42] NAPAG Report "Energy and the Environment in the 21 st Century" The Royal Society and the Royal Academy of Engineers, London, 1996.
[43] D:\bayes\Ye banks and Bayes.htm

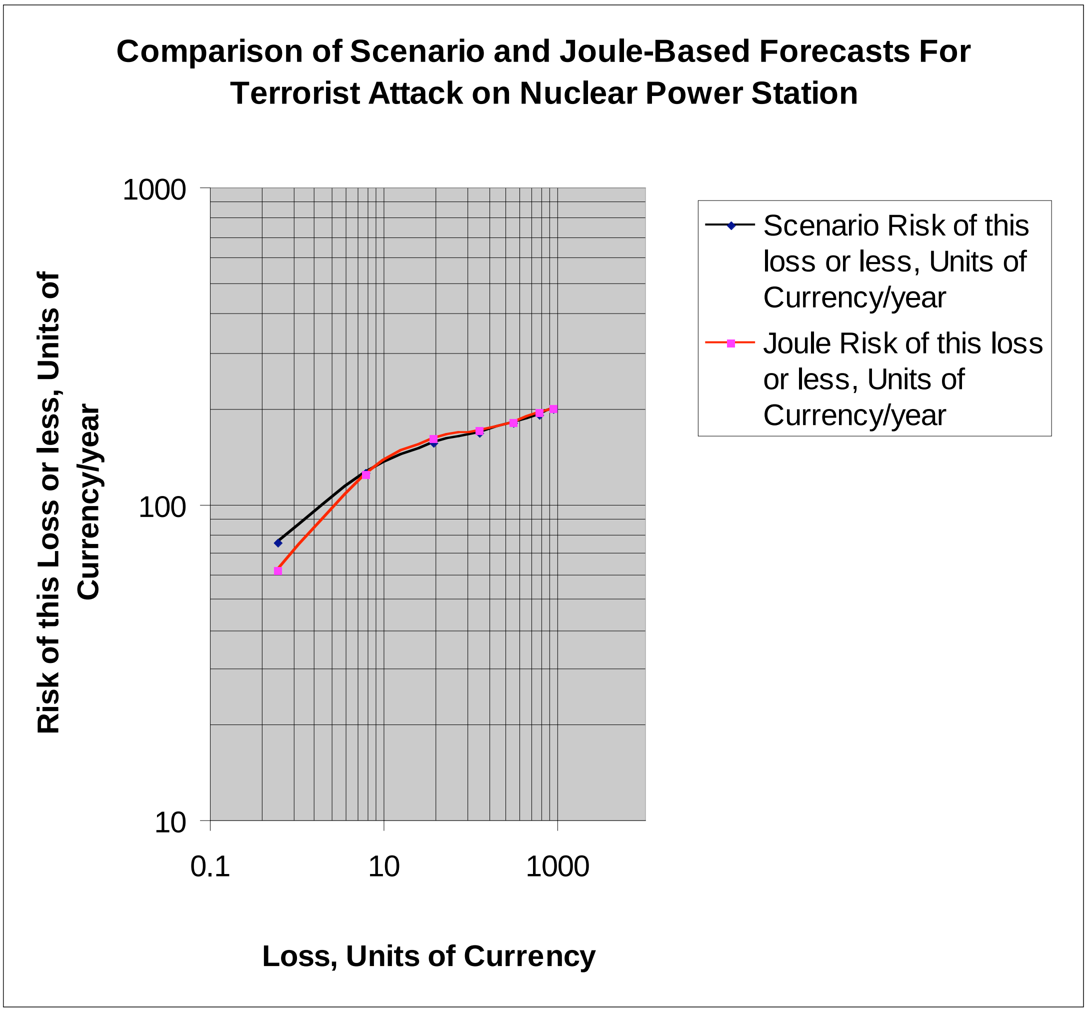
units. Now the terrorist element is 60 units and so the total risk has risen from 100 units to 150 units: an increase of 50% due to the increased risk of terrorist attack.

Figure 44: Use of Bayes' Theorem to estimate Terrorist Risks: Prior and Posterior Estimates of Third Party Risks for a Country's Nuclear Reactors.



We can disaggregate the total terrorist risk so as to show its magnitude for different severities of terrorist attack and this has been done in Figure 45 , where the forecasts produced from the Joule analysis are plotted together with those produced from the analysis of scenarios. Evidently the two approaches produce similar forecasts and both show that the risk tends to tail-off as we move to the most severe accidents.

Figure 45: Comparison of Scenario and Joule-based Forecasts for Terrorist Attack on Nuclear Power Station.



Conclusion Concerning Terrorist Risks to Nuclear Installations.

It is concluded that the Terrorist strike on September 11th 2001 implies that the frequency with which such strikes can be expected to occur on nuclear power stations and other nuclear targets is six times higher than we had previously thought.

We have asserted, nuclear installations were designed so that the calculated contribution of terrorism to the total risk, R, that they present was no more than one tenth of that risk, that is to say R/10. The balance of the risk, not attributable to terrorism, was then equal to 0.9R.

Now we conclude that the risk due to terrorism is actually an order of magnitude higher. More precisely our estimate has increased from R/10 to 6*R/10. The non-terrorist risk remains at 0.9R and so the total risk is not R (as we previously thought) but 1.5R.

Monetary Value of the Terrorist Risk.

The monetary value of the terrorist risk is then calculated to be Aus$ 0.07/MWe.hour. As the losses due to attacks that cost up to about Aus $ 2bn are insured, some of the insurance being backed by Government, they do not add to the cost of nuclear electricity.

We conclude, therefore, that the total risk presented by nuclear installations that fall in the same class of World Terrorism Targets as the WTC and the Pentagon is now fifty percent higher than we previously thought. It is the fact that the WTC and the Pentagon were subject to massive terrorist attacks, of an unprecedented magnitude, that has brought about this revision. The risk was very low before the terrorist attacks occurred and it is still very low, despite the revision that we have made: much lower than the risks presented by coal, gas, oil and hydro summarized above.

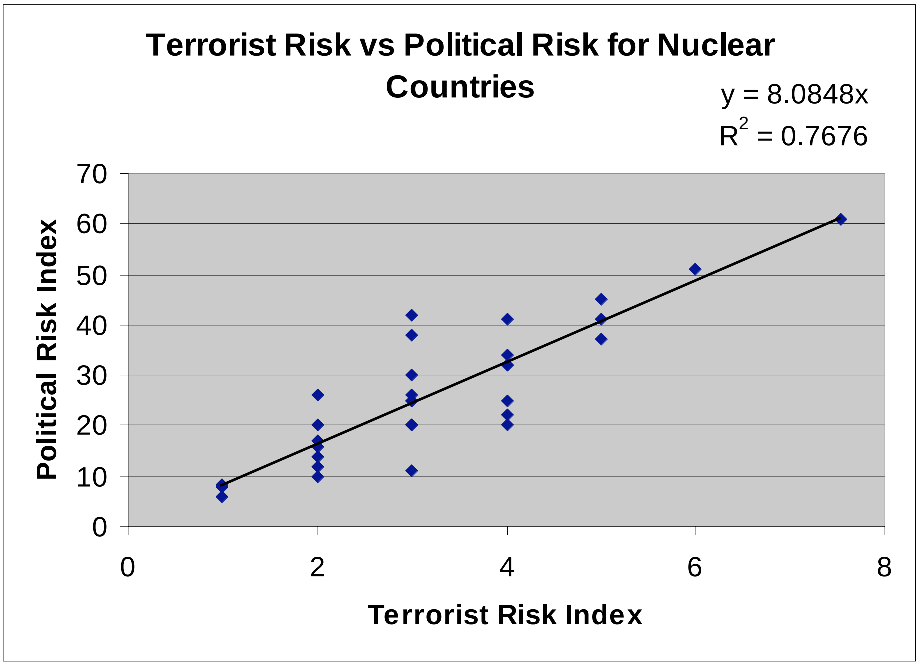
This conclusion is not very sensitive to various assumptions that have had to be made in arriving at it. It is clearly consistent with the views of operators, insurers and regulators round the world, since if they believed that the risk had increased by more than a small factor they would insist on the defuelling of many of the world's nuclear power stations so as to reduce to a much lower level the terrorist risk that they present.

The insurance premiums charged by the UK Government for insuring UK nuclear installations against terrorist attack immediately after "9/11" were calculated in the manner here described. Those charged by the Canadian Government are calculated in the same way.

Correlation between Political Risk and Terrorist Risk.

Elsewhere in this Report we make use of Political Risk Indices. We have discovered that, for countries that have nuclear power stations, these correlated with Terrorist Risk Indices, Figure 46

Figure 46: Correlation between Political Risk and Terrorist Risk for Countries that have Nuclear Power Stations.



Stability of Cost.

We have already shown that the price of uranium has little effect on the cost of nuclear electricity. Above we show that accidents and political intervention will not increase the cost significantly, either.

Natural Gas.

There are now major concerns, particularly in Europe, that countries that have the majority of the world's oil and gas will use these reserves as a political weapon. Superficially one might have thought that a country like Australia or the UK that has its own reserves of oil and gas would be immune to this problem. However the UK has suffered large, very volatile increases in the price of natural gas over the last 12 months. Significantly these increases coincide with the period during which, for the first time in 20 years, the UK has had to import some of the natural gas it consumes, its own rate of production having fallen below the peak demand. Now Australia plans to import natural gas and so one must assess the likelihood that it, too, will be faced with price-hikes and even shortages when it begins to rely on foreign suppliers for some of the natural gas that it intends to import for electricity generation.

In other parts of the world, attention is now focussed on nuclear power as a more secure source of supply than imported natural gas. Is it likely that nuclear power would improve the security of electricity supplies in Australia? Would it help to stabilise electricity prices? In this section of the Report we conclude that the countries from which Australia is likely to import natural gas are as likely to interrupt supplies as have been the Arab states that export oil. This insecurity of supply can lead to price-spikes and loss of electricity-generating capacity. Nuclear power, by adding diversity to Australia's sources of electricity, would improve the security of electricity supplies and help to stabilize electricity prices when gas prices peak and gas imports are interrupted.

Political and Financial Risks of Interruptions to Gas Supplies and Price-Hikes.

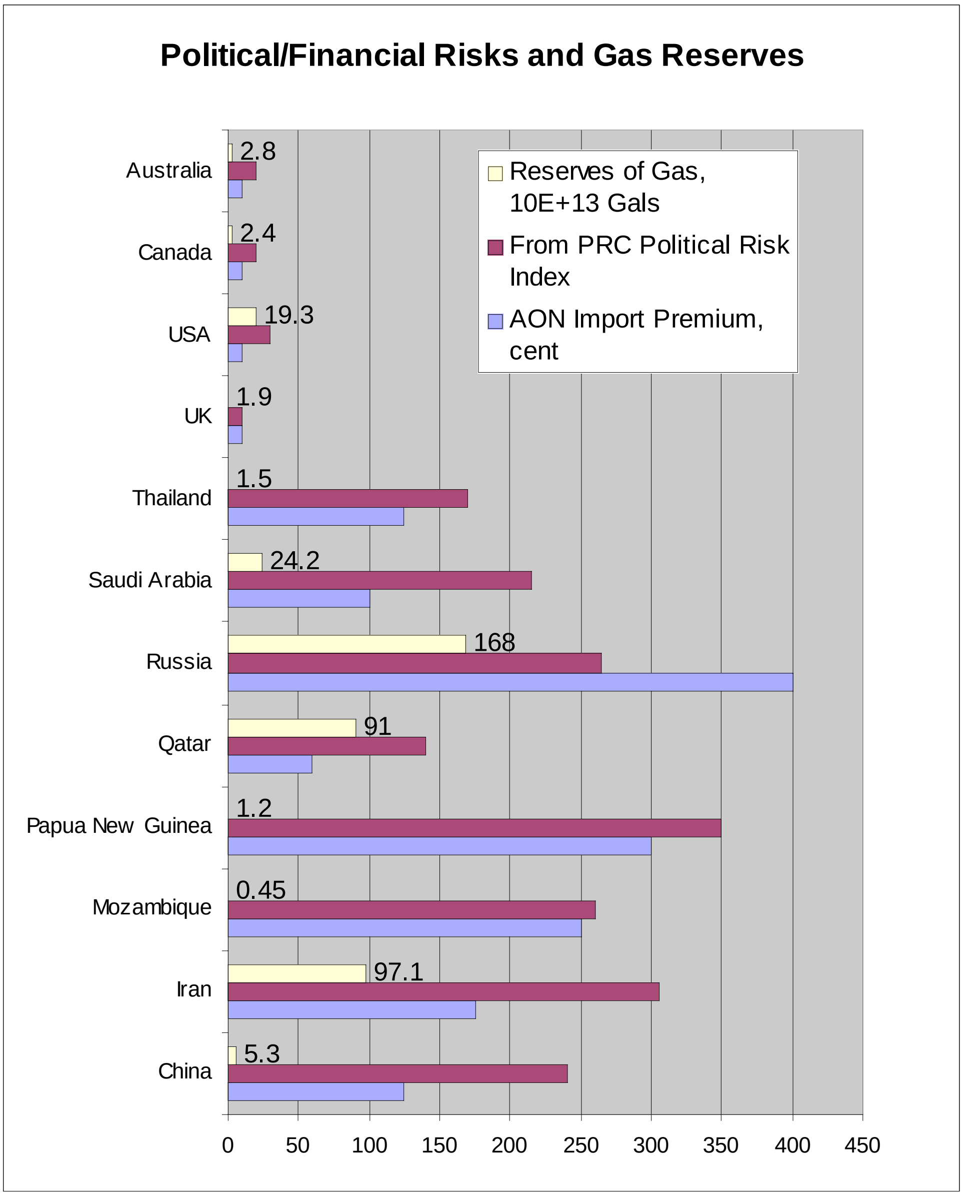
Figure 47 shows that some countries with major reserves of natural gas, such as Russia and Saudi Arabia pose much bigger political and financial risks than do Australia, Canada, and the UK. Papua New Guinea, a country from which Australia may import natural gas via a pipeline and whose reserves are similar to those of Australia, poses a risk as high as does Russia.

It is significant that Arab states, including Saudi Arabia, have interrupted their oil exports about once every ten years for the last 50 years, whilst Russia has interrupted her exports of gas to Georgia for a month and to the Ukraine and more distant countries three times in the ten weeks that have elapsed since the beginning of 2006. This experience, coupled with similar experience in other business sectors, has caused insurers such as Aon to set the high insurance premiums shown in Figure 47. These are the high premiums that organisations in other countries, such as Australia, have to pay to insure their business deals with Russia, Saudi Arabia, Papua New Guinea etc against financial loss due to non-delivery. These premiums are not theoretical numbers: they are firmly based on the losses that insured organisations have suffered, losses that insurers have had to recompense. The political/financial risk indices in Figure 47 are similarly based on actual business experience and they show the same trend as the insurance premiums.

Interruptions of gas supplies do appear to be following the same pattern as the interruptions of oil supplies that have occurred in the last half-century. It is because people have become so concerned about this lack of security of supply that, all over the world, nations are reconsidering nuclear power and will undoubtedly build new nuclear stations. An important ancillary consequence of this will be a reduction in the amount of CO_2 that is pumped into the global atmosphere.

Figure 48 shows how the interruption of oil imports, from the Middle East during the 1974 Arab-Israeli conflict, cut the Gross Domestic Product, GDP, of Japan and the UK by around 10%.

Figure 47:Political/Financial Risks[44] and Gas Reserves. Data labels are gas reserves in 10^{13} gallons.



[44] The Indices for Political Risk used in this work have been developed from a Data Base based on business-experience, prepared by The PRS Group, Inc, 320 Fly Road, Suite 102, PO Box 248, East Syracuse, NY 13057-0248, USA. The forecasts extend to 2007 and have been extended to 2020 for the present study. The Data on Political Risk Insurance Premiums have been developed from a Data Base prepared by AON Plc. 8 Devonshire Square, London EC2M 4PL. These Premiums are based on historic losses.

Figure 48: % Change in GDP due to Interruption of Oil Supplies to Japan and the UK.

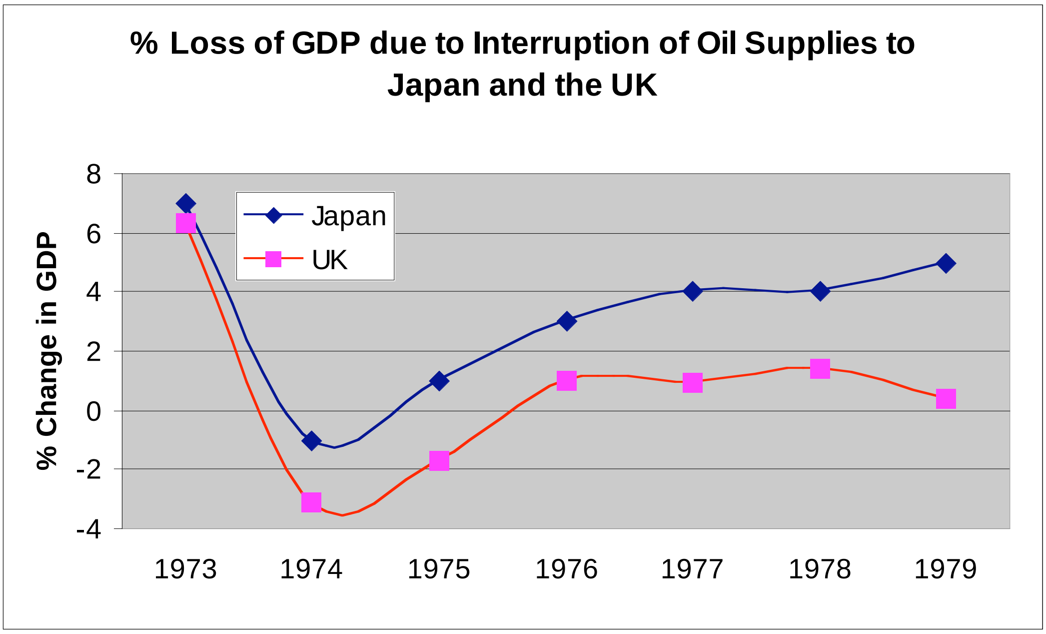


Figure 51 shows the magnitude of the interruptions to oil supplies from the Middle East that have occurred historically. As remarked, Papua New Guinea has similar, relatively poor political and business risks to Arab states that supply oil and Russia, a major gas-supplier.

Minor Terrorist Activity.

Here the scenario that we consider is this: A terrorist blows up a gas pumping station or severs gas pipe(s). The design of the equipment is such that the frequency with which this happens will be the frequency with which a weak Line of Defence (LOD) fails, in this case under terrorist action. A weak LOD includes Human Failures, in this case the failure to identify and prevent a terrorist threat.

The frequency with which a weak LOD fails is of order 0.01/year. The design intent is that no single cause shall contribute more than one tenth of this frequency. In this Report we have argued that the terrorist threat is six times higher today than it was when (for example) nuclear power reactors were designed. The outcome of this analysis is that the minor-terrorist risk to gas transmission is now 0.006/year.

Major Terrorist Activity.

Here the scenario that we consider is this: Terrorists "do a World Trade Centre", sabotaging not just one pipe (c.f. one WTC tower) but all the parallel pipes in a pipeline, for example.

The design of the equipment is such that the frequency with which this happens will be the frequency with which a strong Line of Defence (LOD) fails, in this case under terrorist action. A strong LOD comprises engineered safeguards, designed inter alia to prevent terrorists damaging the plant.

The frequency with which a strong LOD fails is of order 0.0001/year. The design intent is that no single cause shall contribute more than one tenth of this frequency. In this Report we have argued that the terrorist threat is six times higher today than it was when (for example) nuclear power reactors were designed. The outcome of this analysis is that the major-terrorist risk to gas transmission is now 0.00006/year.

Minor Equipment Failure.

The scenario that we consider here is minor equipment failure due to internal or external events: fatigue or earthquake for example. It includes such things as serious damage to existing, operational pipes during digging the trench for adjacent new pipes.

The design of the equipment is such that the frequency with which this happens will be the frequency with which a weak Line of Defence (LOD) fails, i.e. 0.01/year.

Major Equipment Failure.

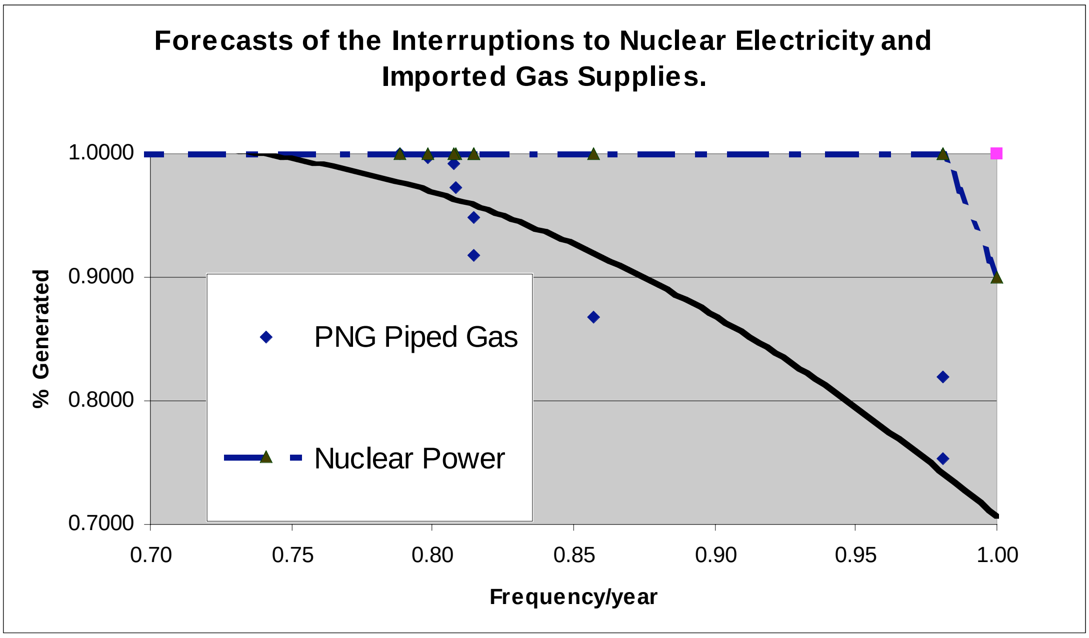
Here the scenario is that, due to internal or external events, there is a release of gas from a small fracture followed by fire that renders pumps inoperative.

The design of the equipment is such that the frequency with which this happens will be the frequency with which a strong Line of Defence (LOD) fails, i.e. 0.001/year.

Forecasts of Interruptions to Australia's Natural Gas Imports: Comparison with Nuclear Electricity.

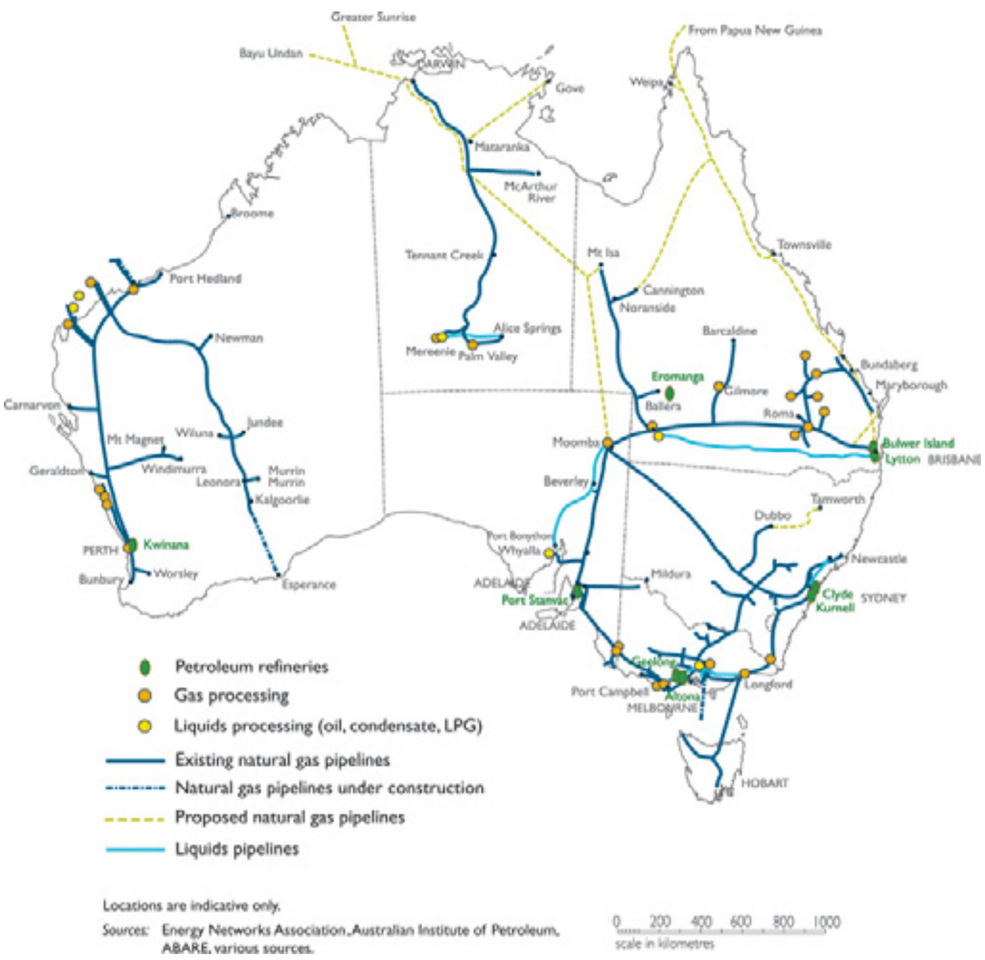
From the Political Risks of trading with the countries from which Australia intends to import natural gas together with the frequency with which gas supplies may be interrupted by accidents or terrorists we have produce Figure 49. It shows the following features:

Figure 49:Forecasts of Interruptions to Electricity from an Australian Nuclear Power Station and of Interruptions of Imported Natural Gas.



- Nuclear electricity is far more secure a source of supply than natural gas imported from the intended foreign suppliers.
- PNG-piped gas is forecast, from the known, numerical political and business risks of trading with PNG, to be unreliable.

Figure 50 : Gas Pipelines in Australia.



Of course, if a power station can use Australian gas then it will be a reliable source of electricity since the supply of Australian gas is not likely to be interrupted. However the geography and sheer size of Australia is such that it is likely that power stations will be built that do not have ready access to Australian gas and which will rely on PNG-piped gas, Figure 50. Accordingly supplies of electricity from these power stations are forecast to suffer the interruptions shown in Figure 49.

Table 20:Probability, per year, of no Nuclear Power or no gas from PNG.

No Nuclear Power	No Gas from PNG
0.2%	3.5%

In Table 20 we integrate the forecasts of Figure 49 to arrive at forecasts of the probability that nuclear power or gas will be interrupted, per year in Australia. We can consider two alternative meanings for these probabilities:

1. Supplies will be interrupted for the stated percentage of time every year. If this were to be the case there would be no problem: the output of a power station does vary by these percentages from year to year and consumers are not inconvenienced nor are profits eliminated. No-one goes into liquidation.
2. Supplies are interrupted, during the stated percentage of years, for a whole year. Or during ten times that percentage for a tenth of a year, say. This is nearer to what has happened in the case of the oil exported from OPEC countries Figure 51. It is a good approximation to what is happening, this year (2006), to the gas that Russia is supposed to be supplying to Georgia. When an interruption of oil supplies to Japan and the UK occurred, lasting many months, in 1974, their economies lost of the order of 10% of their GNP for the year (Figure 48) and there were many bankruptcies plus failures of Japanese banks, to which industrial borrowers could not repay capital-plus-interest because their factories had no electricity and therefore could not make goods for sale.

Papua New Guinea, PNG.

The pipeline project is a joint venture enterprise involving the production and sale of PNG gas to customers in Australia. The project is expected to commence gas sales into Australia in 2009 following construction of a PNG to Queensland pipeline.

In a 12 July 2005 speech on the state of the economy and budget, the PNG Minister for Finance and Treasury highlighted three main elements as critical to achieving a strong economy: (i) creating a stable investment climate; (ii) providing an efficient, effective, and affordable public sector; and (iii) creating a competitive and dynamic private sector. The PNG Government has stated its intention to introduce measures to address problems with inefficient public utilities and investment regulations. The Government acknowledges the need for reform, as evidenced by public discussions, statements of policy and intent, and passage of significant legislation. However, the Asian Development Bank, ADB, notes that the champions of reform appear unable to translate these intentions into concrete and consistent actions. Corruption is a critical problem, and is publicly acknowledged by Government leaders and the general public. As the PNG Government itself notes, country conditions include chronic political instability, weak management capacity in Government, a corrupt civil service, an internal system of patronage, social conflicts and poor security, and small and isolated markets.

Implementation of external assistance, particularly operations involving major reforms or policy actions, has been difficult. A generic PNG issue has been the governance arrangements related to exploitation of natural resources. In March 2005, the Public Service Program loan was closed without release of the second tranche. In May 2005, the World Bank’s Forestry and Conservation Project was cancelled due to failure to agree on loan covenants and alleged breach of PNG legislation related to the award of forest concessions.

In late 2003, at the PNG Government’s request, the Australian government initiated its Enhanced Cooperation Program (ECP) with PNG. Under ECP, Australian civil servants were placed in both advisory and line positions in core government agencies, and Australian police deployed. In May 2005, the Supreme Court declared the ECP Act unconstitutional, resulting in the departure of Australian police from PNG. Discussions are ongoing and the expected resolution is that a reduced number of Australian police will return, in purely advisory and mentoring roles (and no longer 'on the beat'), and that the advisors in core agencies will remain in position, bolstering the Government's reform and anti-corruption efforts.

The PNG private sector is constrained by, among other things, insecurity of land tenure, inefficient financial markets, insufficient physical infrastructure, inappropriate legal infrastructure (including regulation of industries), crowding-out in certain sectors of the private sector by the state and crime and lawlessness. Although the country is rich in natural resources, very low population densities, rugged terrain, complex customary land tenure systems, and poor human resource development hinder its economic development. Degradation of natural resources in rural areas and poor water quality in urban and peri-urban areas contribute significantly to the incidence of poverty and constrain the country's ability to achieve both environmental and health-related MDGs.

Recent increased PNG mineral exploration, development of some small new mines and the decision to proceed with the front-end engineering design for the PNG-Australia gas pipeline may yield growth in mineral and hydrocarbon income by the end of the decade. Access to basic services is poor. Literacy is low, particularly among women. Health service performance is declining at all levels of service delivery. Basic services infrastructure is deteriorating Disease control is inadequate, with low immunization

The World Bank now classifies PNG as a non-core low-income country under stress, characterized by weak government and institutions, coupled with high levels of poverty.

Coal.

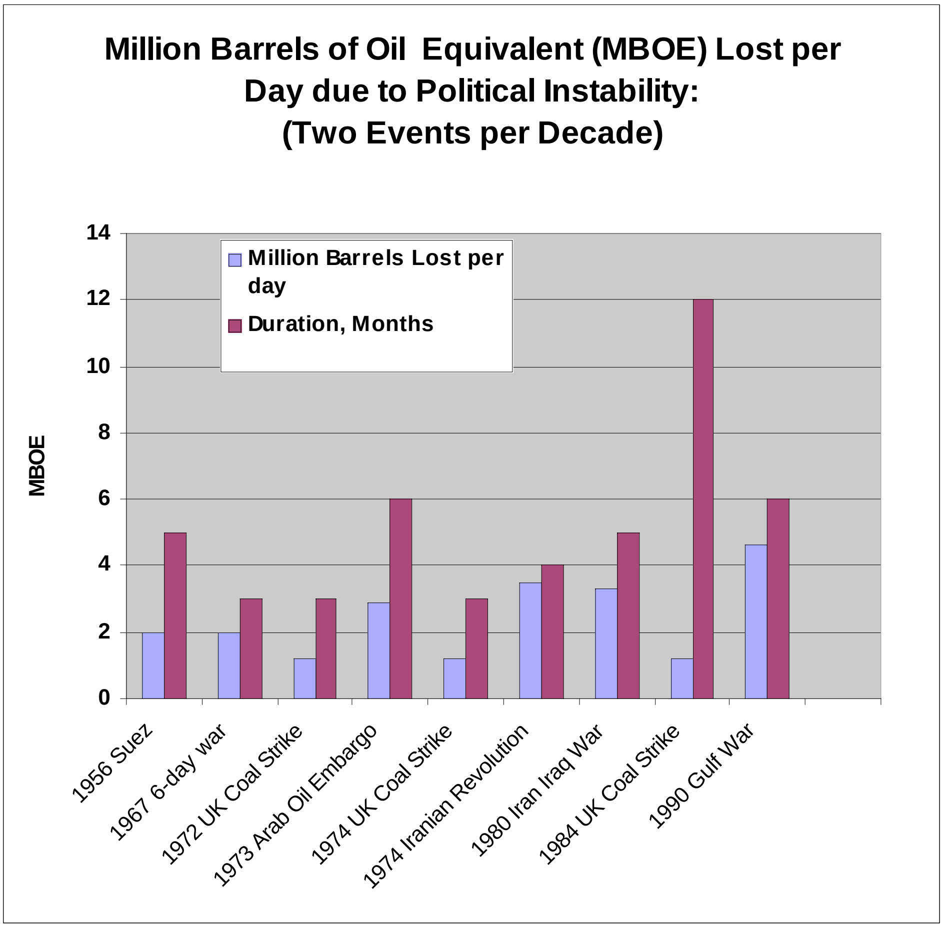
Australia has large reserves of cheap coal and it is for this reason that most of its power stations are coal-fired. However it does not follow that the availability of this coal is guaranteed: there have been substantial coal strikes in Australia, just as there have been in the UK (Figure 51) and although the industry appears stable now, history could repeat itself. Examples of strikes that have occurred in the recent past in the Australian coal industry include the following:

- On 18th December 1998 the national executive of the Australian mining union called a 48-hour national strike involving 15,000 members employed at 250 mines across the country. The directive was issued following reports that three of the country's major hard coking coal exporters--MIM, Shell Coal and North Goonyella--had negotiated a deal with Japanese steel producers slashing the price of coal to $US41 per tonne, $US9 per tonne below the previous year's price. The price cuts meant another round of job cuts and mine closures involving the destruction of up to 2,000 jobs.

- In September 1993 the union called a five-day national strike to pressure the then Labour government to set up a single national coal marketing board to undertake the negotiations for the sale of Australian coal. Despite unprecedented attacks on the conditions of mine workers, the five-day stoppage was the first national strike called in five years.
- Production worth Aus$1m a day was lost during the six-week Hunter Valley No.1 strike, which ended on July 22nd 1997 before a new legal strike began on September 8th. One-third of Australia's coal industry, the country's biggest export earner, was then shut down as a war of attrition between unions and producers erupted into a major new strike.

These Australian coal strikes were not a threat to electricity generation but more severe stoppages are conceivable: another good reason to diversify Australia’s sources of electricity. Nuclear would be a source of such diversification.

Figure 51: Million Barrels of Oil Equivalent, MBOE, lost per day due to Political Instability.



Windpower.

Wind power and other renewables are economically viable in Australia because the Australian Federal Government, like many governments in the world, is encouraging the uptake of renewable energy through legislated measures. The Mandatory Renewable Energy Target (MRET) requires that a certain amount of the energy sold by Australian retailers be from renewables such as wind and solar.

Figure 52:Current estimates of the cost of electricity from Wind Power in Australia[45].

Aus c/kWe.h	Lower	Upper
Windforce 12-BTM	6.45	
Windpower Monthly	4.8	7.1
NREL	6	6.8
IEA	4.5	10.5
US DOE	6	8.3
Australian CEF	7.5	9
Australian Industry	7.5	8.5

Currently wind energy costs around twice as much as energy from coal generation Figure 52, but the cost of wind power and other renewables is falling. Importantly, the cost of fossil fuel based energy does not factor in the environmental costs that we review in this Report and should these be imposed in the future (as seems likely), the gap between wind and fossil fuel based energy will close rapidly. In more remote parts of Australia where fuel costs are higher (e.g. because of transport of diesel), wind energy can be cheaper than fossil fuel based generation.

Figure 53: Installed and proposed Windpower in Australia[46].

Installed (MWe)	572
Proposed (MWe)	5914

It is more expensive to have offshore wind farms. However, this is partially offset by the stronger winds generally found at sea producing more electricity. Australia does not have the space constraints of Europe and is surrounded by deeper seas. It is therefore unlikely Australia will have offshore wind farms for quite some time.

[45] Cost Convergence of Wind Power and Conventional Generation in Australia. June, 2004. A Report for the Australian Wind Energy Association. Karl Mallon PhD, Executive Director, Transition Institute P/L Jamie Reardon MSc, Senior Researcher, Transition Institute P/L. Version 1.34
[46] Australian Wind Energy Association, March 2006.

Table 21: Forecasts of Interruptions to Windpower in Australia. 5,914MWe Capacity.

Source of Interruption.	Days: Duration of Consequent Interruption	Per Year: Likelihood	Loss, GWe.d
Storm	180	5.00E-04	266.13
Tornado	60	1.00E-03	24.84
Seismic	70	2.00E-05	8.28
Plane runs into windfarm	120	3.00E-04	14.19
Connection to Grid is cut	10	3.00E-04	1.18

Figure 54: Forecasts of Interruptions to Australia's Windpower: 5,914MWe Capacity. Frequency of the stated loss or more. Figures of Table 21.

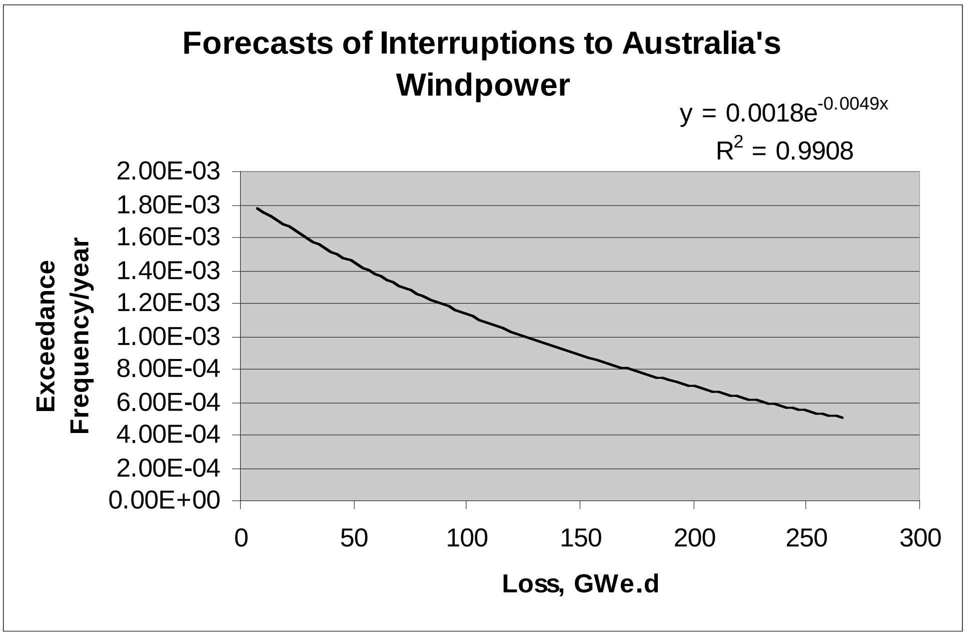


Table 21 and Figure 54 show our forecasts of the frequency with which interruptions to Australia's windpower will cause a stated loss of generation, or a greater loss. Some details of the various sources of interruption that have been analysed to produce these forecasts are as follows:

Interruption to Electricity Supplies from Wind Generators.

Aircraft Crash.

If an aircraft were accidentally to crash into a wind farm then supplies of electricity from many of the turbine generators would be lost for up to a year.

Wind turbines have grown considerably in size over the past 20 years. In 1980 the average size wind turbine had a rotor diameter of 10.5 metres - today there are many wind turbines with rotor diameters of more than 80 metres, roughly 25% larger than the wingspan of a Boeing 747. Consequently, an increasing number of wind turbines exceed the 100 metres limit of height for when obstruction marking may be required by the aviation authorities. Denmark's Nysted Offshore Wind Farm will consist of 72 wind turbines, each having a rated power of 2,2 MW. The hub height is 68.8 m (226 ft), the rotor diameter is 82.4 m (270 ft). Maximum tip height is therefore 110 m (361 ft).

Numerical Weather Prediction and Risk Assessment.

We have used the complex models of the Insurance Industry to forecast the frequency with which Australian windfarms could be damaged by bad weather. Although Numerical Weather Prediction (NWP) is not new, its commercial application in the catastrophe-modeling arena is. Norwegian physicist Vilhelm Bjerknes first proposed the idea of NWP in 1904. He theorized that future weather conditions could be predicted by taking an initial snapshot of current conditions and then solving the set of physical equations that govern fluid flow or, in this case, the atmosphere. Since those early days, advances in computing power, a deeper understanding of the laws of physics, and access to global environmental data have made the commercial application of NWP models possible. NWP has been the focus of decades of intense research conducted by the global scientific community. Billions of dollars have been invested in its development, and the rate of investment continues to increase. Today, NWP is the core operational forecasting technology used by meteorologists who analyze the weather and climate at all major meteorological agencies around the world.

Storm.

Through this large sample, or catalog, of simulated events, the event generation component determines the frequency, magnitude, and other primary characteristics of potential catastrophe events by geographical location.

The wind speed is always fluctuating, and thus the energy content of the wind is always changing. Exactly how large the variation is depends both on the weather and on local surface conditions and obstacles. Energy output from a wind turbine will vary as the wind varies, although the most rapid variations will to some extent be compensated for by the inertia of the wind turbine rotor.

In storms there is the possibility that wind turbines will be damaged. They are provided with over-speed protection and are designed to resist storm- force winds, but these provisions will fail with a calculable probability.

The forecasts that led to Figure 54 have been made using the techniques developed at Riso Laboratory in the EU joule programme, [47] for the frequency with which storms will interrupt Australia's wind generation, for the case where Australia has 5.914 GWe of installed wind generation capacity.

The verification of the structural integrity of a wind turbine structure involves analyses of fatigue loading as well as extreme loading arising from the environmental wind climate. With the trend of persistently growing turbines, the extreme loading seems to become relatively more important. The extreme loading to be assessed in an ultimate limit state analyses may result from a number of extreme load events including transient operation (start/stop sequences), faults, and extreme wind events. Examples of extreme wind events are extreme mean wind speeds with a recurrence period of 50 years, extreme wind shear, extreme wind speed gusts and extreme wind direction gusts. The present analysis addresses extreme wind turbine loading arising only from (a particular class of) extreme wind events included in the IEC-standard (IEC 61400-1, 1998) as extreme load conditions that must be considered as ultimate load cases when designing a wind turbine.

Within the framework of the IEC-standard, these load situations are defined in terms of two independent site variables - a reference mean wind speed and a characteristic turbulence intensity. The available experimental data material relates to the mean wind speed regime between 5m/s and 25m/s, and the present analysis is consequently limited to extreme wind conditions occurring during normal operation of the wind turbine. In the code these are described exclusively in terms of the turbulence intensity. In addition to the code, which is somewhat empirically based, theoretical models, based on probabilistic analysis of multi-variate random processes, exist that predict probability density functions of gust events. Also these models rely heavily on the site turbulence intensity. Thus the turbulence intensity - defined as the standard deviation of the wind speed divided by the mean wind speed - is the crucial parameter concerning modelling of this class of extreme wind conditions.

The standard deviation of the horizontal turbulence component plays a prominent role in the IEC 61400-1 formulation of the fatigue and extreme loading of wind turbines. The values for the class B turbulence intensities in the code claim to represent an 80% quantile level for a data material including measured turbulence characteristics covering "all wind turbine relevant (on-shore) sites". The turbulence intensity specification in the code is thus intended to represent the turbulence characteristics of many different sites rather than to give precise information of one particular site.

Gusts due to thunderstorms, tornados, down bursts etc. are not covered in this section of the analysis, but they are separately evaluated in this Report

Without the cutout speed included in the reliability analysis, the variability in the mean wind speed would have become a much more important uncertainty source with a design point value in the range 35-40 m/sec, which is unrealistic for operation of the wind turbine. This would have led to a significantly higher failure probability in ultimate loading than the one reported here.

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[47] Riso Report R 1111 EN. Gunner Chr. Larsen, Knut Ronold, Hans E. Jørgensen, Kimon Argyriadis and Jaap de Boer, 2002.

The results of these calculations are shown in Figure 55, which shows that in Australia as a whole, the mean return period of wind speeds that will cause a 50% probability that the wind turbines will fail is 2000 years.

Figure 55: Design Wind Speed and Return Speed for Wind Turbine Failure.

Design Life, years	Design Speed, m/s	25% Above Design Speed.	Return period of 25% over design velocity, y
50	35	44	2000

Tornados.

A tornado is a violently-rotating column of air which is usually in contact with the parent thunderstorm - although as many as a third occur without thunder. In the centre of a tornado, winds are actually very light and may descend towards the ground - just like the eye of a hurricane.

A tornado will typically last for a few minutes, track across the land for 2 to 5 kilometres (roughly 1 to 3 miles) and will have a diameter of 20 to 100 metres (roughly 20 to 100 yards). Windspeeds are in the order of 72 to 113 miles per hour - that is, T2 or T3 on the Tornado Intensity Scale. At the more extreme end, some tornadoes track for over 100 kilometres, are over 1 kilometre wide and have winds in access of 300 miles per hour (T10) - such tornadoes are extremely rare, anywhere in the world.

Measuring Tornado Intensity

In the late 1960's, Dr. Theodore Fujita, of the University of Chicago, first developed a scale for classifying tornadoes. The Fujita Scale, or simply F Scale, classifies tornadoes based on their rotational wind speeds and on the damage caused both to man-made structures and to vegetation. The index ranges from F0, representing tornadoes that result in only minimal damage, to F5, the most severe category of tornado causing "incredible" damage. A tornado's intensity will typically change during its brief life. Along a single tornado's path, then, it is not unusual to observe F2 damage at one point, F3 at another, and just F1 at a third. Because tornadoes generally last only minutes and, more often than not, occur out of the range of weather stations or anemometers (instruments used to measure wind speeds), assigning an Fscale classification is often an inexact science. When wind speed observations exist, the task is relatively straightforward. When no measured wind speeds are available, scientists and engineers must estimate wind speeds from observed damage.

A similar measure, the Tornado Intensity Scale was devised by Dr. Terence Meaden of Bradford-on-Avon, Wiltshire, Great Britain, in 1972. This ranges from T0 to T10, with each point representing a range of windspeed, just like the Beaufort Scale (in fact, the Tornado Intensity Scale is based directly on the Beaufort Scale). T0 to T3 are weak tornadoes, T4 to T7 are strong tornadoes and T8 to T10 are violent tornadoes. T10 = F5.

Figure 56 shows Professor Gittus's estimates of the proportion of Australia's tornados having a given F value, or less, arrived at by means of numerical weather analysis.

Figure 56: Percentage of Australia's Tornados Forecast to have the Stated Intensity or less.

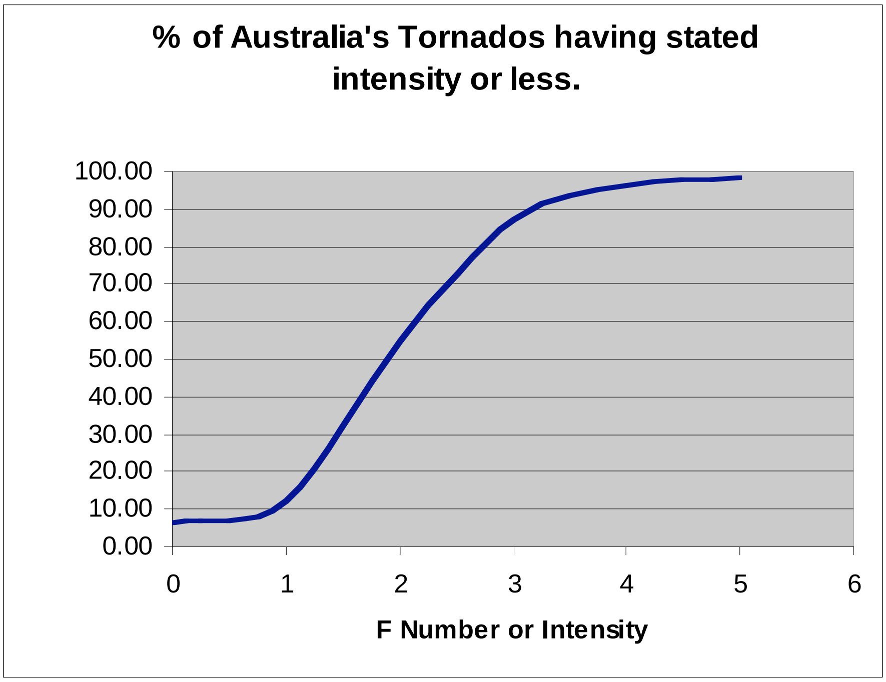


Figure 57: Australia: Forecasts of Wind Speeds in Storms and Tornados produced by Numerical Weather Forecasting.

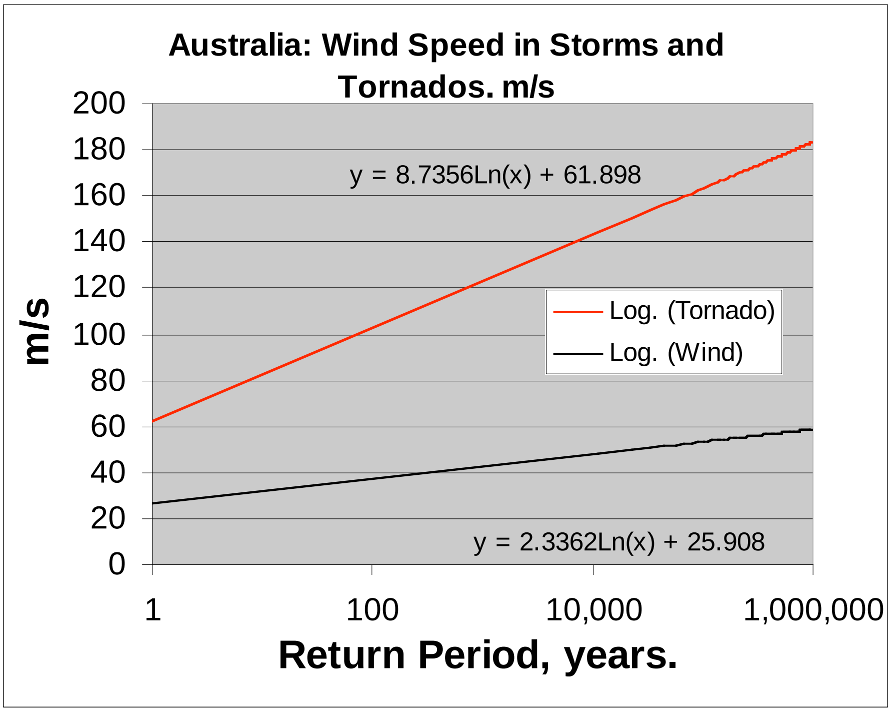


Figure 57 summarizes the forecasts that Professor Gittus has made of the wind speeds in Australia’s storms and tornados.

Predicting the Damage due to Tornados

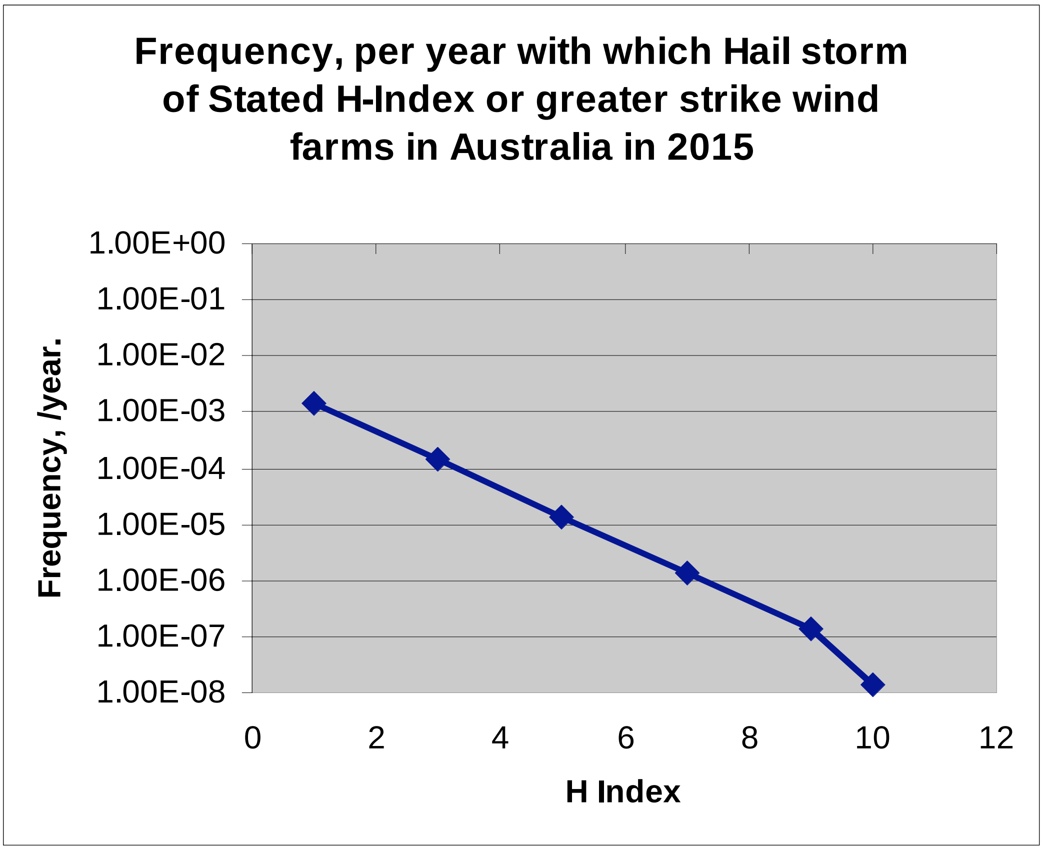
Within cyclones, wind speeds generally increase with height. The air spirals upward to the central core of the tornado to merge with the airflow in the parent cloud at the top. Structural failures occur even in well engineered commercial structures. Structures also sustain damage from airborne debris that act as missiles. These are usually pieces of already damaged structures that are picked up by the force of wind and carried sometimes great distances. The high-speed rotating winds of a tornado can turn almost anything into a missile. To estimate the damage and associated losses from these perils, models use damageability relationships, or damage functions, which have been developed over a period of many years. Post-disaster field surveys provide first-hand data on how structures perform when subjected to such extreme weather conditions. These data are incorporated into the modes through the subsequent calibration and testing of the damageability relationships.

The present estimates for the effects of tornados on the reliability of wind generation in Australia were arrived at by the same methods as for the effects of storms. Even the most up-to-date building codes do not require that buildings and structures such as wind turbines be able to withstand the extreme winds of violent tornadoes. Accordingly it is clear that tornados capable of damaging a wind generator occur somewhere in the Australia every year. The frequency with which wind generators are damaged by tornados are therefore dominated by the fact that the area affected by a tornado is small- smaller than a windfarm. The likelihood that one of the damaging tornados that occur in a given year will occur where there is a wind farm is therefore low.

Hail.

Using the same techniques of numerical weather analysis that were used for storms and tornados we have arrived at Figure 58, in which Professor Gittus's forecasts for the intensity of hailstorms in Australia are plotted. These forecasts, like the others in this section, are for the year 2015 in which Australia should have 5.914 GWe of windpower. The intensity of the Hail storms is measured in terms of an index H.

Figure 58: Frequency with which Hail Storms of differing H values are forecast to occur in Australia.



Earthquakes.

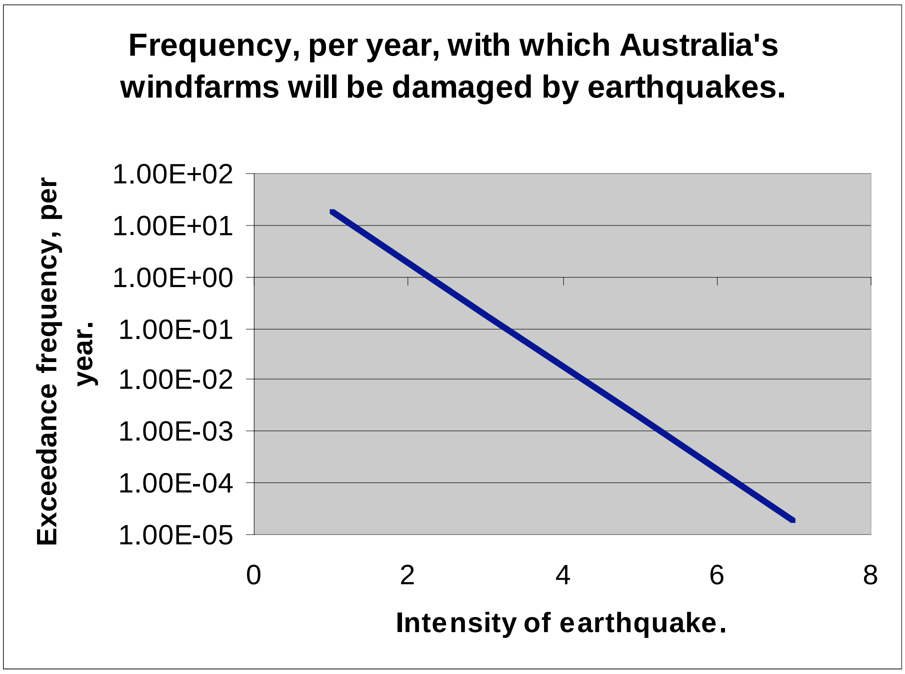
Australia is one of the most active intraplate areas in the world. A high stress drop is characteristic, giving high amplitude, high frequency, short duration motion. Attenuation varies across Australia. The old, cold, hard rocks of Western and Central Australia do not absorb seismic energy greatly, so earthquakes in these areas are felt over longer distances than in Eastern Australia.

Because Australian earthquakes occur only in the top 20 km, one dimension of the rupture area is constrained. This means that the fault rupture for a large earthquake must be quite long. There is a practical limit for fault length of a little over 100 km in Australia. This corresponds to the rupture area of an earthquake of magnitude about

7.5. Australia has large earthquakes, but they occur infrequently An earthquake exceeding magnitude 7 occurs somewhere in Australia every 100 years or so. A typical site in Australia will be within 50 km of a magnitude 7 event every 100,000 years or so. In active areas like Japan, Philippines or California, earthquakes of magnitude 7 occur every few years. The activity in these places is restricted to a much smaller area than that of Australia, so a typical site may be within 50 km of a magnitude 7 event every 100 years or so. Any location in Australia will eventually experience very strong earthquake motion. Low seismicity does not mean weak ground motion. It means that strong earthquake motion happens less often. Earthquakes of magnitude 8 and larger are termed great earthquakes, and normally only occur at plate boundaries. These are unlikely to ever occur within Australia. Earthquakes of magnitude 9 and larger will rupture faults for hundreds of kilometres, so usually only occur on subduction zones such as along the west coast of South America, or the south coast of Alaska.

As seismic waves radiate away from an earthquakes, their amplitude decreases due to geometric spreading. In addition, some energy may be absorbed within the rocks, especially in soft or hot rocks. The rocks in Western and Central Australia are old, relatively cold, and hard, so seismic waves are not greatly attenuated by absorption of energy. The rocks in Eastern Australia are younger and softer, and absorb energy at a rate that is about world average or greater. Earthquakes in Western and Central Australia will be felt over greater distances than those in Eastern Australia.

Figure 59: Frequencies calculated for Earthquakes of various Magnitude in Australia.



The magnitudes that Professor Gittus forecasts for earthquake in Australia are shown in Figure 59.

Machinery Breakdown.

Machinery such as the generator in a wind turbine is normally very reliable and will have breakdown frequency of between 10^{-3} and 10-4 per year of operation.

http://australiasevereweather.com/index.html

Solar Electricity.

Sales of solar PV modules are increasing strongly as their efficiency increases and price falls. But the cost per unit of electricity - at least ten times that of conventional sources, limits its potential to supplementary applications on buildings where its maximum supply coincides with peak demand. Several experimental PV power plants mostly of 300 - 500 kW capacity are connected to electricity grids in Europe and USA. Japan has 150 MWe installed. A large solar PV plant was planned for Crete. Research continues into ways to make the actual solar collecting cells less expensive and more efficient.

Hydropower.

The current installed hydro power production capacity in Australia is over 7600MW, producing approximately 17,700GWe.h per annum of electrical energy, or approximately 9% of the total energy production in Australia. Hydro is almost the sole form of energy produced in Tasmania, but this is the exception in Australia. Even in New South Wales – the state with the next highest installed capacity of hydro power plants – hydro energy production amounts to only 12% of the total energy mix in that state.

Status of dam construction

New dam construction is proceeding slowly throughout the country, with two or three new or major upgrading projects under way at any one time. Projects currently under construction include:

- Improvements to the water supply to Coffs Harbour in New South Wales.
- A major upgrade of Awoonga dam for industrial water supply and irrigation, at Gladstone in Queensland.
- Construction of Harvey dam in Western Australia – part of a $Aus 275m project to improve the supply of potable water to Perth.

However, new dam projects have not been constructed in the state of Victoria for almost 15 years and for more than seven years in Tasmania. In South Australia, new water storage dams have not been constructed for about 25 years, although a number of flood detention basins have.

In New South Wales, Queensland and Western Australia, new dam projects have been under regular construction during this period, primarily for domestic and industrial water supply and to a lesser extent for irrigation purposes.

Upgrading existing projects

The upgrade of existing dams has been an ongoing feature of the industry in Australia, including both capacity upgrading and safety upgrading. Two of the biggest projects are the construction of additional spillway capacity for Warragamba dam near Sydney, New South Wales, and the strengthening by post-tensioning of the 72m high concrete gravity Canning dam in Western Australia.

Trends for new construction

In recent years, following the completion of work on the major government-owned and sponsored projects, the trend has been for private investment in hydro power development. This has primarily been in the fields of small and mini/micro hydro. Construction by retrofitting at existing dams has been a feature of the hydro power industry in Australia over the last decade. This work is still proceeding, with current changes to the regulatory system providing new opportunities for micro and mini hydro systems.

Environmental management

Deregulation and partial privatisation of the electrical supply industry has renewed interest in the prospects for hydro power. Much electricity in Australia is now traded so that distribution companies buy at the best price traded hour by hour. While large coal fired thermal power stations provide much of the base load, gas and hydro power typically fill the intermediate and peak load demands. While there is some interest in new hydro power plants to meet this potential demand, there are a number of hurdles to be overcome, particularly in the areas of environmental approval and native title issues.

NON-PROLIFERATION

A Nuclear power station requires nuclear fuel, which contains the fissile isotope of Uranium, U235 and which may in addition contain fissile isotopes of plutonium, Pu239 and other odd-numbered Pu isotopes. These isotopes, after they have been concentrated by physical processes, can be used as nuclear explosives. Terrorists or other countries may acquire them and use them in nuclear weapons. This is an example of proliferation.

The Non-Proliferation Treaty (NPT) is also known as the Treaty on the Non-Proliferation of Nuclear Weapons. The NPT aims to prevent spread of nuclear weapons to states that do not already possess them while trying to ensure fair access to peaceful nuclear technology under international safeguards. There are two categories of parties to the treaty - nuclear weapon states (NWS) and non-nuclear weapon states (NNWS). Under the treaty, NWS are defined as the five states that exploded a nuclear device before January 1967 (the US, the USSR or now Russia, the UK, France, and China). If Australia builds a nuclear power station then it will be expected to extend its activities under the NPT as a NNWS.

The obligations of NWS and NNWS

NPT obligates the NWS not to transfer nuclear weapons to any other state or assist any non-nuclear weapon state in acquiring, manufacturing or controlling nuclear weapons. Although they are permitted to retain their nuclear weapons, nuclear weapon states are also committed under the treaty to engage in negotiations on nuclear disarmament and on ending the nuclear arms race.

The NPT is the only multilateral treaty that legally binds the five nations to pursue nuclear disarmament negotiations.

Australia, as a Non-nuclear-weapon state, NNWS, on the other hand, already undertakes not to acquire or produce nuclear weapons. Australia would also be required to accept safeguards to detect diversions of nuclear material from its nuclear power generation, to the production of nuclear weapons. This has to be done in accordance with an individual safeguards agreement, concluded between Australia as a non-nuclear-weapon State Party and the International Atomic Energy Agency (IAEA), whereby the nuclear power station, like the ANSTO nuclear site, would be open for audit and inspection.

Supporters of the NPT.

The NPT took effect on March 5, 1970, after being opened for signature on July 1, 1968. Beginning with 43 original parties in 1970, membership increased to 96 in 1975, 132 in 1985, and 178 in 1995. By July 1998, 187 parties had joined the NPT.

Cuba acceded to the treaty on November 4, 2002, thereby becoming the 188th party to the NPT. While the US, the UK and the erstwhile Soviet Union were among the original signatories, France and China joined as late as 1992.

Non-signatories to the treaty.

India, Pakistan, and Israel - have declined to sign the treaty. While India and Pakistan have publicly announced possession of nuclear weapons and have carried out nuclear tests, Israel is also believed to have developed nuclear weapons even though it does not publicly acknowledge or deny it. Because these countries did not detonate a nuclear explosive device before January 1967, they will not be considered NWS under the NPT. This means that if they were to join the treaty, they would have to do so as NNWS, eliminate their nuclear arsenals, and accept comprehensive IAEA inspections on all of their nuclear activities. North Korea initially ratified the treaty, but revoked its signature in 2003 after a dispute over inspections of non-declared nuclear facilities. Iran also signed, but is now believed by some to have violated the provisions of the treaty and to be preparing to make nuclear weapons.

Arguments put forth in favour of and against the NPT.

Critics accuse the NPT of favouring NWS by placing most of the responsibilities of compliance on the NNWS. They contend that it makes them more vulnerable to nuclear aggression or intimidation. Furthermore, some critics claim that the NNWS are economically and industrially disadvantaged in developing nuclear energy for peaceful uses, since the treaty does not require the NWS to accept IAEA safeguards. They also argue that the nuclear non-proliferation pledges and safeguards are ineffectual.

Proponents of the NPT assert that the treaty is a cooperative mechanism for ensuring greater international stability and security. They also note that the treaty establishes norms and verification mechanisms that are helping to control non-compliance.

Present concerns regarding NPT.

Besides North Korea, the NWS are concerned with Iran's potential to develop nuclear weapons.

Article VI and the preamble indicate the NWS parties should pursue reduction and liquidation of their stockpiles. This has remained little more than a promise.

The policies of the US, in particular, have been a significant setback to the disarmament agenda. The US has turned away from a number of elements of the 1995 NPT Review and Extension Conference and the 2000 NPT Review Conference. One major loophole in the NPT is that uranium enrichment is used world-wide to produce nuclear fuel. This is only a small step away from developing nuclear warheads, and this can be done in secret or by withdrawing from the NPT. The NPT treaty parties meet next in May 2005 in a Review Conference (which happens every five years).

Australia's Safeguards Policy.

Australia's uranium is sold for exclusively peaceful purposes, namely electric power generation and related research and development activities. The main components of Australia's safeguards policy are:

1. Careful selection of those countries eligible for the supply of Australian uranium: In the case of non-nuclear-weapons States, sales are made only to countries which are parties to the NPT. These have renounced the nuclear weapons option and accept full-scope IAEA safeguards applying to all their nuclear-related activities; In the case of nuclear weapons States, which must also be parties to the NPT, sales require an assurance that uranium will not be diverted to military or explosive purposes and that it will be subject to IAEA safeguards.
2. Countries wishing to import Australian uranium must conclude a bilateral safeguards agreement with Australia. Provisions include: prior Australian consent to any Australian obligated nuclear material (AONM) being transferred to a third party, enriched beyond 20% uranium-235, or reprocessed. Transfers are permitted only within Australia's network of bilateral safeguards. Fallback safeguards (contingency arrangements to ensure the continued safeguarding of material already present in an importing country in case safeguards under the NPT ever cease to apply);
3. Strong support for the NPT and IAEA safeguards, including the Additional Protocol, with IAEA monitoring to apply.

When adopted in 1977, this was a more rigorous safeguards policy than that of any country supplying uranium to world markets. However, the approach is very similar to that of the USA and Canada.

Australia has 14 bilateral safeguards agreements covering 24 countries (the Euratom agreement covering several). It has always taken the position that rigorous bilateral safeguards are an important and effective complement to the international safeguards system.

Australia's position as a major uranium exporter is influential in the ongoing development of international safeguards and other non-proliferation measures, through membership of the IAEA Board of Governors, participation in international expert groups and its safeguards research program in support of the IAEA.

The Australian Safeguards & Non-Proliferation Office (ASNO) operates the system of bilateral safeguards applying to Australian uranium exports based on customer countries being parties to the NPT. It also administers the domestic safeguards system required by Australia's own NPT agreement with the IAEA.

In addition, ASNO keeps account of nuclear material and associated items in Australia through its administration of the Nuclear Non-Proliferation (Safeguards) Act

1987. ASNO provides information to the IAEA on the small amount of nuclear material in Australia which is subject to safeguards, and on uranium exports. It also facilitates IAEA inspections, including those under the Additional Protocol.

ASNO could expand its activities to cover the NPT requirements of the Australian nuclear power station should it be decided to build such a facility.

Australia has in place an accounting system that follows uranium from the time it is produced and packed for export, to the time it is reprocessed or stored as nuclear waste, anywhere in the world. It also includes plutonium which is in the spent fuel or recovered from it. All documentation relating to AONM is carefully monitored and any apparent discrepancies are taken up with the country concerned. There have been no unreconciled differences in accounting for AONM. This system operates in addition to safeguards applied by the IAEA which keep track of the movement of nuclear materials through overseas facilities and verify inventories.

One aspect of the accounting system is the possibility of obligation exchanges involving equivalent nuclear material held by a single utility or between different utilities. Exchanges are permitted, to simplify accounting and surveillance, provided that they do not result in reducing either the quality or quantity of material subject to Australian safeguards obligations. In low-enriched uranium the focus is on U-235 content.

Each year the ASNO reports to the Australian Parliament on its activities and its accounts of nuclear materials.

The NPT.

The essential features of the IAEA Non Proliferation Treaty and some additional comments on its relevance to Australia are as follows:

INFCIRC/140
22 April 1970
International Atomic Energy Agency

Treaty On The Non-Proliferation Of Nuclear Weapons

ARTICLE I
Each nuclear-weapon State Party to the Treaty undertakes not to transfer to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices directly, or indirectly; and not in any way to assist, encourage, or induce any non-nuclear-weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices.

ARTICLE II

Each non-nuclear-weapon State Party to the Treaty (this is what Australia would become if she built a nuclear power station) undertakes not to receive the transfer from any transferor whatsoever of nuclear weapons or other nuclear explosive devices or of control over such weapons or explosive devices directly, or indirectly; not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices; and not to seek or receive any assistance in the manufacture of nuclear weapons or other nuclear explosive devices.
Comment: It is this Article that is cited by the IAEA when criticising Iran for building an enrichment plant without telling the IAEA that it intended to do so. Such a plant can easily be used to make bomb-grade U235.

ARTICLE III

1. Each Non-nuclear-weapon State Party to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency in accordance with the Statute of the International Atomic Energy Agency and the Agency's safeguards system, for the exclusive purpose of verification of the fulfilment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices. Procedures for the safeguards required by this Article shall be followed with respect to source or special fissionable material whether it is being produced, processed or used in any principal nuclear facility or is outside any such facility. The safeguards required by this Article shall be applied on all source or special fissionable material in all peaceful nuclear activities within the territory of such State, under its jurisdiction, or carried out under its control anywhere.
Comment: This means that the Australian nuclear power station would have to be open to inspection by the IAEA.

2. Each State Party to the Treaty undertakes not to provide: (a) source or special fissionable material, or (b) equipment or material especially designed or prepared for the processing, use or production of special fissionable material, to any non-nuclear-weapon State for peaceful purposes, unless the source or special fissionable material shall be subject to the safeguards required by this Article.
Comment: This means that a state that fabricates the nuclear fuel assemblies for the Australian nuclear power station must ensure that it is subject to inspection by the IAEA.

3. The safeguards required by this Article shall be implemented in a manner designed to comply with Article IV of this Treaty, and to avoid hampering the economic or technological development of the Parties or international co-operation in the field of peaceful nuclear activities, including the international exchange of nuclear material and equipment for the processing, use or production of nuclear material for peaceful purposes in accordance with the provisions of this Article and the principle of safeguarding set forth in the Preamble of the Treaty.

4. Non-nuclear-weapon States Party to the Treaty shall conclude agreements with the International Atomic Energy Agency to meet the requirements of this Article either individually or together with other States in accordance with the Statute of the International Atomic Energy Agency. Negotiation of such agreements shall

commence within 180 days from the original entry into force of this Treaty. For States depositing their instruments of ratification or accession after the 180-day period, negotiation of such agreements shall commence not later than the date of such deposit. Such agreements shall enter into force not later than eighteen months after the date of initiation of negotiations.
Comment: A number of neighbouring States have entered into collective agreements effectively to "police" each other's nuclear activities. Australia might agree to do this with Japan or China, for example.

ARTICLE IV

1. Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II of this Treaty.
2. All the Parties to the Treaty undertake to facilitate, and have the right to participate in. the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy. Parties to the Treaty in a position to do so shall also cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world.

Comment: Australia would, if it built a nuclear power station, wish to join a number of international collaborations on the development of new designs of nuclear reactor etc and is encouraged to do so by this Article.

ARTICLE V

Each Party to the Treaty undertakes to take appropriate measures to ensure that, in accordance with this Treaty, under appropriate international observation and through appropriate international procedures, potential benefits from any peaceful applications of nuclear explosions will be made available to non-nuclear-weapon States Party to the Treaty on a non-discriminatory basis and that the charge to such Parties for the explosive devices used will be as low as possible and exclude any charge for research and development. Non-nuclear weapon States Party to the Treaty shall be able to obtain such benefits, pursuant to a special international agreement or agreements, through an appropriate international body with adequate representation of non-nuclear-weapon States. Negotiations on this subject shall commence as soon as possible after the Treaty enters into force. Non-nuclear-weapon States Party to the Treaty so desiring may also obtain such benefits pursuant to bilateral agreements.

ARTICLE VI

Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control.

ARTICLE VII

Nothing in this Treaty affects the right of any group of States to conclude regional treaties in order to assure the total absence of nuclear weapons in their respective territories.

ARTICLE VIII

1. Any Party to the Treaty may propose amendments to this Treaty. The text of any proposed amendment shall be submitted to the Depositary Governments which shall circulate it to all Parties to the Treaty. Thereupon, if requested to do so by one-third or more of the Parties to the Treaty, the Depositary Governments shall convene a conference, to which they shall invite all the Parties to the Treaty, to consider such an amendment.
2. Any amendment to this Treaty must be approved by a majority of the votes of all the Parties to the Treaty, including the votes of all nuclear-weapon States Party to the Treaty and all other Parties which, on the date the amendment is circulated, are members of the Board of Governors of the International Atomic Energy Agency. The amendment shall enter into force for each Party that deposits its instrument of ratification of the amendment upon the deposit of such instruments of ratification by a majority of all the Parties, including the instruments of ratification of all nuclear-weapon States Party to the Treaty and all other Parties which, on the date the amendment is circulated, are members of the Board of Governors of the International Atomic Energy Agency. Thereafter, it shall enter into force for any other Party upon the deposit of its instrument of ratification of the amendment.
3. Five years after the entry into force of this Treaty, a conference of Parties to the Treaty shall be held in Geneva, Switzerland, in order to review the operation of this Treaty with a view to assuring that the purposes of the Preamble and the provisions of the Treaty are being realised. At intervals of five years thereafter. a majority of the Parties to the Treaty may obtain, by submitting a proposal to this effect to the Depositary Governments, the convening of further conferences with the same objective of reviewing the operation of the Treaty.

ARTICLE IX

1. This Treaty shall be open to all States for signature. Any State which does not sign the Treaty before its entry into force in accordance with paragraph 3 of this Article may accede to it at any time.
2. This Treaty shall be subject to ratification by signatory States. Instruments of ratification and instruments of accession shall be deposited with the Governments of the United Kingdom of Great Britain and Northern Ireland, the Union of Soviet Socialist Republics and the United States of America, which are hereby designated the Depositary Governments.
3. This Treaty shall enter into force after its ratification by the States, the Governments of which are designated Depositaries of the Treaty, and forty other States signatory to this Treaty and the deposit of their instruments of ratification. For the purposes of this Treaty, a nuclear weapon State is one which has manufactured and exploded a nuclear weapon or other nuclear explosive device prior to 1 January, 1967.

4. For States whose instruments of ratification or accession are deposited subsequent to the entry into force of this Treaty, it shall enter into force on the date of the deposit of their instruments of ratification or accession.
5. The Depositary Governments shall promptly inform all signatory and acceding States of the date of each signature, the date of deposit of each instrument of ratification or of accession, the date of the entry into force of this Treaty, and the date of receipt of any requests for convening a conference or other notices.
6. This Treaty shall be registered by the Depositary Governments pursuant to Article 102 of the Charter of the United Nations.

ARTICLE X

1. Each Party shall in exercising its national sovereignty have the right to withdraw from the Treaty if it decides that extraordinary events, related to the subject matter of this Treaty, have jeopardized the supreme interests of its country. It shall give notice of such withdrawal to all other Parties to the Treaty and to the United Nations Security Council three months in advance. Such notice shall include a statement of the extraordinary events it regards as having jeopardized its supreme interests.
2. Twenty-five years after the entry into force of the Treaty, a conference shall be convened to decide whether the Treaty shall continue in force indefinitely, or shall be extended for an additional fixed period or periods. This decision shall be taken by a majority of the Parties to the Treaty.

ARTICLE XI

This Treaty, the English, Russian, French, Spanish and Chinese texts of which are equally authentic, shall be deposited in the archives of the Depositary Governments. Duly certified copies of this Treaty shall be transmitted by the Depositary Governments to the Governments of the signatory and acceding States.

AT WHAT STAGE SHOULD AUSTRALIA JOIN THE GENERATION IV REACTOR FORUM?

Australia should join the Generation IV Forum, GIF, since GIF's interests coincide with those of Australia.

Thus Australia's concerns over energy resource availability, climate change, air quality, and energy security suggest an important role for nuclear power in Australia's future energy supplies. While the current Generation II and III nuclear power plant designs provide a secure and low-cost electricity supply in many markets, further advances in nuclear energy system design can broaden the opportunities for the use of nuclear energy. To explore these opportunities, the U.S. Department of Energy's Office of Nuclear Energy, Science and Technology has engaged governments, industry, and the research community worldwide in a wide ranging discussion on the development of next generation nuclear energy systems known as **"Generation IV"**.

It could well be that, by the time Australia is ready to use nuclear power for part of its electricity generation, one or more of these Generation IV designs will be sufficiently advanced to merit consideration. Even if it is not, engagement with the GIF will give Australian nuclear specialists an unrivalled opportunity to collaborate with the world's leading reactor-development engineers and scientists and this will ready them to give good advice to the Australian Government on the type of plant to choose should Australia decide on the nuclear option.

The Generation IV International Forum (GIF) representing ten countries has announced the selection of six reactor technologies which they believe represent the future shape of nuclear energy. These are selected on the basis of being clean, safe and cost-effective means of meeting increased energy demands on a sustainable basis, while being resistant to diversion of materials for weapons proliferation and secure from terrorist attacks. They will be the subject of further development internationally.

The GIF was initiated in 2000 and formally chartered in mid 2001. It is an international collective representing governments of countries where nuclear energy is significant now and also seen as vital for the future. They are committed to joint development of the next generation of nuclear technology. Led by the USA, Argentina, Brazil, Canada, France, Japan, South Korea, South Africa, Switzerland, and the UK are members of the GIF, along with the EU, Figure 60.

Figure 60: The Countries that comprise the Generation IV Forum, GIF.

In addition to selecting six reactor concepts for deployment between 2010 and 2030, the GIF recognised a number of International Near-Term Deployment advanced reactors available before 2015.

Most of the six systems employ a closed fuel cycle to maximise the resource base and minimise high-level wastes to be sent to a repository. Three of the six are fast reactors and one can be built as a fast reactor, one is described as epithermal, and only two operate with slow neutrons like today's plants.

Only one is cooled by light water, two are helium-cooled and the others have lead-bismuth, sodium or fluoride salt coolant. The latter three operate at low pressure, with significant safety advantage. The last has the uranium fuel dissolved in the circulating coolant. Temperatures range from 510°C to 1000°C, compared with less than 330°C for today's light water reactors, and this means that four of them can be used for thermochemical hydrogen production.

The sizes range from 150 to 1500 MWe (or equivalent thermal) , with the lead-cooled one optionally available as a 50-150 MWe "battery" with long core life (15-20 years without refuelling) as replaceable cassette or entire reactor module. This is designed for distributed generation or desalination.

At least four of the systems have significant operating experience already in most respects of their design, which may mean that they can be in commercial operation well before 2030.

In February 2005 five of the participants signed an agreement to take forward the R&D on the six technologies. The USA, Canada, France, Japan and UK agreed to undertake joint research and exchange technical information.

While Russia is not a part of GIF, one design corresponds with the BREST reactor being developed there, and Russia is now the main operator of the sodium-cooled fast reactor for electricity - another of the technologies put forward by the GIF.

India is also not involved with the GIF but is developing its own advanced technology to utilise thorium as a nuclear fuel. A three-stage program has the first stage well-established, with Pressurised Heavy Water Reactors (PHWRs, elsewhere known as CANDUs) fuelled by natural uranium to generate plutonium. Then Fast Breeder Reactors (FBRs) use this plutonium-based fuel to breed U-233 from thorium, and finally advanced nuclear power systems will use the U-233. The spent fuel will be reprocessed to recover fissile materials for recycling. The two major options for the third stage, while continuing with the PHWR and FBR programs, are an Advanced Heavy Water Reactor and subcritical Accelerator-Driven Systems.

Table 22 : Agenda for GIF Meeting, Reno, Nevada, USA, June 4th to 8th 2006.

EMBEDDED TOPICAL MEETING: Nuclear Fuels and Structural Materials for the Next Generation Nuclear Reactors

EMBEDDED TOPICAL MEETING

Nuclear Fuels and Structural Materials for the Next Generation Nuclear Reactors

June 4–8, 2006 • Reno, Nevada • Reno Hilton

Embedded Topical Meeting Chairs

General Chairs

Lance Snead, *Oak Ridge National Laboratory*
Dave Petti, *Idaho National Laboratory*
Madeline Feltus, *U.S. Department of Energy*
Todd Allen, *University of Wisconsin*

Technical Program Chairs

Timothy Burchell, *Oak Ridge National Laboratory*
John Carmack, *Idaho National Laboratory*
Bill Corwin, *Oak Ridge National Laboratory*
Doug Crawford, *Idaho National Laboratory*
Kathryn McCarthy, *Idaho National Laboratory*
Timothy McGreevy; *Oak Ridge National Laboratory*
Kemal Pasamehmetoglu, *Idaho National Laboratory*
Steve Zinkle, *Oak Ridge National Laboratory*

Paper Deadlines

SUMMARIES DUE:	*January 6, 2006*
AUTHOR NOTIFICATION OF ACCEPTANCE:	*By February 21, 2006*
REVISED SUMMARIES DUE:	*March 7, 2006*

Electronic Submission of Abstracts

Authors are now REQUIRED to use the ANS Template and "Guidelines for TRANSACTIONS Summary Preparation" provided on the ANS Web site at www.ans.org/pubs/transactions. Summaries must be submitted electronically using Adobe Acrobat (PDF) files and original Microsoft Word documents and the ANS Electronic Submission System. Summaries not based on the ANS Template will be REJECTED. Submit a summary at www.ans.org/meetings.

About the Meeting

The Generation IV International Forum (GIF) has selected six advanced systems for consideration: the Gas-Cooled Fast Reactor System (GFR), Lead-Cooled Fast Reactor System (LFR), Molten Salt Reactor System (MSR), Sodium-Cooled Fast Reactor System (SFR), Supercritical Water-Cooled Reactor System (SCWR), and Very-High-Temperature Reactor System (VHTR). All Generation IV systems project in-service and off-normal temperatures that are beyond current nuclear industry experience. All require relatively long service lifetimes for materials and relatively high burnup capability for fuels. Most systems call for use of fast and epithermal neutron spectra, which will challenge materials performance with increased radiation damage. Fuels and materials that meet the requirements of Generation IV systems must be identified, and databases sufficient to support design and licensing must be established. Generation IV systems will require deployment of materials and components operating under new conditions. Therefore, codes and standards must be established for their use. To develop materials for the Generation IV systems, a broad-based materials research and development program has been initiated in the GIF initial development of the systems. This embedded topical will bring together fuels and materials experts in all areas of Generation IV technologies.

Topics

1. Fuels and Materials for Very-High-Temperature Reactors (VHTR)
2. Fuels and Materials for Gas-Cooled Fast Reactors (GFR)
3. Fuels and Materials for Supercritical Water-Cooled Reactors (SCWR)
4. Fuels and Materials for Lead-Cooled Fast Reactors (LFR)
5. Fuels and Materials for Sodium-Cooled Fast Reactors (SFR)
6. Fuels and Materials for Molten Salt-Cooled Reactors (MSR)
7. High-Temperature Design Methodology
8. Microstructural Modeling
9. Materials for Radiation Service

Table 22 gives details of the topics to be debated at the next meeting of GIF, which is in Reno, Nevada, USA on June 4th to 8th, 2006.

GIF Reactor technologies:

Gas-cooled fast reactors.

These are like other helium-cooled reactors which have operated or are under development, these will be high-temperature units - 850°C, suitable for power generation, thermochemical hydrogen production or other process heat. For electricity, the gas will directly drive a gas turbine (Brayton cycle). Fuels would include depleted uranium and any other fissile or fertile materials. Spent fuel would be reprocessed on site and all the actinides recycled to minimise production of long-lived radioactive wastes. While General Atomics worked on the design in the 1970s (but not as fast reactor), none has so far been built.

Lead-cooled fast reactors.

In these reactors, Liquid metal (Pb or Pb-Bi) cooling is by natural convection. Fuel is depleted uranium metal or nitride, with full actinide recycle from regional or central reprocessing plants. A wide range of unit sizes is envisaged, from factory-built "battery" with 15-20 year life for small grids or developing countries, to modular 300-400 MWe units and large single plants of 1400 MWe. Operating temperature of 550°C is readily achievable but 800°C is envisaged with advanced materials and this would enable thermochemical hydrogen production. This corresponds with Russia's BREST fast reactor technology which is lead-cooled and builds on 40 years experience of lead-bismuth cooling in submarine reactors. Its fuel is U+Pu nitride. More immediately the GIF proposal appears to arise from two experimental designs: the US STAR and Japan's LSPR, these being lead and lead-bismuth cooled respectively.

Molten salt reactors.

Here the uranium fuel is dissolved in the sodium fluoride salt coolant which circulates through graphite core channels to achieve some moderation and an epithermal neutron spectrum. Fission products are removed continuously and the actinides are fully recycled, while plutonium and other actinides can be added along with U-238. Coolant temperature is 700°C at very low pressure, with 800°C envisaged. A secondary coolant system is used for electricity generation, and thermochemical hydrogen production is also feasible.

During the 1960s the USA developed the molten salt breeder reactor as the primary back-up option for the conventional fast breeder reactor and a small prototype was operated. Recent work has focused on lithium and beryllium fluoride coolant with dissolved thorium and U-233 fuel. The attractive features of the MSR fuel cycle include: the high-level waste comprising fission products only, hence shorter-lived radioactivity; small inventory of weapons-fissile material (Pu-242 being the dominant Pu isotope); low fuel use (the French self-breeding variant claims 50kg of thorium and 50kg U-238 per billion kWh); and safety due to passive cooling up to any size.

Sodium-cooled fast reactors.

This builds on more than 300 reactor-years experienced with fast neutron reactors over five decades and in eight countries. It utilises depleted uranium in the fuel and has a coolant temperature of 550°C enabling electricity generation via a secondary sodium circuit, the primary one being at near atmospheric pressure. Two variants are proposed: a 150-500 MWe type with actinides incorporated into a metal fuel requiring pyrometallurgical processing on site, and a 500-1500 MWe type with conventional MOX fuel reprocessed in conventional facilities elsewhere.

Supercritical water-cooled reactor.

This is a very high-pressure water-cooled reactor which operates above the thermodynamic critical point of water to give a thermal efficiency about one third higher than today's light water reactors from which the design evolves. The supercritical water (25 MPa and 510-550°C) directly drives the turbine, without any secondary steam system. Passive safety features are similar to those of simplified boiling water reactors. Fuel is uranium oxide, enriched in the case of the open fuel cycle option. However, it can be built as a fast reactor with full actinide recycle based on conventional reprocessing. Most research on the design has been in Japan.

Very high-temperature gas reactors.

These are graphite-moderated, helium-cooled reactors, based on substantial experience . The core can be built of prismatic blocks such as the Japanese HTTR and the GTMHR that is under development by General Atomics. Alternatively it may be pebble bed such as the Chinese HTR-10 and the PBMR under development in South Africa, with international partners. Outlet temperature of 1000°C enables thermochemical hydrogen production via an intermediate heat exchanger, with electricity cogeneration, or direct high-efficiency driving of a gas turbine (Brayton cycle). There is some flexibility in fuels, but no recycle. Modules of 600 MW thermal are envisaged.

Table 23: Features of Generation IV nuclear reactors.

	neutron spectrum (fast/ thermal)	coolant	temperature (°C)	pressure *	fuel	fuel cycle	size(s) (MWe)	uses
Gas-cooled fast reactors	fast	helium	850	high	U-238 +	closed, on site	288	electricity & hydrogen
Lead-cooled fast reactors	fast	Pb-Bi	550-800	low	U-238 +	closed, regional	50-150** 300-400	electricity & hydroge

							1200	n
Molten salt reactors	epithermal	fluoride salts	700-800	low	UF in salt	closed	1000	electricity & hydrogen
Sodium-cooled fast reactors	fast	sodium	550	low	U-238 & MOX	closed	150-500 500-1500	electricity
Supercritical water-cooled reactors	thermal or fast	water	510-550	very high	UO2	open (thermal) closed (fast)	1500	electricity
Very high temperature gas reactors	thermal	helium	1000	high	UO2 prism or pebbles	open	250	hydrogen & electricity

* high = 7-15 Mpa
+ = with some U-235 or Pu-239 ** 'battery' model with long cassette core life (15-20 yr) or replaceable reactor module.
Sources:
DOE 19/9/02.
DOE EIA 2003 New Reactor Designs.

GLOBAL WARMING

Australia as a Member of the Asia Pacific Partnership on Clean Development and Climate.

Australia needs to consider building nuclear power stations in order to fulfil the obligations that it has made to the Asia Pacific Partnership on Clean Development and Climate, formed between Australia, China, India, Japan, the Republic of Korea and the United States.

Growing global demand for energy means that technology must play a critical role in any significant reduction in global greenhouse gas emissions. In this context, the Partnership intends to play a strategically important role in the development, deployment and transfer of more energy efficient and cleaner technologies to curb emissions while at the same time enhancing the growth prospects of economies[48].

In 2001 around 40 per cent of global carbon dioxide emissions were generated by the electricity sector. Emissions from electricity generation in partnership economies accounted for about 17 per cent of global greenhouse gas emissions and about 22 per cent of global carbon dioxide emissions.

The purpose of a recent study, produced for the Partnership, is to assess the potential economic, environmental and energy consumption effects of possible action on the development and deployment of *clean technologies* under the partnership.

The results of this study indicate that widespread adoption of advanced, energy efficient technologies among partnership economies could potentially reduce the overall importance, in the medium to long term, of oil, coal and gas in energy consumption and the electricity fuel mix, *while increasing the importance of nuclear power* and non-hydro renewables.**Error! Bookmark not defined.**

The study foresees an increase in the demand for renewables and nuclear power capacity over the projection period. Typically, the Partnership countries' demand for renewables and nuclear power increases by about 285 gigawatts and 162 gigawatts respectively over the projection period, relative to the reference case. Assuming a nuclear plant size of 1500 megawatts, this implies that an additional 110 nuclear plants are needed in partnership economies in the partnership technology + Carbon Capture & Sequestration scenario relative to the reference case.

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[48] Technological Development and Economic Growth. Inaugural Ministerial Meeting of the Asia Pacifi c Partnership on Clean Development and Climate Sydney, 11–13 January ABARE research report 06.1. Brian S. Fisher, Melanie Ford, Guy Jakeman, Andrew Gurney, Jammie Penm, Anna Matysek and Don Gunasekera. January 2006

The US Department of Energy Five-Laboratory Study.

An analysis by a working group of staff from five US Department of Energy national laboratories projected that between 40,000 and 80,000 MW of renewable generating capacity could be added to the US electricity mix by 2010 for under $50 per ton of carbon (or about $14 per ton of carbon dioxide) [49]. This would increase the market share of renewables by 5 percent to 10 percent of total generation. A US$50-per-ton charge is equivalent to adding 0.5 US¢/kWh to the cost of natural gas-generated power and 1.3US¢/kWh to coal-generated power.

One conclusion of the USDOE laboratories' research was that renewables are necessary for greenhouse gas reductions. "While aggressive energy efficiency and fuel switching can reduce domestic carbon emissions to approximately 1990 levels by 2010, controlling or reducing carbon emissions beyond that date will require greater energy contributions from low-carbon technologies such as renewables."

We may take it that nuclear power may be included in these “renewables” since it adds nothing to global warming.

Kyoto.

The Kyoto Protocol took effect on February 16, 2005, 90 days after it was ratified by the Russian Parliament. Russia was the last industrialized country to join the protocol, leaving only the United States and Australia among industrialized countries on the outside.

Position of Australia.

Australia has refused to sign the Kyoto Agreement due to issues with the protocol. The Australian Prime Minister, John Howard, has argued that the protocol would cost Australians jobs, and that Australia is already doing enough to cut emissions. The Federal Opposition, the Australian Labour Party is in full support of the protocol and it is currently a heavily debated issue within the political establishment. The opposition claims signing the protocol is a "risk free" prospect as they claim Australia would already be meeting the obligations the protocol would impose. As of 2000, Australia was the world's eleventh largest emitter per capita of greenhouse gases.

[49] Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies, *Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond*, Oak Ridge, Lawrence Berkeley, Argonne, Pacific Northwest, National Renewable Energy Laboratory, 1997, on line at www.ornl.gov/ORNL/Energy_Eff/CON444.

The Australian government, along with the United States, agreed to sign the Asia Pacific Partnership on Clean Development and Climate at the ASEAN regional forum on 28 July 2005.

Kyoto Mechanisms and Targets.

The current Kyoto target is to cut in greenhouse gas emissions by at least five percent below 1990 levels. This target must be met between 2008 and 2012, the protocol's first commitment period.

The Intergovernmental Panel on Climate Change (IPCC), which brings together 2,500 of the world's climate experts, projected in its Third Assessment Report in 2001 that the globally averaged surface temperature will increase by between 1.4 and 5.8 degrees Celsius from 1990 to 2100 under a business-as-usual scenario. This projected change is larger than any climate change experienced over the last 10,000 years. The rise in temperature is linked with the emission of greenhouse gases from the burning of fossil fuels and other human activities.

A total of 160 Parties to the Kyoto Protocol have now ratified it, including the most populous developing countries China and India, but only 34 countries and the European Union have legally binding targets to reduce emissions of the six greenhouse gases.

At a UN climate conference held in Montreal in November 2005, officials finalized the protocol's rule book. The rule book detailed three market-based mechanisms for reducing emissions, known as the Kyoto flexible mechanisms

1. **Emissions tradin**g between governments with Kyoto targets,
2. The **Clean Development Mechanism, CD**M and
3. **Joint Implementation**.

Dealing with each of these in turn:

The Emissions Trading Scheme.

The relatively straightforward **Emissions Trading** scheme, involving the 38 largest industrial economies, excludes nonsignatories, namely the U.S. and A*ustralia*. Through this scheme, credits are allocated among countries in proportion to their 1990 emissions and are, in turn, distributed free of charge among leading industrial players in each country. Europe has already set up a system that has allocated tradable carbon credits to an estimated 9,000 industrial installations. The British component alone, 3-5 percent of the estimated world total, is valued at more than 5 billion euros a year. Since Russia's industrial production has dramatically declined since 1990, with energy production falling by 30 percent, several European countries are banking on meeting their Kyoto obligations largely by investing in excess Russian credits. The mainstay of the carbon market is the European Union's *Emissions Trading System* (ETS). This was set up to help the 25-nation EU meet its obligation under Kyoto to bring greenhouse gas emissions down to a level 8% lower than the 1990 levels, by between 2008 and 2012. It covers around 11,500 EU firms, which account for about half of the CO2 emissions of the 25 member states. These huge burners of fossil fuels – mainly steel makers, cement producers and the paper industry – have to meet an individual target for reducing CO2 output. *The ETS penalty is 40 euros for every tonne emitted beyond this threshold, which will rise to 100 euros in 2008.* Those who are below their quotas can sell the remainder to other firms who are above their quota – in other words, a classic financial carrot-and-stick to encourage a carbon cleanup.

Now CO2 is one of the world's fastest-growing markets and will be worth as much as 34bn euros ($40.2bn) annually by the end of this decade. In 2004, the global volume of trade in CO2 was just 94mn tonnes. In 2005, it rose to 800mn tonnes. In January 2006 alone, the figure was more than 262mn tonnes for spot trading among European players alone. In March 2005 a tonne of CO2 sold for seven or eight euros ($8-$9) on the spot market. Now a tonne is changing hands at more than 26 euros ($31.2) – a huge profit for anyone who had the foresight to buy futures before the Protocol took effect.

Powernext Carbon, a venture combining the merged continental European stock market bourse Euronext and a French state financial institution, Caisse des Depots, kicked off with six players in June 2005. Now it has 33, including banks that act as trading intermediaries. Trades concluded in January 2006 amounted to 1.9mn tonnes of CO2, a record, after 1.3mn tonnes in December 2005.

Other Kyoto countries, such as Japan and Canada, have also been mulling carbon markets, although the outlook for the Canadian initiative is uncertain after the election of the Conservative Party, which has been critical of Kyoto in the past.

The US is not directly concerned by the Kyoto Protocol because President George W Bush rejected the draft treaty in 2001, saying its binding commitments were too costly for the oil-dependent US economy. At US federal level, the Senate last year passed a non-binding resolution calling for "mandatory, market-based limits and incentives".

The Clean Development Mechanism.

The **Clean Development Mechanism** allows the Kyoto industrialized countries to invest in sustainable development projects in developing countries, thereby earning carbon credits. Christine Zumkeller, coordinator of the Mechanisms Programme, says the Clean Development Mechanism could generate more than 700 million metric tons of emission reductions by the end of 2012. “This is almost as much as the annual greenhouse gas emissions of Canada,” she said. Originally these credits were to be funded with penalties levied on countries that failed to meet emissions reduction goals, but this provision was dropped in negotiations subsequent to Kyoto. Under CDM development projects are granted credits based on a comparison of their expected outcome versus a business as usual scenario in which the project is not built. Several ventures around the world have already gained financing coupled to the issuance of carbon credits through a *Prototype Carbon Fund* established in 1999 by the World Bank.

Joint Implementation.

A **Joint Implementation** Supervisory Board was created to oversee the Kyoto mechanism that allows developed countries to invest in clean energy projects in central and eastern European transition economies and others. This Joint Implementation mechanism lets the industrialized countries earn carbon allowances, which they can use to meet their emission reduction commitments.

External Costs in Australia[50].

Ben Maddox of the University of Newcastle, Australia has published an analysis entitled “Integrated assessment for Sustainable Regional Energy Systems. An approach Integrating Life Cycle Analysis” In it he uses the ExternE and Economic Models to calculate the monetary worth of the health effects and global warming due to Macquarie Generation’s Bayswater and Liddell coal fired power stations in NSW, Figure 61. These are amongst the largest power stations in Australia. Liddell and Bayswater are licensed to replace up to 5% of normal coal fuel requirements with waste wood (biomass).

Figure 61:Bayswater and Liddell Power Stations.

Maddox’s conclusions for Health Effects are summarized in Table 24. Table 25 shows the total output of the two coal fired power stations with which the Maddox study was concerned. It follows that the calculated financial cost of these health effects was Aus$ 2.11 per MWh.

Maddox used a value of Aus$ 40 per MWe.h for the financial cost of the global warming produced by these power stations. His figures yield a total external cost of *Aus$ 42/MWe.h* and this is comparable with the Externe figures, for EU countries.

[50] Integrated assessment for Sustainable Regional Energy Systems. An approach Integrating Life Cycle Analysis, ExternE and Economic Models Ben Maddox,
University of Newcastle
Australia.

Table 24: ExternE Estimates of the financial value of the Health Impacts of Bayswater and Liddell Coal Fired Power Stations in Australia.

Population Receptor	Condition	Estimated Cost
Asthma (11.3%)	Bronchodilator	$1,618,714
	Cough	$1,890,816
	Lower respiratory symptoms	$121,155
Children 20%	Chronic Cough	$220,506
Adults 80%	RAD	$4,882,379
	Chronic Bronchitis	$7,365,441
Entire population	Chronic Mortality	$33,622,943
	respiratory hospital admissior	$128,464
	Acute	$1,985,752
Total		$51,836,170

In Table 24, using the methodology of ExterE, Maddox has calculated the monetary equivalent of the harm done to the surrounding population by the emissions from the power stations. These emissions are produced by the production of the amounts of electricity generated in 2002, Table 25.

Table 25:Output of Bayswater and Liddell Coal Fired Power Stations in 2002.

	MWh in 2002
Bayswater	15,250,000
Liddell	9,290,000
Total	24,540,000

NewExternE Results for Germany[51]. [52]

Table 26, Table 27 and Figure 62 summarize the NewEx forecasts for Germany. There are similar figures for France and the UK. These forecasts have been produced by NewEx team-members in Germany, France and the UK. The methodology is the same as that employed by Maddox in his studies of the situation at two of Australia's coal-fired power stations.

Table 26: NewEx Forecasts for Germany Summarized.

Aus cent/kWe.h	Hard Coal		
Mortality, YOLL	0.51		
Of Which TSP		0.09	
Sulphates		0.17	
SO2		0.03	
Nox		0.21	
Morbidity due to TSP, SO2, NOx	0.20		
Particulates	0.46		
Sum of Health costs			1.17
CO2 equiv			2.79
Sum of Health and CO2 costs			3.96

The forecasts health effects that Maddox deduces for the Australian coal-fired power stations are an order of magnitude less damaging than those for Germany, Table 27. This is due in large measure to the much smaller population that is affected by Liddell and Bayswater, compared with that affected by German stations. The population density of Germany is 230 people per square kilometre whilst the population density in the region of Australia most affected by the Liddell and Bayswater power stations averages 50 people per square kilometre.

The difference between the values for CO_2 in Table 27 reflect real differences in current estimates of the damage due to global warming.

[51] ExternE:European Commission, Directorate-General XII, Science, Research and Development. ExternE. Externalities of Energy. Vol XX : National Implementation. Prepared by CIEMAT, ES.
[52] NewExt: New Elements for the Assessment of External Costs from Energy Technologies. Final Report to the European Commission, DG Research, Technological Development and Demonstration (RTD), IER, Germany, ARMINES / ENSMP, France, PSI, Switzerland, Université de Paris I, France, University of Bath, United Kingdom, VITO, Belgium. September 2004.

Table 27 also reveals the fact that the damage due to gas fired power stations, per kWe.h, is lower than that for coal both in terms of health and CO2. Nuclear is the least damaging of all, in this table.

Table 27: Summary of NewExt forecasts for Germany, with figures for Liddell & Bayswater for Comparison.

Aus c/kWe.h	Coal	Coal: Liddell and Bayswater	Gas	Nuclear
Health	1.17	0.21	0.24	0.01
CO2	2.79	4.00	1.02	0.05
Sum	3.96	4.21	1.26	0.06

Figure 62 are plotted the data from Table 27: this shows in a dramatic manner the advantages of nuclear power, as measured by the predicted impact of electricity generation upon health and global-warming.

Figure 62: Figures of Table 27.

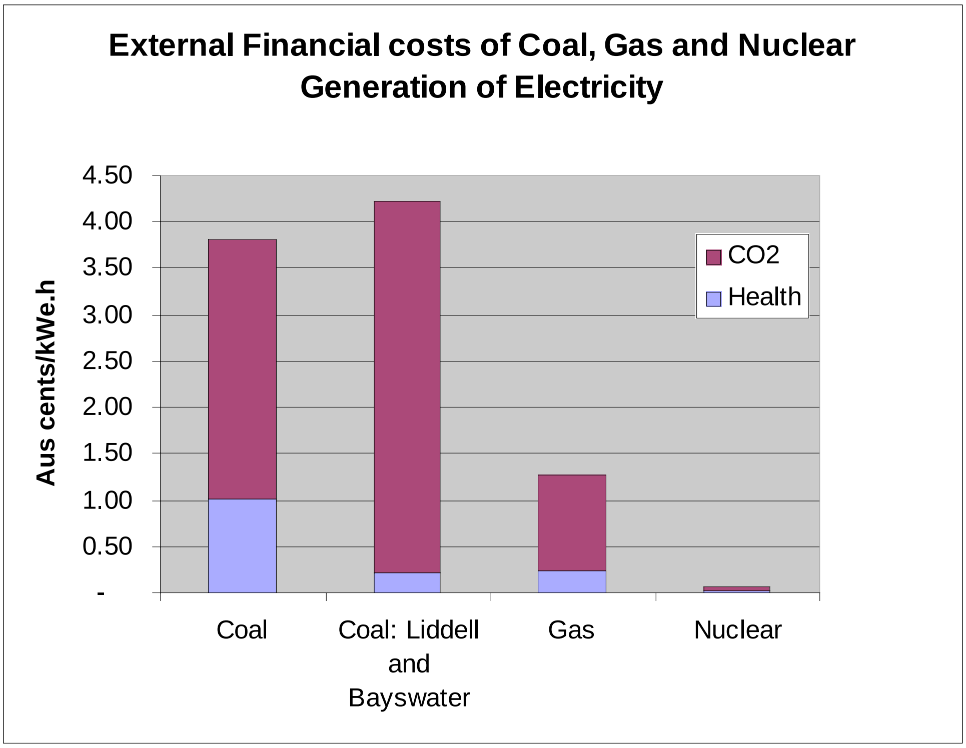
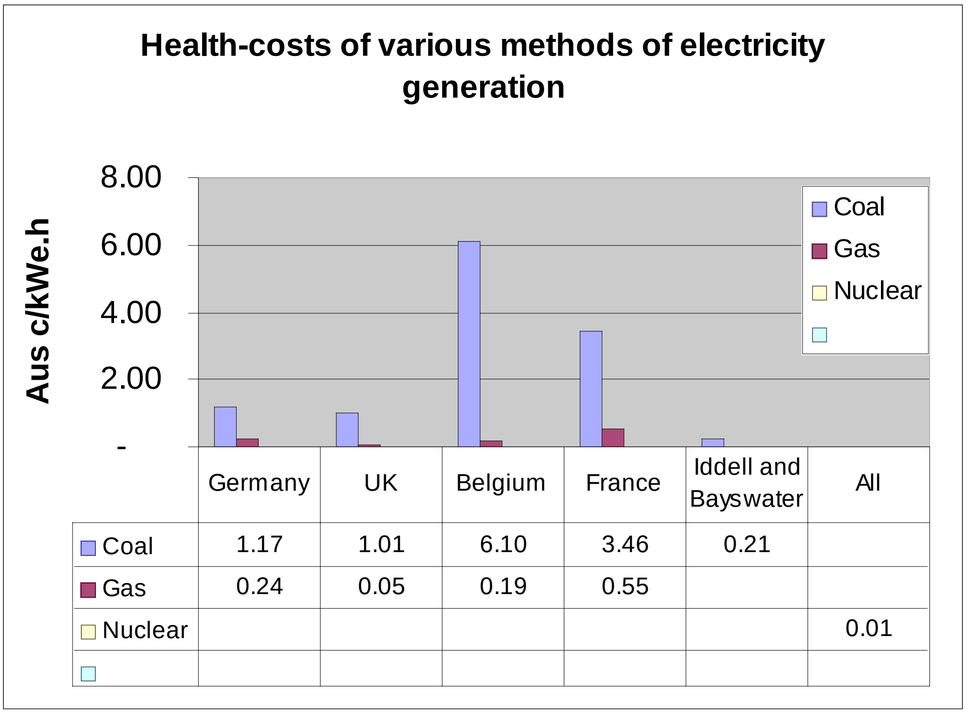
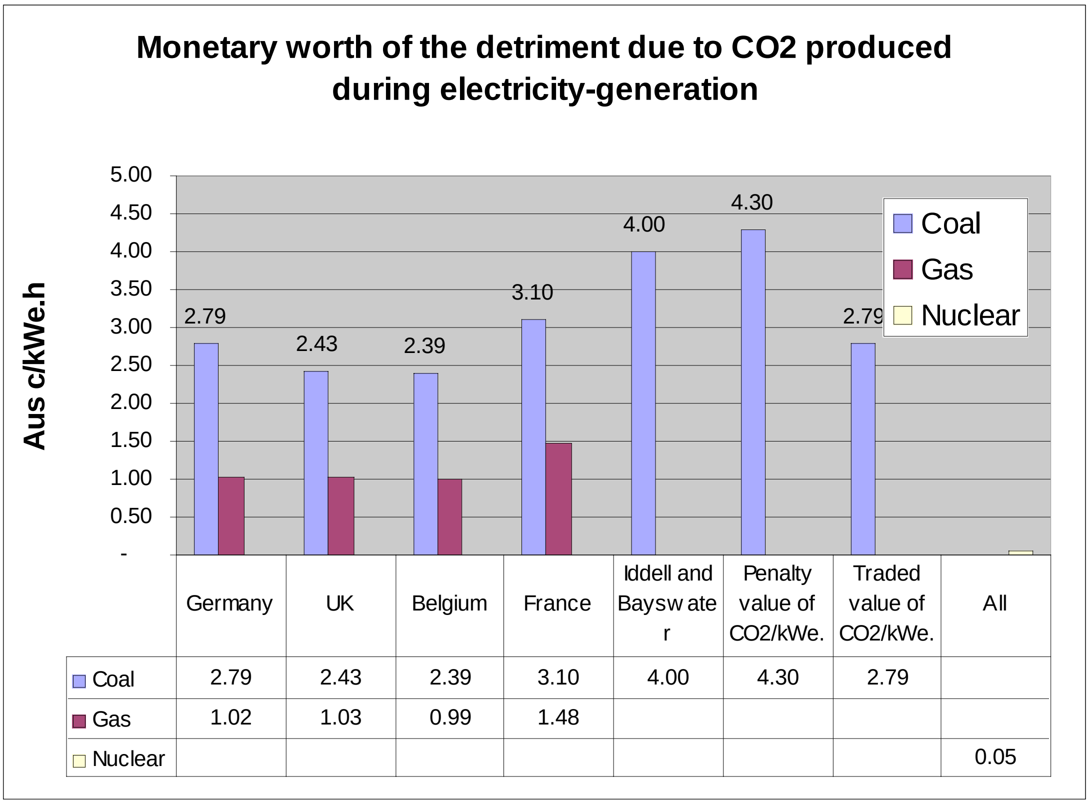


Figure 63: Health costs of various methods of electricity generation: NewExt values for UK, German, France, Belgium and Liddell & Bayswater



In Figure 63 we focus on health effects, comparing Germany, the UK, France, Belgium and Liddell & Bayswater in Australia. The figure of 6.1 Aus c/kWe.h for coal in Belgium is an extreme value for a particular type of hard coal and is included to show the range of values that have emerged from the ExternE and NewExt forecasts. The values for coal in these four European countries, each of which has made its own calculations, range from 1.01 to 6.10 Aus c/kWe.h which may be compared with only 0.21 Aus c/kWe.h for the Australian power stations. It is clear that the value for gas fired generation, in Australia, would be similarly low, compared with the gas-values for the EU, since it is the low population density in Australia that mitigates the total cost of the health effects. We give a single value for nuclear power derived from the ExternE studies of EU countries. It reflects the health effects produced by normal emission of radioactivity from the nuclear power stations and the emissions produced by accidents, including the rare big accidents that can harm many people. It should be noted that accidents are included in the estimation of health effects for gas and coal as well. These accidents, unlike the purely hypothetical nuclear accidents, are well documented and have already been discussed in this Report, Figure 39 etc.

Figure 64:Monetary worth of the detriment due to CO2 produced during electricity generation, in Europe and Australia. (1 kWe.h generated from coal produces 0.8kg of CO_2.)



	Germany	UK	Belgium	France	Iddell and Bayswate r	Penalty value of CO2/kWe.	Traded value of CO2/kWe.	All
Coal	2.79	2.43	2.39	3.10	4.00	4.30	2.79	
Gas	1.02	1.03	0.99	1.48				
Nuclear								0.05

Turning now to global warming: Figure 64 compares forecasts for the EU countries with that for the Australian power stations. It includes the penalty value of CO2 under the Kyoto Emissions Trading Scheme. The ETS penalty is currently 40 euros for every tonne emitted beyond a quota or threshold, which will rise to 100 euros in 2008. Those who are below their quotas can sell the remainder to other firms who are above their quota – in other words, a classic financial carrot-and-stick to encourage a carbon cleanup.

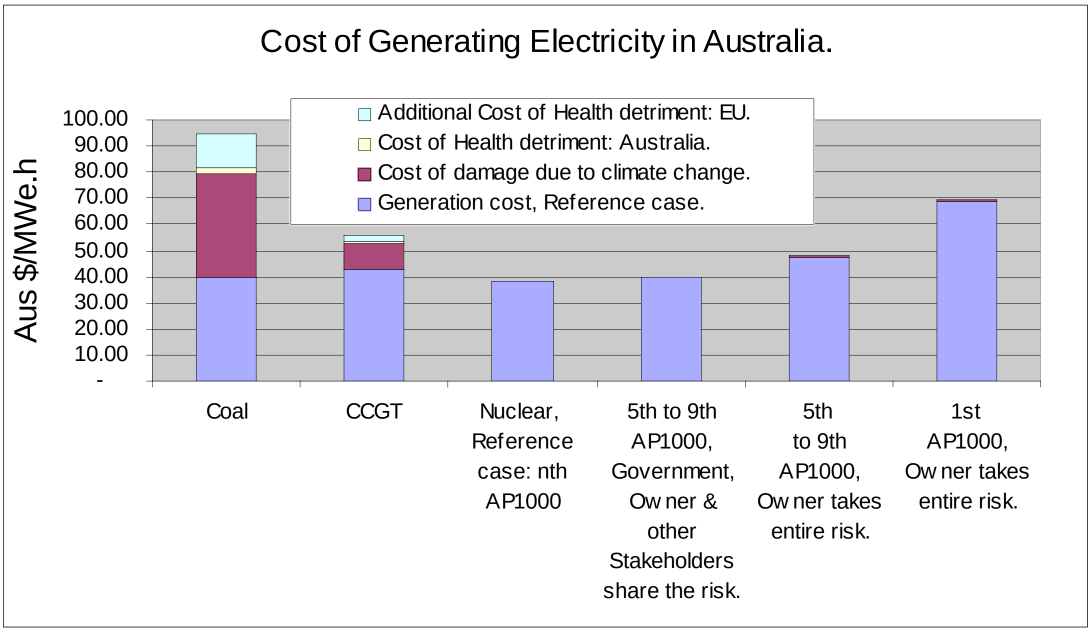
Now CO2 is one of the world's fastest-growing markets and will be worth as much as 34bn euros ($40.2bn) annually by the end of this decade. In 2004, the global volume of trade in CO2 was just 94mn tonnes. In 2005, it rose to 800mn tonnes. In January 2006 alone, the figure was more than 262mn tonnes for spot trading among European players alone. In March 2005 a tonne of CO2 sold for seven or eight euros ($8-$9) on the spot market. Now a tonne is changing hands at more than 26 euros and in Figure 64 we have converted this into the traded value of CO2.

It is clear that the traded value of CO2 is similar to the ExternE values for the harm that it does, through global warming. That is to say the cost of the global warming due to coal-fired power stations is already being factored into the cost of using the electricity that these stations produce, in countries that are actually implementing the Kyoto Protocol and participating in the Emissions Trading Scheme. Australia is not amongst those countries, at present. However if Australia builds a nuclear power station then the electricity that it produces will not contribute to global warming, Figure 64, and so no ETS payments would be required even if Australia ***was*** implementing the Kyoto protocol.

CONCLUDING REMARKS: FORECAST TOTAL COSTS OF GENERATING ELECTRICITY IN AUSTRALIA.

In Figure 65 we bring together our conclusions in the form of costs for the generation of electricity in Australia. From this figure the following conclusions may be drawn:

Figure 65: Forecast total costs of Generating Electricity in Australia.



9. The cost of generating electricity in Australia from the "nth copy" of a nuclear power station such as the AP1000, including financial provision for managing the spent fuel, radioactive wastes and ultimate decommissioning, is cheaper than generating it from coal or a CCGT station. The "nth copy" has settled-down costs, both capital and operating, unlike the first and other early copies which will have "First of a kind" costs.
10. If Australia were to build the world's 5^{th}, 6^{th}, 7^{th}, 8^{th} or 9^{th} AP1000 then the risk of unexpectedly high costs of building and operating the station is higher than for the settled down case. However if this financial risk is shared between the owner, Government and other stakeholders in the manner developed in this Report the cost of the electricity that the station produces will still be no higher than that from new coal or CCGT power stations.
11. If, for the world's 5^{th}, 6^{th}, 7^{th}, 8^{th} or 9^{th} AP1000, the owner takes the entire financial risk, then the nuclear station produces electricity at a cost that is significantly higher than would a new coal fired or CCGT power station. The FOAK risk for the fifth to ninth copy of an AP1000 is reflected in the excess

of the cost of electricity, produced from this power station, over the cost of electricity from the nth AP1000. As we have shown, this risk can be reduced to an acceptably low level by a Government subsidy of 14.31% of the fifth-of-a-kind cost together with a subsidy of 21.41% of the cost of electricity for the first 12 years of operation.

12. If Australia builds the world's first copy of the AP1000, just as Finland has commenced building the world's first copy of the EPR, then it will not be competitive with coal or CCGT power stations. The FOAK risk for the first copy of an AP1000 is reflected in the excess of the cost of electricity, produced from this power station, over the cost of electricity from the nth AP1000. As we have shown, this risk can be reduced to an acceptably low level by a Government subsidy of 53.17% of the first-of-a-kind cost together with a subsidy of 21.41% of the cost of electricity for the first 12 years of operation.
13. The forecast cost of damage to the environment due to the climate change produced by CO2 from a new, Australian coal fired power station is similar in magnitude to the actual cost of generating the electricity. If Australia were to join the Kyoto Emissions Trading Scheme then users of this electricity who exceed their quota would have to pay sums that are similar in magnitude to the climate-change costs that we have here calculated.
14. The 5 measures that Australia currently plans to mitigate global warming will, taken together, reduce Australia's Greenhouse gas emissions by 38 million tons. An equal reduction would be provided by substituting 4 to 5 GWe of nuclear generation for present and planned coal-fired power stations. This could comprise, for example, three AP1000's.
15. The forecast cost of damage to the environment due to the climate change produced by CO2 from a new, Australian CCGT power station is no more than a third that for coal. However our preferred nuclear finance plan, in which stakeholders share the financial risks for a 5th or later copy of an AP1000, is cheaper than CCGT if the total environmental plus generating costs are taken together, as they reasonably might be should Australia sign up to the ETS.
16. The cost of the harm done to people's health by generating electricity from a nuclear power station in Australia is negligible. These health costs are not significant for coal-fired or CCGT generation, either, in Australia. By way of contrast, the health costs for coal-fired generation in EU countries are significant. This is largely due to the higher population and population-density in the EU, compared with Australia.

Annex 1: Offices of the Australian Commonwealth, State and Territory Radiation Safety Authorities.

Commonwealth

Regulatory Branch
ARPANSA
PO Box 655
Miranda NSW 1490
Tel: (02) 9545 8333
Fax: (02) 9545 8348
Email: arpansa@health.gov.au
Internet: http://www.arpansa.gov.au/

Australian Capital Territory

Radiation Safety Section
ACT Dept of Health, Housing & Community Care
GPO Box 825
Canberra ACT 2601
Tel: (02) 6207 6946
Fax: (02) 6207 6966
Email: radiation.safety@act.gov.au

New South Wales

Radiation Control Section
Environment Protection Authority
PO Box A290
Sydney South NSW 1232
Tel: (02) 9995 5481
Fax: (02) 9995 5925
Email: info@epa.nsw.gov.au

Northern Territory

Radiation Health Branch
Department of Health and Community Services
GPO Box 40596
Casuarina NT 0811
Tel: (08) 8999 2983
Fax: (08) 8999 2700

Queensland

Radiation Health
Department of Health
450 Gregory Terrace
Fortitude Valley QLD 4006
Tel: (07) 3406 8000
Fax: (07) 3406 8030
Email: radiation_health@health.qld.gov.au

South Australia

Radiation Protection Division
Environment Protection Authority
PO Box 721, Kent Town
Adelaide SA 5071
Tel: (08) 8130 0700
Fax: (08)8130 0777
Email: RadiationProtection.Branch@state.sa.gov.au
Internet: www.environment.sa.gov.au/epa/radiation.html

Tasmania

Health Physics Branch
Department of Community and Health Services
GPO Box 125B
Hobart TAS 7001
Tel: (03) 6222 7256
Fax: (03) 6222 7257
Email: barbara.shields@dchs.tas.gov.au
Internet: www.dchs.tas.gov.au/services/publichealth/healthradiation/indexrad.html#hp

Victoria

Radiation Safety Section
Department of Hea lth and Community Services
GPO Box 4057
Melbourne VIC 3001
Tel: (03) 9637 4167
Fax: (03) 9637 4508
Email: radiation.safety@dhs.vic.gov.au

Western Australia

Radiation Health Section
Health Department of Western Australia
Locked Bag 2006
Nedlands WA 6009
Tel: (08) 9346 2260
Fax: (08) 9381 1423

Email: radiation.health@health.wa.gov.au
Internet: www.public.health.wa.gov.au/PAGES/RADIATION.HTML

Annex 2: The Westinghouse AP1000 Nuclear Power Reactor.

The AP1000 is an advanced 1117 to 1154 MWe nuclear power plant that uses the forces of nature and simplicity of design to enhance plant safety and operations and reduce construction costs. The AP1000 has 50 percent fewer valves, 83 percent less piping, 87 percent less control cable, 35 percent fewer pumps and 50 percent less seismic building volume than a similarly sized conventional plant. These reductions in equipment and bulk quantities lead to major savings in plant costs and construction schedules. The AP1000 fuel design is based on the 17x17 XL (14 foot) design used successfully at plants in the U.S. and Europe. As with AP600, studies have shown that AP1000 can operate with a full core loading of MOX fuel.

Modular Construction of AP1000 will reduce Interest Charges.

Like the AP600, the AP1000 utilizes modularisation technique for construction, which allows many construction activities to proceed in parallel. This technique reduces the plant construction calendar time, which saves the IDC (Interest During Construction) cost and reduces the risks associated with plant financing. The AP1000 has a site construction schedule of 36 months from first concrete to fuel loading.

USNRC Design Certification of AP1000 Expected before December 2005.

On September 13, 2004, the United States Nuclear Regulatory Commission (U.S. NRC) granted a Final Design Approval (FDA) to Westinghouse for the AP1000 advanced reactor design. The approval is good for five years. The U.S. NRC agency anticipates issuing a standard Design Certification in the form of an Appendix to 10CFR52 before December 2005, or possibly up to five months earlier. If granted, a Design Certification would be good for 15 years and renewable in terms of 10 to 15 years.

Annex 3: South Korea: the Korean Standard Nuclear Plant.

The first nuclear reactor to achieve criticality in South Korea was a small research unit in 1962. Ten years later construction began of the first nuclear power plant Ð Kori-1. It started up in 1977 and achieved commercial operation in 1978. After this there was a burst of activity, with eight reactors under construction in the early 1980s. South Korean energy policy has been driven by considerations of energy security and the need to minimise dependence on current imports. Policy is to continue to have nuclear power as a major element of electricity production.

Under the country's 5th long-term power development plan, finalised in January 2000, eight more nuclear units (9200 MWe) are to be constructed by 2015 (in addition to the four then under construction), while two units will be decommissioned about 2008. This would bring nuclear to one third of the country's total generating capacity and it would supply 45% of the electricity.

In 2003, 123 billion kWh was generated by the nuclear plants, this being 40% of the country's total. At year end 19 units were operating, total 15,880 MWe net, which was 20% of national capacity.

Reactor development

Turnkey Projects.

South Korea’s first three commercial units - Kori 1 & 2 and Wolsong-1, were bought as ***turnkey*** projects. The next six, Kori 3 & 4, Yonggwang 1 & 2, Ulchin 1 & 2, comprised the country's second generation of plants and involved local contractors and manufacturers. At that stage the country had six PWR units derived from Combustion Engineering in USA, two from Framatome in Europe and one from AECL in Canada Ð of radically different design.

Then in the mid 1980s the Korean nuclear industry embarked upon a plan to standardise the design of nuclear plants and to achieve much greater self-sufficiency in building them. In 1987 the industry entered a ten-year technology transfer program with ***Combustion Engineering (now Westinghouse)*** to achieve technical self-reliance, and this was extended in 1997.

A sidetrack from this was the ordering of three more Candu-6 Pressurised Heavy Water Reactor (PHWR) units from AECL in Canada, to complete the Wolsong power plant. These units were built with substantial local input and were commissioned 1997-99.

In 1987 the industry selected the CE System 80 steam supply system as the basis of standardisation. Yonggwang 3 & 4 were the first to use this, with great success.

The KSNP.

A further step in standardisation was the Korean Standard Nuclear Plant (KSNP), which from 1984 brought in some further CE System 80 features and incorporated many of the US Advanced Light Water Reactor design requirements. Six are operating and four more will come on stream in the future. Ulchin-3, a two-loop light water pressurized reactor was the first Korean Standard Nuclear Power Plant (KSNP), which is a modified and improved version of the Yŏnggwang-3 basic design. The plan to develop the KSNP included the use of enhanced safety features and proven technology, simplicity in design, and improved performance. In addition, the improvements in design were made to correspond with updated licensing requirements and industry codes and standards. Some key features of the KSNP include a safety depressurisation system, new equipment to more accurately measure the level of reactor coolant, improved chemical and volume control systems, simplification of operational procedures, and the use of digital technology for the control systems. Ulchin-3 was constructed under the same contractual scheme as Yŏnggwang-3 and -4, but with greater participation by Korean firms. ABB-CE provided the main components of the reactor, the coolant pumps, the plant protection and safety systems, design work, and engineering services. Korean Heavy Industries and Construction Company (Hanjung) manufactured the reactor vessel, steam generators, pressurizers, and jointly developed the turbine generator with GE. Korea Power Engineering Company (KOPEC) worked with Sargent & Lundy to provide architect and engineering services.

Ulchin Unit 5, the seventh in the series of Korean Standard Nuclear Power Plants, was placed into commercial operation in July 2004 by the Korea Hydro Nuclear Power Company. The unit was placed into commercial operation after successfully completing six months of testing at power. Ulchin Units 5 and 6, located on the eastern coast of the Republic of Korea, include a nuclear steam supply system (NSSS) rated at 2825 megawatts thermal and a turbine generator producing up to 1050 megawatts electric (1000 MWe net to the grid).

Ulchin Unit 6 loaded fuel in October 2004 and is expected to complete all testing prior to attaining commercial operation by May 2005. Ulchin 5 and 6 use the Korean Standard Nuclear Plant design, which is based on the Westinghouse Standard System 80® NSSS design. Reactor coolant pumps and reactor vessel internals for Ulchin 5 and 6 were manufactured at the Westinghouse facility in Newington, New Hampshire. The digital plant protection system was manufactured at the Company’s New Britain, Connecticut facility. Ulchin 3 and 4, also based on the Westinghouse Standard System 80® NSSS design, entered service in the late 1990s.

The KSNP+

In the late 1990s, to meet evolving requirements, a program to produce an Improved KSNP, or KSNP+, was started. This involved design improvement of many components, improved safety and economic competitiveness, and optimising plant layout with streamlining of construction programs to reduce capital cost. Shin-Kori 1&2 will represent the first units of the KSNP+ Program, and are expected to be among the safest, most economical and advanced nuclear power plants in the world.

The APR-1400

Beyond this, the Advanced Pressurised Reactor-1400 draws on CE System 80+ innovations, which are evolutionary rather than radical. The System 80+ has US

Nuclear Regulatory Commission design certification. The APR-1400 was originally known as the Korean Next-Generation Reactor when work started on the project in 1992. The basic design was completed in 1999. It offers enhanced safety and a 60-year design life. Cost is expected to be US$ 1400 per kilowatt, falling to US$ 1200/kW in subsequent units. The first APR-1400 units - Shin Kori 3 & 4, are at pre contract stage, and operation is expected by 2011.
KHNP and MOST are negotiating licence renewals to extend operating lifetimes by ten years.

Figure 66: Power reactors operating in South Korea.

Reactor	Type	Net capacity	OpeOpon
Kori 1	PWR	563 MWe	4/78
Kori 2	PWR	612 MWe	7/83
Wolsong 1	PHWR	629 MWe	4/83
Kori 3	PWR	903 MWe	9/85
Kori 4	PWR	903 MWe	4/86
Yonggwang 1	PWR	900 MWe	8/86
Yonggwang 2	PWR	900 MWe	6/87
Ulchin 1	PWR	920 MWe	9/88
Ulchin 2	PWR	920 MWe	9/89
Yonggwang 3	PWR (Syst 80)	950 MWe	12/95
Yonggwang 4	PWR (Syst 80)	950 MWe	3/96
Wolsong 2	PHWR	650 MWe	6/97
Wolsong 3	PHWR	650 MWe	6/98
Wolsong 4	PHWR	650 MWe	6/99
Ulchin 3	*PWR (KSNP)*	960 MWe	6/98
Ulchin 4	*PWR (KSNP)*	960 MWe	6/99
Ulchin 5	*PWR (KSNP)*	960 MWe	1/04
Ulchin 6	*PWR (KSNP)*	960 MWe	12/04
Yonggwang 5	*PWR (KSNP)*	950 MWe	5/02
Yonggwang 6	*PWR (KSNP)*	950 MWe	12/02
Total: 20		16,840 MWe	

South Korean reactors under construction or on order

Reactor	Type	Net capacity	Start-up*
Shin Kori 1	*PWR (KSNP+)*	950 MWe	2008
Shin Kori 2	*PWR (KSNP+)*	950 MWe	2009
Shin Wolsong 1	*PWR (KSNP+)*	950 MWe	2009
Shin Wolsong 2	*PWR (KSNP+)*	950 MWe	2010
Shin Kori 3	PWR (APR1400)	1350 MWe	2010
Shin Kori 4	PWR (APR1400)	1350 MWe	2011

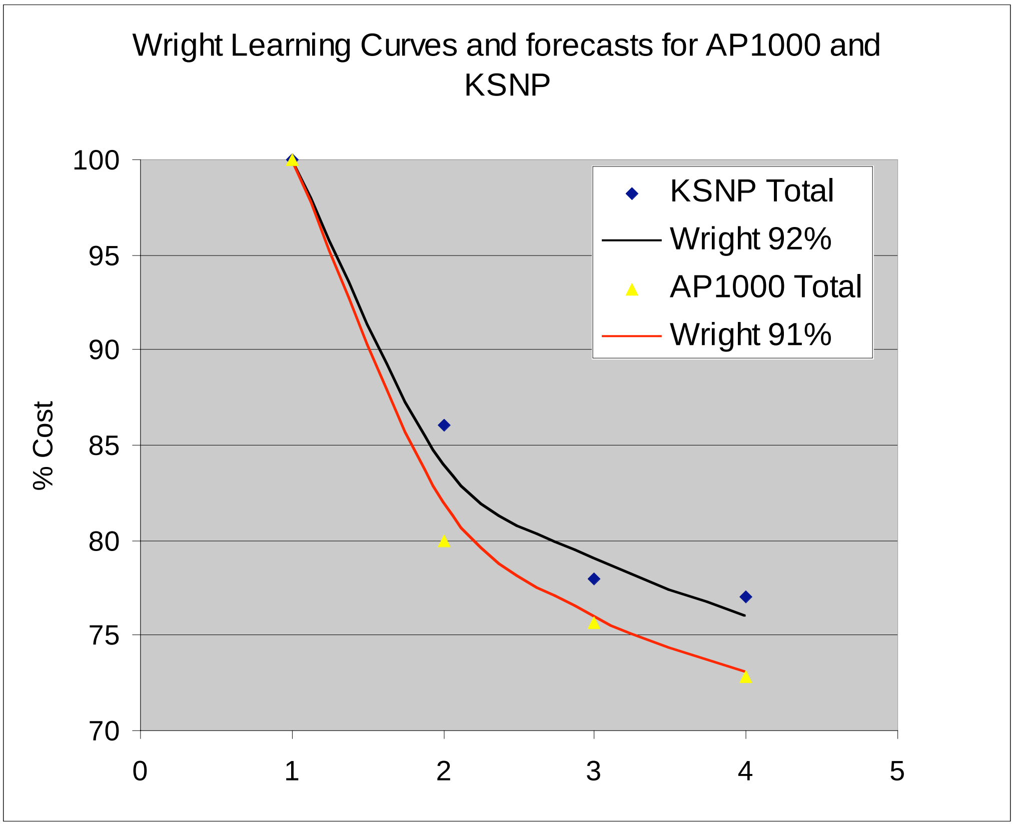
? near Ulchin	PWR (APR1400)	1350 MWe	2015
? near Ulchin	PWR (APR1400)	1350 MWe	2015
total		9,200 MWe	

* Latest announced commercial operation

Annex 4: FOAK costs and Learning Curves.

Figure 67 shows the Cost of each of a series of 4 KSNP or AP1000 plants, together with the Wright Learning Curves that best fit each set of points. The Wright Learning Coefficients are 92% for the KSNP and 91% for the AP1000.

Figure 67: Wright Learning Curves for AP1000 and KSNP.



The concept of the learning curve was introduced to the aircraft industry in 1936 when T. P. Wright published an article in the February 1936 *Journal of the Aeronautical Science*. Wright described a basic theory for obtaining cost estimates based on repetitive production of airplane assemblies. Since then, learning curves (also known as progress functions) have been applied to all types of work from simple tasks to complex jobs like manufacturing a Space Shuttle.

The theory of learning is simple. It is recognized that repetition of the same operation results in less time or effort expended on that operation. For the Wright learning curve, the underlying hypothesis is that the direct labour man-hours necessary to complete a unit of production will decrease by a constant percentage each time the production quantity is doubled. If the rate of improvement is 20% between doubled quantities, then the **learning percent** or ***Wright Learning Coefficient*** would be 80% (100-20=80). While the learning curve emphasizes time, it can be easily extended to cost as well.

The learning percent is usually determined by statistical analysis of actual cost data for similar products. Lacking that, one may use the following guidelines from "Cost Estimator's Reference Manual- 2nd Ed.," by Rodney Stewart:

- 75% hand assembly/25% machining = 80% learning
- 50% hand assembly/50% machining = 85%
- 25% hand assembly/75% machining = 90%

or

1. Aerospace 85%
2. Shipbuilding 80-85%
3. Complex machine tools for new models 75-85%
4. Repetitive electronics manufacturing 90-95%
5. Repetitive machining or punch-press operations 90-95%
6. Repetitive electrical operations 75-85%
7. Repetitive welding operations 90%
8. Raw materials 93-96%
9. Purchased Parts 85-88%

A calculator is available on the internet. [53]

[53] http://www1.jsc.nasa.gov/bu2/learn.html

Annex 5: Insurance.

Lloyd's of London Syndicate 1176 Nuclear Insurance[54].

Syndicate 1176 provides both Third Party Liability and Property Damage Insurance:

Property Damage

The syndicate provides physical damage cover within the nuclear fuel cycle. The largest values the syndicate insures are nuclear power stations although the syndicate also covers manufacturers of nuclear fuel and radio isotopes, their transport and ultimately their safe storage. Whilst there is very limited catastrophe exposure, the syndicate specifically excludes cover for earthquake in Japan. In addition, the syndicate provides some business interruption cover following damage to a power station.

Liability

The syndicate provides a limited liability policy to most non-US nuclear power stations. The policies issued are unique in that there is an aggregate limit for the whole lifetime of the nuclear site and also claims have to be made within ten years of an occurrence. These coverages, which normally include terrorism coverage are enshrined in national nuclear laws and international conventions and typically the Government picks up exposure in excess of insurers' policy limits. Even though the liability results have been excellent, the syndicate limits its exposure to 20% of its maximum line on liability business.

Terrorism

In most countries property terrorism is excluded or coverage is provided through Government reinsurance schemes such as Pool Re in the UK (for property insurance) and under TRIA in the USA. Coverage is given in some countries where terrorism risk is lower. Whilst there are significant protections against terrorism and, the construction of power stations make significant loss from terrorism unlikely, the syndicate currently limits its exposure to 50% of the maximum line for terrorism.

[54] http://www.google.co.uk/search?hl=en&q=nuclear+risk+insurers+nri&meta=

Transit

The syndicate generates a small amount of premium insuring the transit of nuclear fuel and waste. The limits are typically modest and there has never been a significant transit loss. Transit of nuclear materials is undertaken to strict international standards and involves the very best safety procedures.

Business Placements

Most of the syndicate business comes through international pools of nuclear capacity. Countries which have nuclear insurance have established nuclear pools which insure risk in their country. As few pools have sufficient domestic capacity the national pools reinsure on a reciprocal basis with the other foreign pools.

Syndicate 1176 is the leading participant of the British Nuclear Pool, NRI Limited, in which it owns a share of the management company in proportion to its share (currently approximately 35%) of the Pool. Any profits/losses made from these operations are paid to the syndicate account. The British Nuclear Pool insures mainly UK indigenous business, which it then reciprocally reinsures with other countries Nuclear Pools (non-UK) for a share of their indigenous risks.

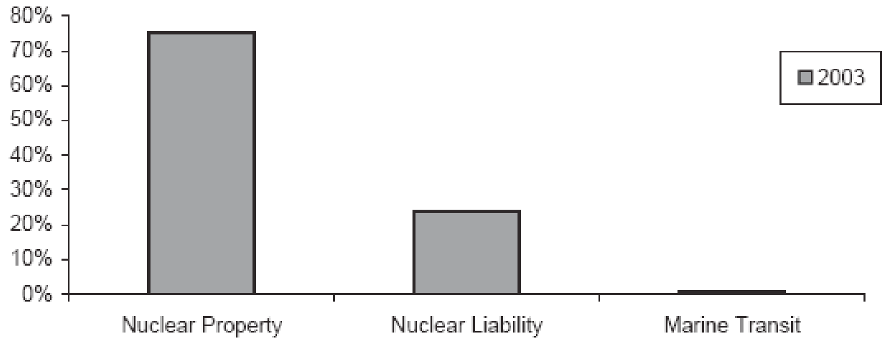
The syndicate further is involved as indigenous insurer in the Canadian, Swiss and Japanese Nuclear Pools. The exposures and premiums received from the pools are net of the interpool reciprocal reinsurances. In addition, syndicate 1176 provides reinsurance capacity to the nuclear insurance mutuals and underwrites some open market business. The syndicate is careful to aggregate exposures to ensure that they are within the limits set within the syndicate.

2003 Year of Account

The business has successfully transferred to Chaucer for the 2003 year of account. As a result of the discontinuance of Cox syndicate 1208 which underwrote in parallel with Syndicate 1176, Syndicate 1176 pre-empted to £12.6 million in 2003. In addition, qualifying quota share capacity took the combined 2003 capacity to £15 million. Syndicate 1176 is expecting to underwrite approximately £14.0 million of premium which is about £0.5 million more than planned. The syndicate has suffered one loss to date which has resulted in a gross claim of £1 million. This resulted from a human error during the nuclear refuelling process in a power station in Hungary. Should there be no further loss a significant profit is still expected.

Figure 68: Syndicate 1176 Premiums.

Analysis of Estimated Gross Premium Income at 36 Months



Excluding Third Party Liability.

Excluding Third Party Liability, The insurance offered by the US mutual nuclear insurer NEIL typifies what is available. It is as follows[55]:

Primary Property And Decontamination Liability Insurance Policy

The following is a summary of the Primary Property and Decontamination Liability Insurance Policy in effect as of

Overview

The Policy provides up to $500 million of primary property and decontamination liability coverage. Pursuant to the Atomic Energy Act of 1954, the Policy provides for priority of payment of expenses incurred in connection with the stabilization and decontamination of the reactor vessel. The Policy provides coverage for direct physical damage to, or destruction of the Insured Property as a result of an Accident.

Premium and Retrospective Premium Adjustment

The premium is based on the amount of the coverage, the deductible and various rating criteria. The premium is payable by wire transfer on or before the beginning of the policy period. The Policy is not effective until the premium has been paid and the Insured has received written notice from the Company that all other conditions for coverage have been satisfied.

[55] http://www.nmlneil.com/policies.html

In the event the Institute of Nuclear Power Operations rates the site as not meeting the industry standard of acceptable performance, the Company may increase the premium by up to 25%.

The Company has the ability to make a call on the Member Insured for payment of a retrospective premium adjustment to cover losses incurred by the Company during the Policy Year. The Board of Directors determines the amount of a retrospective premium adjustment. The maximum amount is ten times the annual premium.

Definition of “Accident”: Coverage Considerations

This is an "All Risk" Policy subject to New York state law. This Policy provides coverage for certain expenses and costs resulting from Property Damage caused by an “Accident." For purposes of the Company's Policy, ***"Accident" is defined as a sudden and fortuitous event, an event of the moment, which happens by chance, is unexpected, and unforeseeable. It does not include any condition which develops, progresses or changes over time, or which is inevitable.*** The date of the Accident shall be the later of when such Accident occurred or is discovered; provided that the Accident occurred at a time when the Insured was insured by NEIL.

Force Majeure is Insured.

Subject to the exclusions, the Policy provides coverage for losses caused by fire, windstorm, lightning, explosion, machinery breakdown, and the like. Certain perils such as flood and earthquake are excluded but may be added back by endorsement.

Deductibles

The policy allows different deductibles for the Turbine Generator Units, the Balance of Plant, and transit. There can also be different deductibles for each unit on the site.

Valuation Provision

The value of the Insured Property at the time of an Accident is the replacement cost of such property, but only if it is replaced with identical property on the same premises and intended for the same occupancy and use. In the event the Insured elects not to replace or repair the damaged property, the value of the Insured Property is the actual cash value of such property at the time of the Accident.

The value of nuclear fuel in the core is the value of a full fuel core reduced to reflect the proportion of usable burnup consumed. Spent nuclear fuel on site is considered to have a zero value.

Transits: Extensions of Coverage

The Policy provides transit coverage up to a maximum sublimit of $10 million and subject to a deductible. The coverage applies to shipments of Insured Property between points and places within the continental United States, District of Columbia, Canada, Mexico and the countries of the European Union. Coverage for the shipment of Insured Property outside these geographical limitations is available by endorsement.

The Policy extends coverage to include Expediting Expense, which is the cost to make temporary repairs or temporary replacement, and to expedite the permanent repair or replacement. Expediting Expense is limited to the greater of $2,500,000 or an amount equal to ten percent of the Loss up to a maximum sublimit of $10 million.

Exclusions

The "All Risks" coverage provided by the contract is modified by certain exclusions, which are contained in the Policy. These exclusions are the standard exclusions normally found in property insurance policies and are summarized below:

1. Gradual accumulation of radioactive contamination.
2. Radioactive contamination resulting from off-site sources.
3. Neglect of the Insured to act in a prudent manner.
4. Unexplained or mysterious disappearance of Insured Property.
5. Delay, inherent vice, loss of use, or loss of market.
6. Infidelity or any fraudulent, dishonest, or criminal acts by or on behalf of the Insured or any other party at interest.
7. Any dishonest act done by or at the instigation of an employee of any Insured.
8. Damage resulting from a governmental order, except acts of destruction for the purpose of preventing the spread of Accidental Property Damage.
9. Seizure, destruction or confiscation by governmental order, or risks of contraband or illegal transportation or trade.
10. Losses attributable to manufacturing or processing operations.
11. Losses resulting from gradual, ordinary or natural deterioration or wear and tear, including fatigue and corrosion of any kind.
12. Losses caused by dampness, dryness or extreme changes of the temperature of the atmosphere.
13. Losses due to flood including flood caused by or resulting from hurricane, tornado, or windstorm. (Coverage may be added by endorsement.)
14. Losses resulting from earthquake, volcanic eruption, landslide, or subsidence. (Coverage may be added by endorsement.)

The Policy is extended to provide coverage for damage to the property of employees of the Insured and the property of others for which the Insured is liable.

Finally, the Policy provides coverage for damage to Insured Property, which is necessarily removed from the site to reduce potential loss for a limited time period.

The Policy has a War Risk Exclusion, which applies to hostile or warlike action in time of peace, or war, which takes place within the 48 contiguous states of the United States, Alaska, Hawaii and the District of Columbia, including the territorial waters thereof. For international Insureds, the exclusion applies to acts that occur within the country where the Insured unit is located. ***The exclusion does not apply to acts of terrorism or sabotage***.

The Policy does not provide coverage for damage to the following types of property:

1. Accounts, money, securities and the like.
2. Manuscripts, drawings, records, data storage, media and program devices, and the like.
3. Vehicles licensed for highway use, aircraft or watercraft.

The Policy does not cover:

1. Any Accidental Property Damage, to the extent that it is recoverable from a contractor, manufacturer or supplier under warranty or guaranty. The EPC Contractor therefore has policies that cover these things.
2. The cost of making good any faulty workmanship, material, construction or design. Again the EPC Contractor has insurance that covers some aspects of these things.
3. Cost associated with more than one opening or closing of a turbine generator unit in connection with one Accident.
4. Any sums, which the Insured may be obligated to pay as damages because of bodily injury or personal injury, or because of damage to property, not described in the Declarations, or for which the Insured is covered ***or would be entitled to coverage under a nuclear energy liability policy.***

Other Policy Conditions

Concealment, Fraud. The Company has no obligation to make any payment under the Policy if, whether before or after an Accident, any Insured has willfully concealed or misrepresented in writing any material fact or circumstance concerning this insurance.

Renewal and Cancellation of Policy. The policy will automatically renew for successive one-year terms until either NEIL or the Member terminate the policy by providing written notice at least three months prior to the anniversary date. The Insurer may cancel the Policy, upon the approval of its Board of Directors, at any time upon 60 days written notice to the Insured. The Insured is entitled to receive a refund of the excess of paid premium above the pro rata premium for the expired time.

The Policy is automatically cancelled if (i) the INPO[56] membership is suspended or cancelled by INPO and (ii) the Insured fails to notify the Insurer within five days after receipt of notice of such suspension or cancellation.

Internationally, the insured must maintain membership in WANO[57].

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[56] INPO is the Institute of Nuclear Power Operators, the Trade Association for US Nuclear Power stations.
[57] WANO is the World Association of Nuclear Operators, the global nuclear trade association.

In the event the Insured fails to pay any retrospective premium or purchases other insurance covering the Insured Property that impairs the Company's ability to collect or purchase reinsurance, the Policy shall automatically terminate.

Inspection and Suspension. The Company has the right to perform inspections of the Insured Property at any reasonable time. ***In the event the Company finds a dangerous condition or the Nuclear Regulatory Commission suspends or revokes the operating license or issues a shutdown order, the Company may immediately suspend coverage under the Policy.***

Requirements in case of Accidental Property Damage. This section explains the obligations of the Insured in the event of a loss. The Insured must file a written notice immediately following a loss and a proof of loss within 12 months after the Accidental Property Damage.

When Loss Payable. Losses are payable within 60 days after receipt of the Proof of Loss from the Insured and agreement with NEIL as to the amount to be paid.

Suit. Any suit, action, or proceeding for the recovery of any claim must be commenced within 18 months after the Accident giving rise to such claim.

Subrogation. The Company has the right of assignment of all right of recovery against any party for the Loss. The Company waives any right of subrogation against the Insureds and any party furnishing services, materials, parts, or equipment in connection with the planning, construction, maintenance, operation or use of the Insured

Property. The Company also waives rights of subrogation against any party against whom the Insured has waived rights of subrogation, in writing, prior to the accident.

Aggregate Amount of Liability and Reduction of Policy Amount by Loss. This provision provides for automatic reinstatement of Policy limits after a Loss for no additional premium.

Choice of law. The Policy is to be construed and enforced in accordance with New York State law.

Dispute Resolution. Disputes arising out of the Policy are to be resolved through arbitration.

Payments for Acts of Terrorism Endorsement

In November 2001, the Members adopted an Endorsement that would be added to all NEIL and ONEIL[58] policies creating an aggregate limit for all Insureds who suffer Accidental Property Damages as a result of an act of terrorism.

Aggregate Limits and Period

[58] ONEIL is a branch of NEIL that seeks business in Europe.

The Terrorism Endorsement creates a limit of $3.24 billion, plus any additional amounts the Insurer receives from reinsurance, indemnity and any other sources. The limit would be applicable to all Insureds who sustain Accidental Property Damage from acts of terrorism that occur within a 12-month span, beginning on the date of the first Act.

Payment Priorities: Payments will be made first for damages covered under the Property policies. If the losses exceed the available resources, all Insureds with claims will receive a proportionate share of those resources.

NEIL I - ACCIDENTAL OUTAGE INSURANCE POLICY

The following are extracts from the NEIL I Policy in effect as of July 1, 2002. For more complete information, please refer to the entire contract document.

Overview

NEIL I provides insurance of up to $490 million to cover a prolonged accidental outage of a nuclear unit. The Policy is issued on an agreed value basis with indemnification being approved in advance.

Premium and Retrospective Premium Adjustment

In the event the Institute of Nuclear Power Operations ("INPO") rates the site as not meeting the industry standard of acceptable performance, the Company may increase the premium by up to 25%.

The Company has the ability to make a call on the Member Insured for payment of a retrospective premium adjustment to cover Losses incurred by the Company during the Policy Year. The Board of Directors determines the amount of each retrospective premium adjustment. The maximum amount is ten times the annual premium.

Coverage Considerations

The Policy will pay a pre-determined weekly indemnity in the event of an Outage that is caused by Property Damage caused by an "Accident" For purposes of the ompany's Policy, "Accident" is defined as a sudden and fortuitous event, an event of the moment, which happens by chance, is unexpected, and unforeseeable. It does not include any condition which develops, progresses or changes over time, or which is inevitable. The Accidental Property Damage must be the direct, efficient and dominant physical cause of the Outage.

The Policy defines a Cessation Outage as starting at midnight of the day the Unit ceases generating electric power, and a Delay Outage as starting at midnight of the first day on which the Unit could have resumed the generation of electric power.

At the expiration of the ***Waiting Period***, the Company will pay the Insured 100% of the weekly indemnity selected by the Insured for each of the next 52 weeks of the Outage and 80% of the weekly indemnity for the remaining weeks of the Outage up to the limit purchased or 104 weeks, whichever occurs first. The maximum weekly indemnity that may be selected is $4.5 million.

In the event of an Outage occurring at more than one unit by reason of the same Accident, the weekly indemnity for each unit is limited as follows: 80% of the single unit recovery when two units are out of service; 60% of the single unit recovery when three units are out of service; and 50% of the single unit recovery when four units are out of service.

The Policy does not cover Partial Outages (i.e. a unit that can only run at 80%)

Exclusions

Exclusions under the Policy are summarized below:

1. Gradual accumulation of radioactive contamination.
2. Radioactive contamination resulting from off-site sources.
3. Fraudulent, dishonest, or criminal acts by or on behalf of the Insured.
4. Order of Civil Authority, except acts of destruction for the purpose of preventing the spread of fire.
5. Governmental act, decree, order, regulation, statute or law prohibiting or preventing the commencement, recommencement or continuation of any operation of the unit.
6. Local, state or federal ordinance or law regulating construction or repair of buildings or structures, or suspension, lapse or cancellation of any lease or license, contract or order, or interference at the unit by strikers or other persons.
7. Losses resulting from gradual, ordinary or natural deterioration or wear and tear including fatigue and corrosion of any kind.
8. Loss caused by dampness, dryness or extreme changes of the temperature of the atmosphere.

The Policy has a War Risk Exclusion that applies to hostile or warlike action in time of peace or war, which takes place within the 48 contiguous states of the United States, Alaska, Hawaii and the District of Columbia. For international Insureds, the exclusion applies to acts that occur within the country where the Insured unit is located. ***The exclusion does not apply to acts of terrorism or sabotage***.

Conditions

Aggregate Limit of Liability and Reduction of Policy Amount by Loss. The Policy limit is reduced by the amount of the Losses resulting from the Outage. The Company has the option of providing for reinstatement of the limit upon payment of an additional premium.

Concealment and Fraud. Same as NEIL Primary Policy.
Renewal and Cancellation of Policy. Same as NEIL Primary Policy.
Inspection and Suspension. Same as NEIL Primary Policy.
Requirements in Case of Loss. The Insured is required to file a written notice after an Outage exceeds ten weeks or for which a claim is expected to be made under the Policy. A Proof of Loss is required to be filed within twelve months after the completion of an Outage.
Subrogation. Same as NEIL Primary Policy.
Suit. Same as NEIL Primary Policy.
Choice of Law. Same as NEIL Primary Policy.

Payments for Acts of Terrorism Endorsement

In November 2001, the Members adopted an Endorsement that would be added to all NEIL and ONEIL policies creating an aggregate limit for all Insureds who suffer Accidental Property Damages as a result of an act of terrorism. The Endorsement creates a limit of $3.24 billion, plus any additional amounts the Insurer receives from reinsurance, indemnity and any other sources. The limit would be applicable to all Insureds who sustain Accidental Property Damage from acts of terrorism that occur within a 12-month span, beginning on the date of the first Act.

Payment Priorities. Payments will be made first for damages covered under the Property policies. If the losses exceed the available resources, all Insureds with claims will receive a proportionate share of those resources

NEIL II - DECONTAMINATION LIABILITY, DECOMMISSIONING LIABILITY AND EXCESS PROPERTY INSURANCE POLICY

The following are extracts from the NEIL II Policy in effect as of July 1, 2002. For more complete information, please refer to the entire contract document.

Overview

The NEIL II Policy provides Decontamination Liability, Decommissioning Liability and Excess Property insurance up to a maximum limit of $2.25 billion for those losses from Accidental Property Damage that exceed the Attachment Point. The Attachment Point is the greater of the amount covered by all Underlying Insurance Policies or $500 million.

Premium and Retrospective Premium Adjustment

The premium is based on the amount of the coverage selected and various rating criteria. The premium is payable by wire transfer on or before the beginning of the policy period. The Policy is not effective until this has been paid and the Insured has received written notice from the Company that all other conditions for coverage have been satisfied.

In the event INPO rates the Site as not meeting the industry standard of acceptable performance, the Company may increase the premium by up to 25%.

The Insured is subject to a retrospective premium adjustment to cover all Losses incurred by the Company during the Policy Year. The Board of Directors determines the amount of the retrospective premium adjustment. The maximum amount is ten times the annual premium.

Coverage Considerations

This is a "following form" Policy, which is subject to New York state law. This Policy will follow the form of the Primary Underlying Policy, and will ***indemnify the Insured for the expenses incurred when discharging their legal obligation to protect the public health and for the expenses incurred to remove debris of and decontaminate Insured Property following Property Damage caused by an "Accident."*** For purposes of the Company's Policy, "Accident" is defined as a sudden and fortuitous event, an event of the moment, which happens by chance, is unexpected, and unforeseeable. It does not include any condition which develops, progresses or changes over time, or which is inevitable. The date or time at which the Accidental Property Damage is discovered is deemed the date or time of an Accident. The Policy provides coverage for Losses in excess of the Attachment Point that are caused by earthquake, windstorm or flood, even if such coverage not provided by the Underlying Insurance Policies.

The Policy provides for payment of expenses to be made in the following order: Losses under Nuclear Liability Coverage; Losses under Decommissioning Liability Coverage; Losses under Debris Removal and Decontamination Coverage; Property Damage Coverage; Functional Total Loss Coverage.

The Policy does allow for early payment of property damage provided that the Insured certifies that there are sufficient Policy limits above those required to discharge their legal obligation under the Act. Internationally, the Insured must discharge any legal obligations placed on it by virtue of any applicable laws, decrees or orders.

This Policy would indemnify the Insured for a shortfall in the Decommissioning Trust Fund only if the Accidental Property Damage exceeds the Attachment Point, and results in the permanent cessation of the unit.

The value of Insured Property at the time of an Accident is the replacement cost of the property, but only if the damaged property is repaired or replaced with identical or like kind property on the same premises and intended for the same occupancy and use and used in connection with a nuclear facility. In all other cases, the value of the Insured Property at the time of the Accident will be the Actual Cash Value.

The Policy also includes coverage for Functional Total Loss that would indemnify the Insured for the "Functional Value" of the undamaged Functional Property. The Policy contains a War Risk Exclusion, which applies to hostile or warlike action in time of peace, or war, which takes place within the 48 contiguous states of the United States, Alaska, Hawaii and the District of Columbia. For international Insureds, the exclusion applies to acts that occur within the country where the Insured unit is located. The exclusion does not apply to acts of terrorism or sabotage.

Conditions

Concealment and Fraud. Same as NEIL Primary
Renewal and Cancellation of Policy. Same as NEIL Primary
Inspection and Suspension. Same as NEIL Primary
Requirements in Case of Accidental Property Damage. The Insured's obligations in the event of Accidental Property Damage include filing a written notice immediately following a loss and filing a proof of loss within 12 months after the amount of Accidental Property Damage, exceeds the Attachment Point.

When Loss Payable. Expenses for Nuclear Liability, Debris Removal and Decontamination Liability, Excess Property Damage and Functional Total Value are payable within 60 days after receipt and approval of a proof of loss. Losses with respect to Decommissioning Liability are payable within 60 days after the later of the filing of a proof of loss or a certification that the Insured has discharged its legal obligation.

Aggregate Limit of Liability and Reduction of Policy Amount by Loss. The Policy limit is reduced by payment of Losses. However, the limit under the Policy is automatically reinstated for no additional premium for subsequent Accidents.
Subrogation. Same as NEIL Primary
Choice of Law. Same as NEIL Primary
Dispute Resolution. Same as NEIL Primary

Blanket Coverage

In exchange for a reduced NEIL II premium, multiple sites may share a portion of their NEIL II limit. This shared limit is blanketed across all the sites involved, above a common NEIL II attachment point. This option is available to Members who own multiple sites, or multiple owners who want to share their limit. The maximum amount of the blanket limit is $1 billion. After a loss the Blanket Limit does not reinstate.

Payments for Acts of Terrorism Endorsement

In November 2001, the Members adopted an Endorsement that would be added to all NEIL and ONEIL policies creating an aggregate limit for all Insureds who suffer Accidental Property Damages as a result of an act of terrorism. The Endorsement creates a limit of $3.24 billion, plus any additional amounts the Insurer receives from reinsurance, indemnity and any other sources. The limit would be applicable to all Insureds who sustain Accidental Property Damage from acts of terrorism that occur within a 12-month span, beginning on the date of the first Act.

Payment Priorities

Payments will be made first for damages covered under the Property policies. If the losses exceed the available resources, all Insureds with claims will receive a proportionate share of those resources

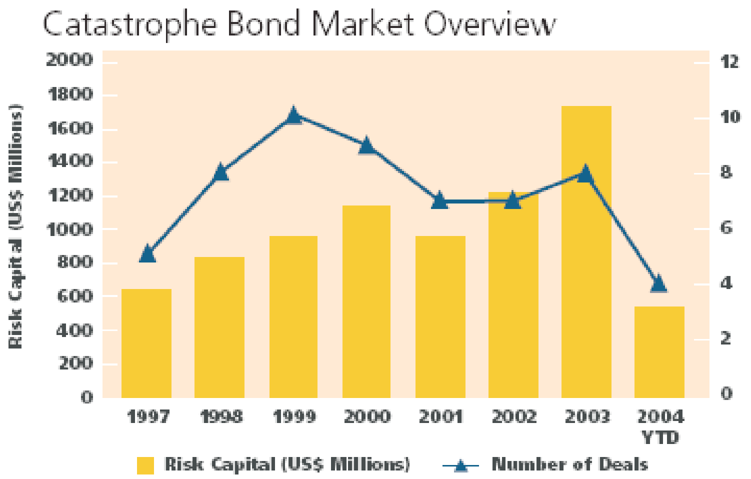
Catastrophe Bonds.

Force Majeure perils, such as hurricane, earthquake, flood, terrorism and most recently personal accidents are increasingly insured by the issuance of Catastrophe Bonds.

This method of insurance has not been extended to cover conventional nuclear insurance. However it could be applied to some of the risks inherent in the construction of nuclear power stations. It would cover aspects of Force Majeure.

Figure 69 is an overview of the Catastrophe bond market. It was made in the summer of 2004 and so the figures for 2004 are incomplete.

Figure 69: Catastrophe Bond Market Overview. [59]



The catastrophe bond market witnessed yet another record year in 2003, with total issuance of US$1.73 billion, an impressive 42-percent year-on-year increase over the 2002 record of US$1.22 billion. During the year, a total of eight transactions were completed, with three originating from first-time issuers. Since 1997, when the market began in earnest, 54 catastrophe bond issues have been completed with total risk limits of almost US$8 billion.

The trend toward larger transactions continued in 2003, with the average issue size hitting a new high of US$217 million, up from US$174 million in 2002. In addition,

[59] Guy Carpenter, 2004.

shelf offerings – a registration of a new issue without selling the entire issue at once – are becoming more common. Following its first successful catastrophe shelf offering, Pioneer, Swiss Re obtained an additional US$293 million of catastrophe protection through the Arbor Program shelf offering. Shelf offerings are advantageous for issuers as they facilitate the fast and efficient offering of securities as needs or market conditions dictate.

Catastrophes that Affected Nuclear Power Stations in 2003.

Honshu, Japan Earthquake – 26th May 2003

On 26th May 2003, Sendai in north-east Japan was hit by a 7.0Ms earthquake, causing several injuries following landslides in Iwate and Miyagi. The quake, which had its epicentre 20 kilometres off the Pacific coast of Miyagi, sparing potentially catastrophic damage, was followed by minor tremors.

The earthquake shutdown bullet trains operating in the area as well as the Onagawa nuclear plant operated by Tohoku Electric Power Co. According to the General Insurance Association of Japan, the quake caused a total insured loss of around 1,466 million yen (USD12.3 million). Reports stated that total economic damage caused by the earthquake amounted to 5,415.3 million yen.

Typhoon Maemi – South Korea – 11th to 13th September 2003

Typhoon Maemi hit south-eastern South Korea on 12th September 2003 as a category 3 typhoon, with wind gusts reaching 130 miles per hour and rainfall of up to 450 mm. The storm killed around 120 people and generated more than USD500 million in insurance-related losses15. The typhoon also left more than 25,000 people homeless. Maemi was the most powerful typhoon to hit Korea since records began and it caused severe disruption and damage. According to Munich Re, total economic losses stands at USD4.8 billion15.

Maemi blew into the country with such intensity that shipping containers were hurled into the air and eight giant cargo cranes were toppled over in Pusan, South Korea's largest port. Several ships and buildings were destroyed.

The government said that the storm destroyed approximately 5,000 houses (a further 13,000 were damaged) and forced 20 major companies to shut down on the south-eastern coast. ***Maemi also halted operations at five nuclear power plants, cutting electricity to 1.4 million homes***. Transport was also disrupted as floods triggered landslides that damaged transport links and derailed a train. The typhoon also damaged around 800 roads and 30 bridges.

Floods in France – 2nd December 2003

The floods that hit south-eastern France in early December 2003 cost insurers one billion euros (USD1.2 billion), according to the French insurance industry group

Federation Francaise des Societes d’Assurances (FFSA). The floods were among the worst to hit France in recent years and declared a national catastrophe by Prime Minister Jean-Pierre Raffarin.

Heavy rain in late November caused French rivers to overflow, flooding swathes of land, killing seven people and causing extensive damage. Flood waters and high winds disrupted road, rail and air traffic and ***forced four nuclear power reactors to shut down due to flooding along the River Rhone***. The flooding in the Ardèche killed one person. It also forced the EDF (Electricité de France) to ***shut down the nuclear power plant in Cruas-Meysse (the Ardèche)*** because waste vegetation carried by the water was obstructing the water-intake system used for cooling the plant’s reactor.

Annex 6: The Price of Uranium

Uranium prices are strongly linked to the price of nuclear fuel. However, the price of nuclear fuel does not have a strong effect on the price of electricity from nuclear power stations. This is because the overbearing determinant of the price of nuclear electricity is the cost of servicing the substantial capital cost of the nuclear power station. However the price of uranium has doubled in the last 12 months and historically it has varied by an order of magnitude. These are large changes, big enough to exert a significant effect on electricity prices.

Effect on Nuclear Accidents upon Uranium Prices.

There is no evidence of a sudden large, permanent fall in uranium prices or uranium share prices following ***any*** of the INES events that have occurred, although the fact that uranium shares have not ***risen*** (until recently) for many years, is largely due to the fact that the INES 5 accident at Three Mile Island thirty years ago halted the rapid expansion of the nuclear power industry, worldwide.

Can we expect uranium prices, nevertheless, to experience a sudden, large and permanent fall if some ***future*** severe nuclear event occurs?

We can foresee the following scenarios:

If an INES 3 Accident Occurs.

Suppose an INES 3 event occurs somewhere in the world. There is no indication that such events have an important permanent effect on the price of uranium or the value of uranium shares. The recent accident at Mihama achieved great publicity, particularly in Japan, easily equivalent to that which the earlier Tokai Mura accident achieved. The latter was INES 3 to 4 (depending on when it was rated). Neither of these recent incidents had a significant effect on the price of uranium. If the accident at Mihama had any effect, that effect was dwarfed by the unrelated rise in uranium prices.

If an INES 7 Accident Occurs.

The only event rated at INES 7 was the Chernobyl accident. If such an accident were to happen in the West then it is widely believed that the world's nuclear industry would be severely affected: people typically say "It would shut down ***all*** the reactors: nobody would be prepared to have one operating on his doorstep". However ***the Chernobyl accident did not shut down any of the other nuclear reactors***, not even those of identical, faulty design in the Ukraine or Russia. As a consequence the Chernobyl accident did not cause a permanent large decrease in the value of uranium: as it did not shut down any other reactors it did not reduce the market for uranium.

What, then ***would*** be the impact on uranium prices of another Chernobyl-scale nuclear accident in the West?

In the USA.

Supposing it occurred in the USA and was due to a fault such as the corrosion of a reactor pressure vessel lid, like the corrosion first detected at Davis Besse. Then it is on balance probable that all reactors of similar design in the USA would be shut down for inspection to see if they had a similar fault. Note that a number of reactors, in the USA and elsewhere, were found to have the same corrosion problem as Davis Besse, although of course no accident has resulted. Some have been shut down pending replacement of the corroded lid. Given the reliance that France and Japan place on nuclear power, it is unlikely that they would shut down ***all*** their reactors, although Japan might well shut down any reactors of similar design for inspection. The likely outcome is that about a quarter of the world's reactors would be shut down for up to a year. There would certainly be a move out of nuclear power, following the event, and this would involve building new gas-fired power stations since they can be built quickly. So would inevitably settle to a lower price level in the medium term. In anticipation of that development it would fall steeply immediately after the event, recovering to a new long-term downward trend over the coming year.

In France.

If such an accident happened in France then the French would be bound to keep most of their remaining nuclear power stations operating, since they rely on the almost completely. The strong arguments that they would immediately deploy to justify this action would be used in the USA and to a lesser extent in other countries to justify not shutting down nuclear power stations. Here again, following a sudden slump, uranium prices would recover to a level that recognized that uranium would continue to be purchased, to fuel most of the world's nuclear power stations for a decade.

Due to a Terrorist Act.

There is a general fear that terrorists may inflict a "9/11" attack on a nuclear power station. I have shown that the balance of probabilities is that ***this is no more likely than a nuclear accident, having similar consequences***. Significantly both the British and Canadian Governments have asked for my forecasts on this matter. Both Governments, having examined my conclusions, accept them and have priced the insurance of such risks at precisely the values that I arrived at.

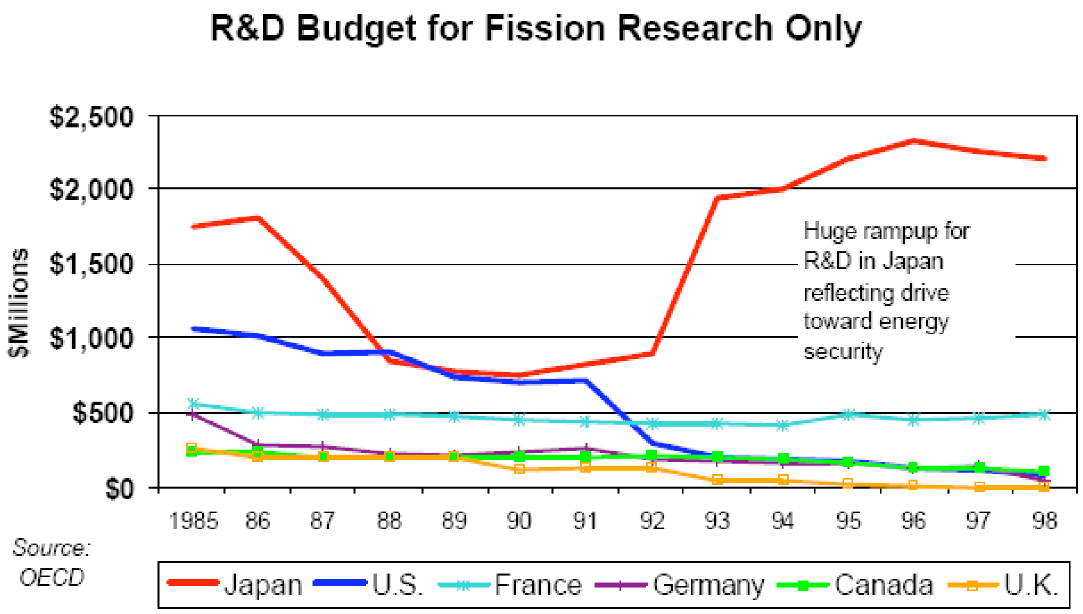
If such an event occurred in the USA, then France would not shut down its nuclear power stations, nor would Japan. The need for nuclear electricity in France would certainly outweigh concerns about a similar terrorist attack and strong arguments about the low level of terrorist risk in France would quickly be deployed. Japan would cite France's robust attitude as part of its reason for following suit and keeping its nuclear power stations in service.

The pattern would be, once again, a sudden drop in uranium prices, followed by recovery to a lower level, consistent with continuing to supply uranium to the nuclear power stations during the decade of their inevitable gradual replacement by gas.

Annex 7: R & D on Nuclear Fission in UK and Other Countries.

Worldwide, nuclear fission R&D has declined since the early 1980s from its $5 billion-per-year peak to about $3 billion a year, almost all of it in OECD countries. Japan has taken over the lead in funding for nuclear power-related research with large recent increases; French R&D support has been stable at $500 million per year since 1985. UK expenditure is comparatively small.

Figure 70: R&D Budgets of Japan, USA, France, Germany, Canada and the UK for Fission Research.



Since 1985, Japan has funded and managed 60% of global R&D on the next generation of nuclear reactors. Japanese companies recently built two GE ABWR reactors and have executed orders for 10 new reactors by 2010. These companies are pioneering modular construction techniques, an important step in accelerating new plant construction and reducing cost.

Annex 8: Types of Contract.

Bechtel has just completed its first Lump Sum EPC Contract in China. In this Annex we place such a Contract in the context of the many combinations of Contract Delivery Methods, Contract Formation etc that are possible.

Contract Delivery Methods

- General Construction Contracts (Design-Bid-Build)
- Design-Build Contracts (Self-Performed or Subcontracted Design)
- EPC Contracts (Engineering, Procurement and Construction)
- Construction Management Contracts (CM At-Risk or Agency CM)
- Fast Track Contracts (Phased Design and Construction)
- Joint Venture or JV / Design-Build Contracts
- Contract Delivery Comparison Studies (GC, D-B, or CM)

Contract Formation

- Lump Sum Contracts (Stipulated Sum)
- Cost Plus Contracts (Fixed Fee or Percentage)
- Unit Price Contracts (Labour Time and Materials, T&M)
- Guaranteed Maximum Price Contracts (GMP)
- Governmental Contracts (DOD or DOE)

Contract Terms & Conditions

- Contract Language (Wording, Enforceability and Insurability)
- Exculpatory Clauses and Difficult or Ambiguous Language
- Contractual Liability Exclusions (Hold Harmless Clauses)
- Liquidated Damages, Schedule Delay and Force Majeure Clauses
- Privity of Contract and Subcontract Administration Issues

Contract Indemnification Agreements

- Limits of Contractual Liability
- Form Types: Limited Form, Intermediate Form and Broad Form
- Third Party Actions and Subcontract Indemnification Clauses
- Risk Assumption, Risk Transfer, Risk Allocation and Risk Mitigation

Contract Liabilities and Exposures

- Breach of Contract (Warranty, Bonding and Subcontractor Default)
- Liquidated, Consequential and Punitive Damages

- Design Responsibility (Design Assumption or Design Delegation)

- **Contract Administration and Claim Management**
  - Contract Negotiation (Client Advocate with Objective View)
  - Contract Claim Prevention (Change Order and Claim Analyses)
  - ADR (Arbitration, Mediation) and Litigation Support

Annex 9:Nuclear Third Party Liability.

International Framework

Ever since the first commercial nuclear power reactors were built, there has concern about the possible effects of a severe nuclear accident, coupled with the question of who would be liable.

Before 1997, the international liability regime was embodied primarily in two instruments:

- the IAEA's **Vienna Convention** on Civil Liability for Nuclear Damage of 1963, and

- the OECD's **Paris Convention** on Third Party Liability in the Field of Nuclear Energy of 1960 which was bolstered by the Brussels Supplementary Convention in 1963.

These Conventions were linked by the **Joint Protocol** adopted in 1988. They are based on the concept of civil law and share the following main principles:
a. Liability is channelled exclusively to the operators of the nuclear installations;
b. Liability of the operator is absolute, i.e. the operator is held liable irrespective of fault, except for "acts of armed conflict, hostilities, civil war or insurrection";
c. Liability of the operator is limited in amount. Under the Vienna Convention the upper ceiling is not fixed*; but it may be limited by legislation in each State.
d. Liability is limited in time. Generally, compensation rights are extinguished under both Conventions if an action is not brought within ten years; this is to be increased to 30 years.
e. The operator must maintain insurance or other financial security for an amount corresponding to his liability or the limit set by the Installation State, beyond this level the Installation State can provide public funds but can also have recourse to the operator;
f. Jurisdiction over actions lies exclusively with the courts of the Contracting Party in whose territory the nuclear incident occurred;
g. Non-discrimination of victims on the grounds of nationality, domicile or residence.

* The Paris Convention set a maximum liability of 15 million Special Drawing Rights - SDR (about US$ 20 million), but this was increased under the Brussels Supplementary Convention up to a total of 300 million SDRs (about US$ 400 million), including contributions by the installation State up to SDR 175 million and other Parties to the Convention collectively on the basis of their installed nuclear capacity for the balance. These limits are to be increased three-fold.

Following the Chernobyl accident in 1986, the IAEA initiated work on all aspects of nuclear liability with a view to improving the basic Conventions and establishing a comprehensive liability regime. In 1988, as a result of joint efforts by the IAEA and OECD/NEA, the Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention was adopted. This broadened the coverage of the two Conventions combining them into one expanded liability regime. It was also intended to obviate any possible conflicts of law in the case of international transport of nuclear material. It entered in force in 1992.

In 1997 governments took a significant step forward in improving the liability regime for nuclear damage when delegates from over 80 States adopted a **Protocol to Amend the Vienna Convention** and also adopted a **Convention on Supplementary Compensation for Nuclear Damage.** The amended Vienna Convention sets the possible limit of the operator's liability at not less than 300 million SDRs (about US$ 400 million). The 1997 Convention on Supplementary Compensation defines additional amounts to be provided through contributions by States Parties collectively on the basis of installed nuclear capacity and a UN rate of assessment, basically at 300 SDRs per MW thermal (ie about US$ 400 million total). Both these changes have yet to be ratified.

The Convention is an instrument to which all States may adhere regardless of whether they are parties to any existing nuclear liability conventions or have nuclear installations on their territories. The Protocol contains a better definition of nuclear damage (now also addressing the concept of environmental damage and preventive measures), extends the geographical scope of the Vienna Convention, and extends the period during which claims may be brought for loss of life and personal injury. It also provides for jurisdiction of coastal states over actions incurring nuclear damage during transport.

In 2001, contracting parties to the Paris and Brussels Conventions agreed new limits on liability: Operators (insured) € 700 million, Installation State (public funds) € 500 million, Collective state contribution (Brussels) € 300 million => total € 1500 M. This Protocol is expected to be ratified as soon as states have enacted relevant legislation.

Beyond such provision there is at least a tacit acceptance that the installation state will make available funds to cover anything in excess of these provisions.

Canada.

In **Canada** the Nuclear Liability Act 1976 is in line with the international conventions and establishes the licensee's absolute and exclusive liability for third party damage. Suppliers of goods and services are given an absolute discharge of liability. At present a limit of 75 million CAD per power plant is set on the insurance cover required for individual licensees, but this is under review. A pool of insurers provides cover, and claimants need not establish fault on anyone's part, but must show injury. Beyond the cap level, any further funds would have to be provided by the government.

US Framework

The USA takes a somewhat different approach. Here, the Price Anderson Act has since 1957 been central to addressing the question of liability for nuclear accidents. Details can be found on the US NRC Website.[60].

UK

In the **UK**, the Energy Act 1983 brought legislation into line with revisions to the Paris/Brussels Conventions and set a limit of liability for particular installations. In 1994 this limit was increased to £140 million for each major installation, so that the operator is liable for claims up to this amount and must insure accordingly. This is covered through a pool comprising 13 insurance companies and 40 Lloyds syndicates. Beyond £140 million, the Paris/Brussels system applies up to SDR 300 million.

In 2001, contracting parties to the Paris and Brussels Conventions agreed new limits on liability: Operators (insured) € 700 million, Installation State (public funds) € 500 million, Collective state contribution (Brussels) € 300 million => total € 1500 M. This Protocol is expected to be ratified as soon as states have enacted relevant legislation.

Beyond such provision there is at least a tacit acceptance that the installation state will make available funds to cover anything in excess of these provisions.

[60] http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/funds.html

Other Countries.

In mainland **Europe**, individual countries have legislation in line with the international conventions and where set, cap levels vary, eg France: FF 600 million, Sweden: SDR 300 million. These will be superseded by the 2001 Euro currency figures above. Germany has unlimited liability and requires DM 1 billion security of which DM 500 million is normally provided by the State.

Annex 10: Australia's Energy White Paper[61].

Australia's access to low-cost energy underpins much of her industrial base. Exports of energy earn Australia more than $24 billion a year. The nation's energy resources also provide the competitively priced power needed for key industries such as aluminium, cement, steel, and paper. The energy sector is a major employer, directly providing jobs for 120 000 Australians, and supports many hundreds of thousands more in the broader community. Australia's energy sector spans the production and supply of stationary energy (such as electricity and gas), transport energy (mainly petroleum based fuels) and energy for export. The sector encompasses the identification and development of primary energy sources such as coal, gas, oil and uranium, as well as renewables like hydroelectricity, wind, solar and biomass. It includes the conversion of the raw, primary energy sources into final energy sources such as electricity and refined petroleum fuels and their delivery and marketing to final consumers. Australians spend about $50 billion on energy each year, while energy exports earn more than $24 billion a year.

Initiatives announced in the recent Energy White Paper to achieve the Australian Government's energy objectives include: >

1. A complete overhaul of the fuel excise system to remove $1.5 billion in excise liability from businesses and households in the period to 2012–13 >
2. *The establishment of a $500 million fund to leverage more than $1 billion in private investment to develop and demonstrate low-emission technologies.*
3. A strong emphasis on the urgency and importance of continued energy market reform
4. The provision of $75 million for Solar Cities trials in urban areas to demonstrate a new energy scenario, bringing together the benefits of solar energy, energy efficiency and vibrant energy markets
5. *The provision of $134 million to remove impediments to the commercial development of renewable technologies.*
6. Incentives for petroleum exploration in frontier offshore areas as announced in the 2004-05 budget.
7. New requirements for business to manage their emissions wisely.
8. A requirement that larger energy users undertake, and report publicly on, regular assessments to identify energy efficiency opportunities.

It is conceivable that items 2 and 5 in the above list could provide FOAK funding for a new nuclear power station.

Developing Australia's abundant low-cost energy resources is a key to her future prosperity. Australia is the world's fourth largest producer, and largest exporter, of coal. She supplies 8 per cent of the world trade for liquefied natural gas, and possesses 40 per cent of the world's low-cost uranium reserves. Australia's

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61 SECURING AUSTRALIA'S ENERGY FUTURE. Department of the Prime Minister and Cabinet, 3-5 National Circuit, BARTON ACT 2600, ISBN 0 646 43547 7. 2004

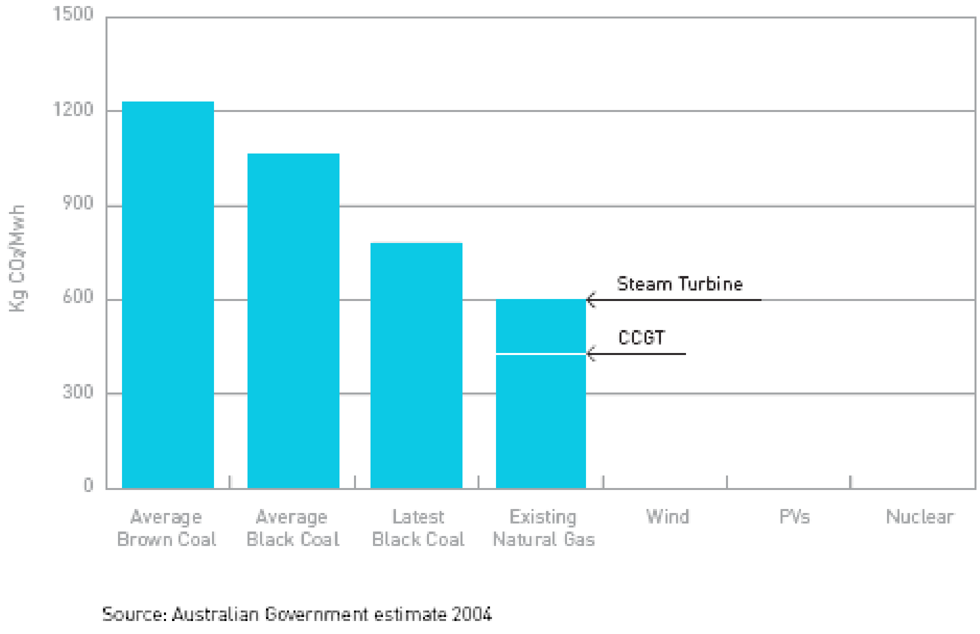
known oil reserves are significant, but are projected to decline in the absence of new discoveries. Australia has significant wind and solar resources, and limited large hydro resources. Investment committed on energy projects under development in Australia totaled $11.1 billion at April 2004 and a further $38.8 billion in investment is under consideration.

Global Warming.

The White Paper notes that Australia is committed to a prosperous economy with a lower greenhouse signature. The Australian Government has a comprehensive strategy for meeting greenhouse objectives in the short and long term, while underpinning the value of existing resources, and maintaining competitiveness. > Australia will continue to actively pursue an effective global response that encompasses the world's major emitters and avoids distortions that might lead to the international transfer of economic activity and emissions with no environmental benefits. The Kyoto Protocol does not meet these criteria. > Australia remains firmly committed to achieving its Kyoto target of keeping emissions to 108 per cent of 1990 levels by 2008–12. With current policy measures, she is on track to meet this target and will continue to monitor progress.

The shape of future international action on climate change is unclear, but the potential costs of future adjustments and long life of energy assets makes it prudent to prepare for the future. The Australian Government's strategy includes a suite of approaches focused primarily on reducing the cost of meeting a future greenhouse constraint: - reducing the cost of a broad range of low-emission energy technologies for the future, including establishment of a $500 million fund to support industry-led demonstration projects of these technologies, and a further $100 million to support development of smaller-scale renewable technologies - $75 million Solar Cities trials to provide working demonstrations of how technology and efficient markets can combine for a sustainable energy future - facilitating commercially attractive emissions reductions, including through mandatory energy efficiency opportunity assessments, an enhanced Greenhouse Challenge programme and better energy markets - supporting uptake of low-emission energy by continuing the Mandatory Renewable Energy Target, and removing barriers to the use of renewable energy.

Figure 71:kg of Carbon Dioxide emitted when one Megawatt. hour of electricity is generated from various sources.



The White Paper says that Australia has large resources of energy, such as gas, hydro, wind uranium and solar, which have lower emissions intensities than coal. Combined-cycle gas-fired electricity, for example, has emissions typically one-half of new black coal plants, while energy technologies such as wind, solar and *nuclear* can deliver electricity with virtually zero emissions. Impediments exist to the use of some of these sources. Gas reserves, while substantial, are mostly far from major domestic markets and cannot be delivered in large volumes without significant additions to pipeline or shipping capacity. Australia's large-scale hydro potential is largely exploited, with little scope for expansion. Wind and solar energy are intermittent. This will limit their penetration in the longer term unless affordable electricity storage becomes available.

Use of uranium reserves raises cost, safety and waste disposal issues in power generation. While industrialised countries on average generate 24 per cent of electricity from nuclear power (IEA 2002 b), Australia is not contemplating the domestic use of nuclear power, the White Paper says.

Other potential low-emission electricity sources, like electricity produced using 'hot dry rocks' or fossil fuel generation with capture and storage of emissions, are yet to be commercially demonstrated. Many of these impediments can be overcome with sufficient expenditure. However, wide-scale uptake of low-emission base load electricity generation at current costs would lead to substantial increases in electricity prices, which would reduce Australia's competitiveness. This situation will remain for some time, even though the cost of many energy sources is falling.

LNG development could increase Australia's energy emissions by around 1 per cent of energy sector emissions. However, to the extent that exported Australian gas replaces more greenhouse intensive energy in the importing country, global emissions may decrease as a result of Australian gas production.

Similarly, exports of uranium reduce global emissions to the extent the nuclear power produced replaces higher emission sources. Under the Kyoto Protocol arrangements, the emissions from producing these fuels would be credited to Australia, but the emissions savings from their consumption would accrue to the country that uses them.

The Australian Government has allocated more than $1 billion for greenhouse gas abatement. Major elements include:

6. Minimum Energy Performance Standards for appliances, equipment and buildings will deliver 8.3 Mt of abatement in 2010 as well as more than $4 billion in net economic benefits over the 2003–2018 period.
7. The Greenhouse Challenge programme will deliver 13.2 Mt of abatement in 2010 and has helped more than 700 Australian companies identify and act on emissions abatement opportunities while saving money and increasing product quality.
8. The Mandatory Renewable Energy Target will deliver 6.5 Mt of abatement in 2010 and drive over $2 billion in investment in new renewable energy generation.
9. The Greenhouse Gas Abatement programme has allocated over $100 million to companies to achieve large scale abatement in the 2008–12 period, and will deliver 10.3 mt of abatement.
10. The Ozone Protection and Synthetic Greenhouse Gas Management Act 1989, as amended in 2003, sets the international standard for managing synthetic greenhouse gases.

Substituting one 1GWe Nuclear Reactor for Coal-Fired Power Station saves 7 to 9 million tons of CO_2.

The 5 measures listed above will, taken together, reduce Australia's Greenhouse gas emissions by 38 million tons. An equal reduction would be provided by substituting 4 to 5 GWe of nuclear generation for present and planned coal-fired power stations. This would comprise, for example, three or perhaps four EPR's.

Thus a 1 GWe nuclear reactor produces 1000 x 24 x 365 = roughly 8,700 GWh per year. If we produce electricity with coal we emit 800 to 1050 grams of CO2 per kWh, Table 28, . Therefore to produce 8,700 GWh of electricity out of coal we will emit roughly between 7 and 9 million tonnes of CO2.

Table 28: Amounts of Carbon Dioxide emitted by Coal-fired and other types of power station.

Electricity generation : CO2 emissions in g/ kWh (life cycle analysis)	
coal	800 to 1050
gas turbines	430
nuclear	6
hydraulic	4
wood	1500 without replantation
photovoltaïc	60 to 150
wind generation	3 to 22

The Australian Government's 2004–05 Budget included a strengthened approach to greenhouse policy. The government is building on the success of its current climate change programme with a significant strengthening to focus and integrate its measures in five strategic areas:

1. Positioning Australia to further reduce its greenhouse signature as the economy continues to grow strongly
2. Engaging internationally to contribute to developing an effective global response to climate change
3. Addressing the risks, capturing the opportunities and preparing Australia for the impacts of climate change
4. Building an understanding of the science of climate change and a capacity to measure greenhouse emission trends accurately
5. Advancing whole of government policy making in this area.

Australia's vigorous and successful pursuit of the Kyoto 108 per cent target underlines the willingness to play a positive role in addressing global emissions. Many of the measures designed to achieve savings in the 2008–12 period will have benefits for much longer. *But the Australian Government will not ratify the Kyoto Protocol, as it does not provide the effective global framework required for meeting long-term objectives.*

Annex 11: NewExternE [62].

In this Annex are given Tables extracted from the NewExterne Study and, in the case of nuclear power, the ExternE Study:

7.2.3 Germany

Table 41: Power generation before and after NewExt – Germany

[Euro-Cent / kWh]	Hard Coal		Oil		Gas	
	before NewExt	NewExt	before NewExt	NewExt	before NewExt	NewExt
Public health						
Mortality - YOLL	0.35	0.36	0.90	0.77	0.05	0.07
of which TSP	0.05	0.07	0.02	0.02	0.00	0.00
SO_2 as sulphates	0.17	0.13	0.66	0.51	0.00	0.00
SO_2 as SO_2	0.02	0.01	0.07	0.03	0.00	0.00
SO2 as total	0.19	0.14	0.73	0.54	0.00	0.00
NO_x as total	0.11	0.15	0.15	0.21	0.05	0.07
NO_x (via ozone)	-0.01	0.00	-0.01	-0.01	0.00	0.00
NO_x (via nitrates)	0.12	0.16	0.17	0.22	0.05	0.07
Morbidity	0.12	0.15	0.23	0.33	0.05	0.03
of which TSP, SO_2, NO_x	0.14	0.18	0.25	0.37	0.07	0.03
NO_x (via ozone)	-0.02	-0.02	-0.02	-0.04	-0.02	-0.01
Crops	-0.003	-0.003	-0.01	-0.01	0.00	0.00
of which SO_2	-0.002	-0.002	-0.01	-0.01	0.00	0.00
NO_x (via acid and N dep.)	-0.001	-0.001	-0.001	-0.001	0.00	0.00
NO_x (via ozone)	0.00	0.00	0.00	0.00	0.00	0.00
Materials	0.02	0.02	0.05	0.05	0.003	0.003
CO_{2equiv}	1.51	1.51	1.67	1.67	0.66	0.66

[62] NewExt: New Elements for the Assessment of External Costs from Energy Technologies. Final Report to the European Commission, DG Research, Technological Development and Demonstration (RTD), IER, Germany, ARMINES / ENSMP, France, PSI, Switzerland, Université de Paris I, France, University of Bath, United Kingdom, VITO, Belgium. September 2004.

Table 42: Up- and Downstream processes before and after NewExt - Germany

[Euro-Cent / kWh]	Hard Coal		Oil		Gas	
	before NewExt	NewExt	before NewExt	NewExt	before NewExt	NewExt
SO_2	0.02	0.01	0.17	0.14	0.001	0.001
NO_x	0.01	0.01	0.04	0.05	0.01	0.02
Particulates	0.25	0.34	0.10	0.13	0.04	0.05
Sum air pollutants	0.27	0.36	0.31	0.33	0.05	0.07
CO_{2equiv}	0.21	0.21	0.15	0.15	0.10	0.10
Sum air pollutants and CO_{2equiv}	0.48	0.57	0.46	0.48	0.15	0.17

7.2.4 United Kingdom

Table 43: Power generation before and with NewExt - United Kingdom

[Euro-Cent / kWh]	Hard Coal		Oil		Gas	
	before NewExt	NewExt	before NewExt	NewExt	before NewExt	NewExt
Public health						
Mortality - YOLL	0.59	0.61	0.58	0.54	0.03	0.05
of which TSP	0.10	0.13	0.01	0.01	0.00	0.00
SO_2 as sulphates	0.33	0.25	0.38	0.29	0.00	0.00
SO_2 as SO_2	0.04	0.02	0.04	0.02	0.00	0.00
SO_2 as total	0.37	0.27	0.42	0.31	0.00	0.00
NO_x as total	0.12	0.21	0.15	0.21	0.03	0.05
NO_x (via ozone)	-0.07	-0.03	-0.03	-0.01	-0.01	-0.01
NO_x (via nitrates)	0.19	0.24	0.17	0.22	0.05	0.06
Morbidity	0.08	0.14	0.16	0.20	-0.02	-0.01
of which TSP, SO_2, NO_x	0.25	0.31	0.23	0.26	0.02	0.03
NO_x (via ozone)	-0.17	-0.17	-0.06	-0.06	-0.04	-0.04
Crops	-0.07	-0.07	-0.03	-0.03	-0.02	-0.02
of which SO_2	-0.002	-0.002	-0.004	-0.004	0.00	0.00
NO_x (via acid and N dep.)	-0.003	-0.003	-0.001	-0.001	-0.001	-0.001
NO_x (via ozone)	-0.07	-0.07	-0.03	-0.03	-0.01	-0.01
Materials	0.03	0.03	0.02	0.02	0.002	0.002
CO_{2equiv}	1.66	1.66	1.16	1.16	0.75	0.75

Table 44: Up- and Downstream processes before and after NewExt - United Kingdom

[Euro-Cent / kWh]	Hard Coal		Oil		Gas	
	before NewExt	NewExt	before NewExt	NewExt	before NewExt	NewExt
SO_2	nd	nd	0.10	0.08	nd	nd
NO_x	nd	nd	0.04	0.06	nd	nd
Particulates	nd	nd	0.01	0.02	nd	nd
Sum air pollutants	nd	nd	0.15	0.16	nd	nd
CO_{2equiv}	0.16	0.16	0.09	0.09	0.02	0.02
Sum air pollutants and CO_{2equiv}	nd	nd	0.24	0.25	nd	nd

7.2.1 Belgium

Table 37: Power generation before and with NewExt - Belgium

[Euro-Cent / kWh]	Hard Coal A		Hard Coal B		Gas	
	before NewExt	NewExt	before NewExt	NewExt	before NewExt	NewExt
Public health						
Mortality - YOLL	3.51	2.95	0.49	0.50	0.05	0.12
of which TSP	0.13	0.16	0.08	0.10	0.00	0.00
SO_2 as sulphates	2.71	2.09	0.27	0.22	0.00	-0.003
SO_2 as SO_2	0.30	0.13	0.03	0.01	0.00	0.00
SO_2 as total	3.01	2.22	0.30	0.23	0.00	-0.003
NO_x as total	0.37	0.57	0.10	0.16	0.05	0.12
NO_x (via ozone)	-0.15	-0.07	-0.03	-0.01	-0.01	-0.01
NO_x (via nitrates)	0.52	0.63	0.14	0.18	0.06	0.13
Morbidity	0.99	1.05	0.12	0.17	0.00	0.02
of which TSP, SO_2, NO_x	1.35	1.41	0.20	0.25	0.02	0.06
NO_x (via ozone)	-0.36	-0.36	-0.08	-0.08	-0.03	-0.04
Crops	-0.27	-0.27	-0.05	-0.06	-0.02	-0.02
of which SO_2	-0.03	-0.03	-0.003	-0.003	0.00	0.00
NO_x (via acid and N dep.)	-0.003	-0.003	-0.001	-0.001	-0.001	-0.001
NO_x (via ozone)	-0.24	-0.24	-0.05	-0.05	-0.02	-0.02
Materials	0.21	0.21	0.03	0.03	0.003	0.003
CO_{2equiv}	1.69	1.69	1.75	1.75	0.74	0.74

Table 38: Up- and Downstream processes before and with NewExt - Belgium

[Euro-Cent / kWh]	Hard Coal A		Hard Coal B		Gas	
	before NewExt	NewExt	before NewExt	NewExt	before NewExt	NewExt
SO_2	0.32	0.27	0.32	0.27	nd	nd
NO_x	0.11	0.16	0.11	0.16	nd	nd
Particulates	0.08	0.11	0.08	0.11	nd	nd
Sum air pollutants	0.51	0.54	0.51	0.54	nd	nd
CO_{2equiv}	0.09	0.09	0.09	0.09	0.04	0.04
Sum air pollutants and CO_{2equiv}	0.60	0.63	0.60	0.63	nd	nd

7.2.2 France

Table 39: Power generation before and with NewExt - France

[Euro-Cent / kWh]	Hard Coal				Oil			
	before NewExt NI data	**before NewExt EdF data**	**NewExt NI data**	**NewExt EdF data**	**before NewExt NI data**	**before NewExt EdF data**	**NewExt NI data**	**NewExt EdF data**
Public health								
Mortality - YOLL	1.16	0.99	1.18	1.09	2.47	2.32	2.02	2.02
of which TSP	0.06	0.00	0.08	0.00	0.05	0.05	0.06	0.06
SO_2 as sulphates	0.53	0.32	0.41	0.24	2.05	1.68	1.58	1.30
SO_2 as SO_2	0.04	0.02	0.02	0.01	0.14	0.11	0.06	0.05
SO_2 as total	0.56	0.34	0.42	0.25	2.18	1.80	1.64	1.35
NO_x as total	0.53	0.65	0.68	0.83	0.24	0.48	0.31	0.61
NO_x (via ozone)	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
NO_x (via nitrates)	0.53	0.64	0.68	0.83	0.24	0.47	0.31	0.61
NMVOC (via ozone)	0.00	0.00	ng	ng	0.00	0.00	ng	ng
Morbidity	0.46	0.40	0.59	0.55	0.94	0.90	0.96	0.98
of which TSP, SO_2, NO_x	0.45	0.39	0.58	0.53	0.94	0.88	0.95	0.97
NO_x (via ozone)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NMVOC (via ozone)	ng	ng	ng	ng	ng	ng	ng	ng
Crops	0.11	0.13	0.11	0.13	0.03	0.093	0.03	0.09
of which SO_2	-0.01	-0.01	-0.01	0	-0.02	-0.02	-0.02	-0.02
NO_x (via acid and N dep.)	-0.01	-0.01	-0.01	-0.01	0.01	0	0.01	0
NO_x (via ozone)	0.12	0.15	0.12	0.15	0.05	0.12	0.05	0.12
NMVOC (via ozone)	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.00
Materials	0.03	0.03	0.03	0.03	0.05	0.07	0.05	0.07
CO_{2equiv}	2.06	1.55	2.06	1.55	1.65	1.29	1.65	1.29

[Euro-Cent / kWh]	Gas			
	before NewExt NI data	**before NewExt EdF data**	**NewExt NI data**	**NewExt EdF data**
Public health				
Mortality - YOLL	0.18	0.06	0.22	0.07
of which TSP	nd	nd	nd	nd
SO_2 as sulphates	nd	nd	nd	nd
SO_2 as SO_2	nd	nd	nd	nd
SO_2 as total	nd	nd	nd	nd
NO_x as total	0.18	0.06	0.22	0.07
NO_x (via ozone)	0.00	0.00	0.00	0.00
NO_x (via nitrates)	0.17	0.06	0.22	0.07
NMVOC (via ozone)	ng	ng	ng	ng
Morbidity	0.07	0.03	0.12	0.04
of which TSP, SO_2, NO_x	0.07	0.02	0.11	0.04
NO_x (via ozone)	0.00	0.00	0.00	0.00
NMVOC (via ozone)	ng	ng	ng	ng
Crops	0.04	0.01	0.04	0.01
of which SO_2	0.00	0.00	0.00	0.00
NO_x (via acid and N dep.)	-0.003	-0.001	-0.003	-0.001
NO_x (via ozone)	0.04	0.01	0.04	0.01
NMVOC (via ozone)	0.00	0.00	0.00	0.00
Materials	0.001	0.001	0.001	0.001
CO_{2equiv}	0.76	0.70	0.76	0.70

Table 40: Up- and Downstream processes before and after NewExt - France

[Euro-Cent / kWh]	Hard Coal		Oil		Gas	
	before NewExt	NewExt	before NewExt	NewExt	before NewExt	NewExt
SO_2	0.21	0.17	0.67	0.55	0.03	0.02
NO_x	0.01	0.02	0.02	0.02	0.03	0.05
Particulates	0.45	0.62	nd	nd	nd	nd
Sum air pollutants	0.68	0.81	0.68	0.58	0.06	0.07
CO_{2equiv}	0.25	0.25	0.18	0.18	0.34	0.34
Sum air pollutants and CO_{2equiv}	0.93	1.06	0.86	0.75	0.39	0.40

Table 6.10 Damages of the nuclear fuel cycle

	mECU/kWh		σ_g
	0%	3%	
POWER GENERATION			
normal operation			
Public health			
fatal cancer[1] - YOLL *(VSL)*	0.059 *(0.099)*	0.00017 *(0.00034)*	B
non-fatal cancer	0.034	0.00010	B
hereditary effects	0.020	0.000060	B
Accidents	ng		
Occupational health - YOLL *(VSL)*	0.063 *(0.084)*	0.056 *(0.071)*	A
Beyond design accidents	0.0034 *(0.0046)*	0.00050 *(0.00076)*	B
OTHER FUEL CYCLE STAGES			
Public health			
radiological impacts YOLL *(VSL)*	3.5 *(4.7)*	0.010 *(0.015)*	B
non-radiological impacts[2] YOLL *(VSL)*	0.56 *(2.7)*	0.43 *(2.1)*	B
Occupational health	0.060		A
Crops	0.00016		B
Ecosystems	iq		
Materials	0.0077		B
Monuments	ng		
Noise	ng		
Visual impacts	ng		
Global warming			C
low	0.075		
mid 3 %	0.35		
mid 1 %	0.91		
high	2.7		

[1] Yoll= mortality impacts based on 'years of life lost' approach, VSL= 'value of statistical life' approach.
[2] Including power generation stage
ng: negligible; nq: not quantified; iq: only impact quantified; - : not relevant

Table 6.11 Sub-total damages of the nuclear fuel cycle

		mECU/kWh	
Discount rate for health effect valuation:		**0%**	**3%**
YOLL ***(VSL)***	low	4.4 *(7.8)*	0.60 *(2.3)*
	mid 3 %	4.7 *(8.1)*	0.90 *(2.6)*
	mid 1 %	5.2 *(8.6)*	1.5 *(3.2)*
	upper	7.0 *(10.4)*	3.3 *(5.0)*

Annex 12 : Professor John H Gittus: CV and Who's Who Entry.

John Gittus obtained an external First Class Honours degree in mathematics from London University. He is a Fellow of the Royal Academy of Engineering and has Doctor of Science degrees from the Universities of London and Stockholm.

He was elected a Regents' Professor at the University of California in Los Angeles in 1990.

He is a Royal Academy of Engineers Professor, teaching at the Universities of London, Plymouth and Swansea.

Professor Gittus is a consultant and advisor to Government Ministries, public bodies and private industry in the UK, Canadian, Japanese and Australia on nuclear and energy matters.

He and Mr Michael Dawson run Lloyd's of London Syndicate 1176, the biggest commercial insurer of nuclear installations in the world: they insure almost all the world's nuclear power stations. The Syndicate has been the most profitable in the Lloyd's market for several years.

He was formerly a UKAEA Director responsible for

- The safety of nuclear reactors,
- The UK's Research and Development on the Pressurized Water Reactor and
- The safety of the nuclear propulsion units of the UK nuclear submarine fleet.

He headed the Task Force that designed the Anglo-American project for the construction of the £2bn Sizewell B nuclear power station.

Topics on which he has recently advised his clients include:

- The Security of Supplies of gas, oil, coal and nuclear power in the UK, the other G8 countries, India, China and elsewhere.
- The provision of finance for the construction of nuclear and wind turbine power stations in the UK, USA, Republic of South Africa and China.
- Nuclear Insurance: Risks, Premiums and Capital.
- The Market Value of Westinghouse and certain other UK and USA Nuclear assets.
- Setting up Joint Ventures between GE Healthcare and Russian radiopharmaceutical businesses.
- Safety and Reliability of pipelines.
- The Risk presented to Nuclear Installations and Operations by Terrorists. (in UK, Japan, Australia and Canada).
- Safety Legislation and Regulation.

- Management of Radioactive Wastes.
- The Safety Analysis of the Pebble Bed Modular Reactor, Republic of South Africa (RSA), and the global market to this new type of nuclear power reactor.

Other recent work that Professor Gittus has done, under Contract to the stated clients, includes the following:

- BNFL, on Security of Supply for nuclear, fossil fuel and renewable sources of energy. This analysis formed one of the two main planks of BNFL's submission to the 2002 UK Energy Review. The analysis continued for two years after that Review.
- Sumitomo/CRIEPI, for a METI review of Japan's plans for the amounts of electricity that Japan will produce from nuclear, fossil fuel and renewable sources, 2005-2020. This involved forecasts of the Security of Supply of various scenarios and of the impact on global warming and public health,
- Chaucer Syndicates and (earlier) Cox Insurance, both of the Lloyd's of London insurance market, with whom Professor Gittus has had Contracts over the last decade. Professor Gittus advises on the risks presented by nuclear power stations and other installations, world-wide. Syndicate 1176, one of the Chaucer Syndicates, insures these at premiums computed by Professor Gittus: it is the most profitable Syndicate in the Lloyd's market.
- The UK DTI, the corresponding Ministry of the Japanese and the Canadian Governments: under four Contracts Professor Gittus has forecast the current risks of terrorist attack on nuclear installations in the UK, Japan and Canada.
- Lloyd's Insurance market: Professor Gittus has developed and maintains databases on the Political, Financial and Business risks that are, and have been, presented by 134 different countries. Professor Gittus has used these databases to compute under other contracts, the Security of Supply of electricity, generated from domestic and imported fuels, for the UK and the other G8 countries.
- ESKOM and the PBMR Company, Republic of South Africa: Professor Gittus continues to advise the CEO and Chairman of the PBMR Company on the safety, reliability and marketability of the Pebble Bed Modular Reactor, PBMR. In three earlier Contracts he made an independent evaluation of the PBMR; led the team that prepared the Safety Analysis Report, Rev1; made forecasts of the global market for the PBMR.

Publications.

Much of the work done under Contract by Professor Gittus is the subject of Confidentiality agreements with his clients. However in a number of cases he has been permitted to publish summaries of work or to present it at meetings of professional bodies. Examples are as follows:

1. BNFL Responses to Specific Questions in "UK Energy Policy Consultation" 5th September 2002. This document gives BNFL's detailed responses to the specific questions raised in the DTI Energy Consultation. It should be read in conjunction with BNFL's main submission to the Consultation "Nuclear Now… for Tomorrow's Generation". Professor Gittus produced the forecasts of Security of Supply for the current and certain revised scenarios in this

BNFL submission under Contract to BNFL and this BNFL document acknowledges this fact.

2. Nuclear now…for tomorrow's generation. BNFL's Submission to the Consultation on UK Energy Policy" Submitted to DTI 5th September 2002. Professor Gittus produced the forecasts of Security of Supply for the current and certain revised scenarios in this BNFL submission under Contract to BNFL and this BNFL document acknowledges this fact.
3. "The Future Security of UK Electricity Supplies: An Analysis". Professor John H Gittus. August 15th 2002. This is the source of the work described by BNFL in its submission to the 2002 Energy Review (items 1 and 2 above). With the permission of BNFL it has been placed on Professor Gittus's Website, **gittus.com**. That Website also contains the eight detailed Reports that Professor Gittus subsequently produced under Contract to BNFL, backing up his analysis. These Reports deal separately with the Security of Supply of all the fuels used in the UK, now and for the coming 20 years: coal, oil, gas, LNG, uranium, windpower, hydro, plus the reliability of the National Grid. All threats to these energy supplies are analysed: political interruptions, business failure, depletion of resources, competition with other users for dwindling reserves, natural hazards such as earthquake, winter storms, lightening; accidents to plant, pipelines and ships, piracy,etc.
4. "Political risk & the insurance context of energy imports to the UK" Professor John Gittus. Conference on "Political & Economic Implications Of Increasing Dependency On Gas Imports" Westminster Energy Policy Forum, Bishop Partridge Room, Church House Conference Centre, 5th October 2004. 8.45am-1.00pm. "Responding to the risks associated with energy supply scenarios". Professor J H Gittus. Presentation at the Institute of Mechanical Engineers, Birdcage Walk, London, April 13th 2005.
6. "Comparison of Security of Electricity Supplies in G8 Countries, 2004 to 2024". Professor John H Gittus. "Power UK", February 2004.
7. "Keeping the Lights Burning". Professor John H Gittus. Presentation at the House of Commons to the All-Party Committee on Atomic Energy. April 27th 2004.
8. Lord Gray of Contin, in a House of Lords Debate on Security of Supply, June 30th 2004, quoted forecasts that Professor Gittus had made to him and other members of the All-Party Committee on Atomic Energy.
9. "Security of the UK Energy Supplies". Professor John H Gittus. The Energy Industries Club, London.
10. "The Future Security of the UK's Energy Supplies". Professor John H Gittus. Fuellers' Conference. Royal College of Surgeons.
11. "Security of the UK's Energy Supplies". Professor John H Gittus. At "Energy Security, the Risks and Realities" The Royal United Services Institute for Defence and Security Studies. November 3rd and 4th 2004. Whitehall, London.
12. "Forecasts of the Security of Electricity Supplies in UK and other G8 Countries." A Personal Presentation by Professor John H Gittus to Stephen Timms, MP, Minister of State for Energy, e-Commerce and Postal Services. July 20th 2004.
13. "The Nuclear Renaissance: Business Opportunities and Risks". Tuesday 25th October 2005, "Energy, the Big Issues". Conference at The Institute of Physics, Portland Place, London.

Entry From Who's Who

Name

GITTUS, John Henry.

Awards

DSc. DTech; FREng 1989.

Positions

Consultant, GE Healthcare, since 1999. Consultant, Chaucer Holdings Plc since 2002; Consultant, Serco Plc (formerly AEA Technology) since 1993; Consultant Sumitomo Corporation 2000-. Other Consultancies.

Education

BSc London 1st Maths; DSc Phys London 1976. DTech Metall Stockholm 1975. CEng, FIMechE, FIS, FIM. FREng 1989

Work

British Cast Iron Res. Assoc., 1947-1955; Mond Nickel Co., R&D Labs, Birmingham, 1955-1960 (develt Nimonic series high temp. super alloys for aircraft gas turbine engines); United Kingdom Atomic Energy Authority, 1960-1989: Research Manager, Springfields; Head, Water Reactor fuel develt; Head, Atomic Energy Tech. Br., Harwell; Director: Water Reactor Safety Research; Safety and Reliability Directorate, Culcheth; Communication and Information; Restructuring. Dir Gen., British Nuclear Forum, 1990-1993. Consultant: Argonne Nat. Lab., USA, 1968; Oak Ridge Nat. Lab., 1969. Visiting Professor: Ecole Polytechnique Fédérale, Lausanne, 1976; Univ. de Nancy, 1984; Regents' Prof., UCLA, 1990-; visiting Prof, Plymouth Univ., 1997-.
Editor-in-Chief, Res Mechanica, 1980-1991.

Publications

Uranium, 1962; Creep, Viscoelasticity and Creep-fracture in Solids, 1979; Irradiation Effects in Crystalline Solids, 1979; (with W. Crosbie) Medical Response to Effects of Ionizing Radiation, 1989; (with P A M Dirac) Dirac's Large Numbers Hypothesis. numerous articles in learned jls.

Recreations

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