CHAPTER 7

WHAT WILL BE REQUIRED OF THE BRITISH GOVERNMENT TO BUILD THE NEXT NUCLEAR POWER PLANT?

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INTRODUCTION

In May 2005, Tony Blair said, "Nuclear power is back on the agenda with a vengeance."[1] His chief scientific adviser and other government spokespeople suggested that up to 20 new nuclear units would be needed. This was taken by many, internationally, as a signal that the United Kingdom (UK) was about to launch an aggressive new program to build nuclear power stations. However, in evidence to a Parliamentary Select Committee, the Energy Minister, Malcolm Wicks said:

> It is not for government to say that we shall have X nuclear reactors and so on. Government will not be building nuclear reactors, will not say they want X number of nuclear reactors. I always thought myself that if at the moment one fifth of our electricity is from nuclear, if the market came forward with something to replicate that broadly in the future, from my own point of view it seems to me that would make a useful contribution to the mix. We are not going to do anything to facilitate that, nor this percentage nor that percentage.[2]

Subsequently, after a challenge by Greenpeace, the High Court found in February 2007 that the government's consultation process on nuclear power was inadequate and had to be repealed. "Mr. Justice Sullivan said that the consultation exercise was 'seriously flawed and that the process was manifestly inadequate and unfair' because insufficient information had been made available by the Government for consultees to make an 'intelligent response'."[3]

The government's Green Paper on energy published in May 2007 therefore made no specific commitments on nuclear power. However, one of Gordon Brown's first statements as the Prime Minister in June 2007 seemed to preempt the consultation. He told Parliament on July 4 that ". . . we have made the decision to continue with nuclear power, and . . . the security of our energy supply is best safeguarded by building a new generation of nuclear power stations."[4]

A new consultation was announced in May 2007 and was closed to submissions in October 2007. In January 2008, the government announced the result of the consultation, which again favoured new nuclear construction. The new White Paper stated: "[A]gainst the challenges of climate change and security of supply . . . the evidence in support of new nuclear power stations is compelling . . ."[5]

The commitment not to provide subsidies was reiterated: "It will be for energy companies to fund, develop and build new nuclear power stations in the UK, including meeting the full costs of decommissioning and their full share of waste management costs."[6] The utilities most likely to build nuclear plants, EDF and E.ON both supported the suggestion that subsidies would not be needed. Vincent de Rivaz, CEO of EDF Energy (UK) said: "We have made it clear we are not asking for subsidies, all costs will be borne by us."[7] While E.ON said in a press release: "It also believes that there is no requirement for either government subsidies or for a guaranteed long-term cost of carbon to make new nuclear power stations economic."[8]

This confidence is in contrast to the situation in the United States where the government has committed billions of dollars to subsidies for new nuclear plants and where industry has frequently stated that new nuclear plants without subsidies and guarantees would not be feasible. For example, in December 2007, Christopher Crane, President of Exelon Generation (one of the utilities that has stated an intention to build new nuclear plants), stated: "If the loan guarantee program is not in place by 2009, we will not go forward."[9]

This report examines whether the "free market" really will build new nuclear power plants in the UK without strong support from public funds other than a few enabling measures, for example, on licensing reactor designs, to include a review of what commitments the UK government has actually made. Additionally, this chapter looks at why owning and operating a nuclear power plant is so economically risky and what the specific risks are. It reviews the UK's track record with nuclear power, an important criterion used by the financial community to judge investment risk. This data show that nuclear power has a poor record in the UK. Financial costs borne by electricity consumers and taxpayers for this have been high, but, at least as important, the opportunity cost of placing resources in fruitless nuclear expansion programs has also been high. If these resources had gone into developing renewables and energy efficiency programs, the UK would be closer to making its electricity supply system sustainable.

This chapter also looks at experience in Finland and the United States with attempts to relaunch nuclear power programs. The order of the Olkiluoto 3 plant was portrayed by nuclear advocates as a demonstration that nuclear orders were possible in a liberalized electricity market without subsidy. However, closer examination of the terms of the deal show a number of apparent subsidies, while experience with the first 2 years of construction of the plant have been very poor, reinforcing how economically risky nuclear power plants are. The Bush administration tried to relaunch nuclear ordering, using federal subsidies to kick-start the process with a handful of new plants. Ordering was then expected to be self-sustaining. However, it became clear that the subsidy and guarantee program would have to be open-ended if nuclear orders beyond that of a handful of heavily subsidized units were to be placed.

This chapter reviews the claims that the use of financial instruments, such as bonds, could mean that the problems of dealing with economic risk could be overcome at low cost. Finally, a review of what guarantees and subsidies companies hoping to build nuclear power plants in Britain might seek and what the cost to the public might be is provided.

Issues of decommissioning and waste disposal have received a great deal of publicity in the UK. There have been extensive debates concerning the government's commitment to ensure that the full costs of decommissioning and a full share of waste management costs would be borne by energy companies and not subsidized by taxpayers. However, while the cost of these processes is high and very uncertain, the fact that they do not take place for up to a century or more after the plant is built means that, in any normal economic appraisal, these costs are discounted away. Ensuring that adequate financial arrangements are in place for decommissioning and waste disposal is therefore an important issue from a public policy point of view. However, the cost of these arrangements is not likely to be a major item for a company in its decision whether to build new nuclear plants. There is, therefore, only limited coverage of waste and decommissioning issues in this chapter.

WHAT HAS THE GOVERNMENT PROMISED ON SUBSIDIES AND GUARANTEES?

The statement by Tony Blair indicating that nuclear power is once again a significant policy agenda issue caught the headlines, but it contains no specific promises. The government's more precise statements are less aggressive. The 2006 Review stated:

> Any new nuclear power stations would be proposed, developed, constructed and operated by the private sector, who would also meet full decommissioning costs and their full share of long-term waste management costs. The Government does not take a view on the future relative costs of different generating technologies. It is for the private sector to make these judgments, within the market framework established by government. The actual costs and economics of new nuclear will depend on, amongst other things, the contracts into which developers enter, and their cost of capital for financing the project.[10]

In evidence to the Trade and Industry Select Committee, Energy Minister Malcolm Wicks was more blunt.

> It is not for government to say that we shall have X nuclear reactors and so on. Government will not be building nuclear reactors, will not say they want X number of nuclear reactors. I always thought myself

> that if at the moment one fifth of our electricity is from nuclear, if the market came forward with something to replicate that broadly in the future, from my own point of view it seems to me that would make a useful contribution to the mix. We are not going to do anything to facilitate that, nor this percentage nor that percentage.[11]

And in response to a question on subsidies: "Is that the Government's position? No direct subsidies and no indirect subsidies. Am I clear on that?" he said, "No cheques [checks] will be written, there will be no sweetheart deals." And:

> No, there will not be any special fiscal arrangements for nuclear. It should not be a surprise, with respect, because we have said it very clearly in the Energy Review. You could pursue this if you wanted by saying that nuclear waste is quite a complex subject and we are going to look very carefully at that to make sure that the full costs of new nuclear waste are paid by the market.

The main concession was on licensing:

The idea of prelicensing is that you can say, here is a wind farm, here is a nuclear reactor, or a gas-powered station; let us prelicense it so that the regulators are satisfied that it is safe and all the other things as a piece of kit. Then the local inquiry can purely be about local issues rather than becoming a national or international occasion to reopen the whole debate about whether windmills or nuclear are desirable. That is what we are trying to do.[12]

DECOMMISSIONING

The only apparent exception to the no-subsidies and guarantees rule concerns the arrangements for waste disposal. In February 2008, the government launched a Consultation on Funded Decommissioning Programme Guidance for New Nuclear Power Stations.[13] The title is misleading as the report covers waste disposal costs as well as decommissioning, and the proposals represent a significant departure from previous expectations relating to waste disposal as well as to decommissioning.

- On decommissioning, the government is proposing that companies would have to demonstrate detailed and costed plans for decommissioning, waste management, and disposal before they even begin construction of a nuclear power station;
- Set money aside into a secure and independent fund from day one of generating electricity; and,
- Have additional security in place to supplement the Fund should it be insufficient, for example, if the power station closes early.[14]

If these proposals are carried through with adequate measures to ensure that if estimated decommissioning costs increase, the companies will be required to make sufficient additional contributions to make up the shortfall, they appear a good base. However, closer examination reveals a number of issues not well-accounted for.

On timing, the proposals assume a plant will operate for 40 years. This will be followed by a 7-year defueling period. Stage 1 then follows, taking 5 years;

stage 2 is forecast to take a further 5 years; stage 3 is expected to take 10 years; and final site clearance is expected to take 6 years. So the elapsed time from plant closure to end of decommissioning is 37 years. This is a welcome shortening compared to the proposals for existing British plants, which is currently based on timescales of in excess of 100 years from plant closure to completion of decommissioning.

Little guidance is given on discounting. For example, no indication of the level of discount rate that can be assumed is shown, nor is it specified how long into the future liabilities can be discounted for. However, the area where it appears a guarantee is expected is in the following paragraph:

> We anticipate that operators will request that the Government provide them with a fixed unit price at the time they seek approval for their Funded Decommissioning Programme. This will occur alongside the regulators' licensing and permitting processes. At this time, the Secretary of State would use the cost modelling methodology it has developed, together with information from the NDA's parametric cost modelling work on the estimated costs of disposal facilities, to determine the fixed unit price, including the appropriate risk premium. The cost modelling methodology is described in greater detail at paragraphs 4.5.1 – 4.5.39 and further information on when we expect to be in a position to set a fixed unit price for operators is set out in the Roadmap paragraphs 2.25 – 2.32 and Table 2. To help future operators with their planning, the Government would expect to give operators a non-binding indicative price at an earlier date than when the Government would be willing to provide them with a final fixed unit price.[15]

This makes it clear that once the plant is ready to be built, the companies' contribution to the decommissioning fund would be capped, and, if costs increased beyond the level covered by the risk premium, taxpayers would have to foot the bill. Given the very rapid rate of escalation of decommissioning cost estimates in advance of the most challenging stage of decommissioning work actually being attempted, there must be a very large risk that the estimated cost will fall far short of the actual cost, even if the risk premium is included. This therefore represents a major taxpayer-funded cost guarantee.

WASTE DISPOSAL

On waste disposal, the cost guarantees are much clearer. For low-level waste, no guarantees are involved. Operators will be expected to make their own arrangements for waste disposal and "will be required to meet these costs from operational expenditure for operational low level waste, and from the Fund for decommissioning low level waste."[16] While the cost of low-level waste disposal is far from stable, the process is technically well-established.

However, intermediate and high-level (spent fuel) waste is subject of a major cost guarantee backed by taxpayers (it is assumed that spent fuel will not be reprocessed). The consultation states: "The Government would expect to set a fixed unit price based on the operator's projected full share of waste disposal costs at the time when the approvals for the station are given, prior to construction of the station."[17]

Given that neither intermediate nor high-level waste disposal is established anywhere, the costs of such processes must be regarded as highly speculative. The government does try to provide evidence that the risk of cost escalation will be taken account of:

> In return for giving operators certainty over when they will transfer title to and liability for their waste and spent fuel to the Government, we will set the level of the risk premium to take account of the risk to the Government that the construction of disposal facilities is not complete by the date or dates specified in the agreed schedule. This risk premium will be built into the fixed unit price for the waste disposal service.[18]

However, as with decommissioning, such untried, technically challenging, and socially contentious processes must involve a huge degree of uncertainty.

WHY IS NUCLEAR POWER ECONOMICALLY RISKY AND DOES THIS MATTER?

Who Bears the Risk?

Any investment in a large new power station is economically risky because of the scale of the investment, the technologically challenging nature of power production, and the scope to choose options that turn out, for example because of movements in fossil fuel prices, to prove uneconomic. These risks were borne by consumers under the old model of organization of the electricity industry where electricity generation was a monopoly in a given territory. If the cost of a power plant was higher than forecast or it proved to be more expensive than the alternatives, the additional costs were paid by consumers. While this did expose consumers to investment risk, consumers were compensated because the cost of capital for new power stations was low since financiers could rely on the generation company recovering any costs it incurred from consumers.

One exception to this was in the United States where regulators could force generation companies to absorb some or all of the cost of investments if the regulator judged that the costs were excessive. In practice, this provision was not used until the mid-190s. Then, as nuclear plants began to come on line at prices far above their cost estimates, regulators began to disallow recovery of costs that they judged imprudent. Ordering nuclear power plants became a major economic risk for U.S. electric utilities, and ordering ceased in 1979, with all plants ordered after 1974 subsequently cancelled. Dozens of nuclear orders were cancelled to avoid exposure of utilities to this risk.

Elsewhere, developments in shifting investment risk from electricity consumers were not accomplished until the 1990s. One of the main motivations for the trend to reform and liberalize electricity industries was a desire to expose electricity generation companies to more investment risk, with the expectation that this would act as a financial discipline. If the company made a bad decision, the cost would be paid for from the profits of the company, not by consumers.

Why Is Nuclear Power Particularly Economically Risky?

As argued above, any investment in a substantial power plant is a significant economic risk and, if the company building the plant bears the consequences of that risk the cost of capital will be much higher than under the old system. Financiers will fear that companies building new power plants could go bankrupt if the power plant cannot compete in the wholesale electricity market and will therefore charge a substantial risk premium on loans to build the plant to cover the risk that the loan will not be repaid if the company fails. Nuclear power is among the most capital intensive of power generation technologies with financial charges expected to account for more than half the total kilowatt (kWh) cost of generation. Therefore, making the electricity generation business a competitive one will inevitably disadvantage nuclear power compared to other less capital-intensive technologies.

However, nuclear power plants are far more economically risky than other types of power plant. This risk arises from a number of sources:

- Nuclear power plants are far more complex than most power plants, and there is far more potential for errors to be made in construction;
- Nuclear power plants are mostly constructed on-site, whereas other types of power plants can be assembled mainly in factories, where costs and quality are easier to control;
- Many of the costs arising from nuclear power generation are beyond the control of the companies, for example, projected costs for waste disposal and decommissioning have escalated sharply in the past couple of decades, while safety regulators may impose additional requirements on the company as a result of problems arising in other countries. For example, the Chernobyl and Three Mile Island accidents led to new regulatory requirements being imposed on plants where no problems had occurred.

However, the main perception of risk arises from the poor record of the nuclear industry in meeting its forecasts.

WHO ARE THE INTERESTED PARTIES AND WHAT ARE THEIR MOTIVATIONS?

In a decision to order a nuclear power plant, there are three sets of interests directly involved: (1) the commercial companies selling and buying the plant, (2) the governments, and (3) the financial community, including financiers, credit rating agencies, and investment analysts. Each of these has a rather different perspective on the issue.

The Companies.

The duty of a commercial company is to maximize the profits for its shareholders. In a perfect market, profits will be maximized by choosing the cheapest production technologies and maximizing internal efficiency. However, perfect markets do not exist and companies rely heavily on making strategic decisions, for example, to reduce their exposure to risk, or build their reputation, or build customer loyalty. Commercial companies discount future costs and benefits, so their outlook tends to be rather short-term, and financial consequences more than, say, 20 years in the future carry little weight. For plant vendors, some sales may have a particular value if, for example, they demonstrate a technology or open up a valuable new market. Companies may accept lower profits or even make a loss on a particular order if, in the long term, it strengthens the company's position. Generation companies will, all things being equal, look for the lowest cost technology if they are operating in a competitive market. However, if a technology needs protection from the market, it might be very attractive to a company if the government is prepared to provide that protection, for example, if the technology has particular environmental advantages.

Government.

Governments have a number of perspectives. They have a strategic duty to increase the competitiveness of the country's economy. Approaches vary widely on this from the interventionist approach, where they become involved in commercial deals, to the "hands-off" free market approach. Some governments see nuclear power as providing a cheap or at least a stable-price source of power that can largely be regarded as indigenous, and they therefore see it as their duty to promote nuclear power. Here, we will not debate whether these perceptions are valid, but most people would regard it as part of the government's responsibility to at least guide energy policy in a strategic direction. Even the most free-market of governments, such as those of Margaret Thatcher (UK) and Ronald Reagan (U.S.) have tried to promote nuclear power.

Governments of the home country of nuclear vendors may also try to promote reactor sales, for example, by providing loan guarantees or by making enabling political deals. The French government provided loan guarantees for the Olkiluoto Plant to promote the interests of the French vendor, Areva. The United States has recently concluded a bilateral agreement with India to allow U.S. companies to supply reactors and reactor technology to India. This breaks an international embargo on the supply of reactor technology and equipment going back more than 30 years resulting from India's nuclear weapons test in 1974.

The Financial Community.

In the past, while electricity was a monopoly industry, the financial community had a limited role in nuclear power investment decisions, at least for developed countries with stable economies. Full cost recovery from consumers was guaranteed, therefore the commercial risk attached to a nuclear power plant order was minimal. However, as was demonstrated by the collapse in 2002 of British Energy, owning and operating nuclear power plants is now a highly risky venture, and that risk is borne at least in part by the shareholders. Credit rating agencies will examine the investments and decisions of a company and use that information to assess their credit rating, which will, in turn, affect the cost of capital to that company. Financiers will assess the riskiness of a project and on that basis, as well as the general credit rating of the company, decide whether to lend money and at what rate. Investment analysts will look at the decisions of the companies assessing the likely profitability of the company. On that basis, they will decide whether to buy or sell shares, or recommend whether to buy or sell. Institutional investors have the power to force management changes if they are unhappy with the decisions being taken.

The decision to order a nuclear power plant is often seen as a two-way deal between the vendor and the utility, but the reality is that the third party of the deal is the financial community. If ordering a nuclear plant would adversely affect a company's share price or its credit rating, the company would have to think very hard before placing that order. The situation was summed up very neatly by Thomas Capps, CEO of a U.S. utility (Dominion) linked with a bid to build a nuclear plant under the Nuclear 2010 initiative: "We aren't going to build a nuclear plant anytime soon. Standard & Poor's and Moody's would have a heart attack. And my chief financial officer would, too."[19]

WHAT ARE THE RISKS?

Construction Cost and Time.

The usual rule-of-thumb for nuclear power is that about two-thirds of the generation cost is accounted for by fixed costs, that is, costs that will be incurred whether or not the plant is operated, and the rest by running costs. The main fixed costs are the cost of paying interest on the loans and repaying the capital, but the decommissioning cost is also included. In the United States, an assessment of 75 of the country's reactors showed predicted construction costs to have been $45 billion, but the actual costs were $145 billion.[20] In India, the country with the most recent and current construction experience, completion costs of the last 10 reactors have averaged at least 300 percent over budget.[21]

Over-runs in construction time also have high economic consequences. A delay in completing the plant will increase the interest that has to be paid on the loans needed to finance the plant. If the output of the plant is contracted to a customer, the plant owner might have to pay expensive compensation to the customer. The market value of a day's output of a 1,000 megawatt (MW) nuclear power plant could be around $1.5 million, so a year's delay could mean that $0.5 billion of power could have to be bought from the market. If supply is tight, the cost of buying this extra replacement power could be significantly more than the contract price.

Operating Performance.

For a capital intensive technology like nuclear power, high utilization is of great importance so that the large fixed costs (repaying capital, paying interest, and paying for decommissioning) can be spread over as many saleable units of output as possible. In addition, nuclear power plants are physically inflexible, and it would not be wise to start up and shut down the plant or vary the output level more than is necessary. As a result, nuclear power plants are operated on "base-load," except in the very few countries (e.g., France) where the nuclear capacity represents such a high proportion of overall generating capacity that this is not possible. Even in France, the amount of load-following is small. A good measure of the reliability of the plant and how effective it is at producing saleable output is the capacity factor. The capacity factor is calculated as the output in a given period of time expressed as a percentage of the output that would have been produced if the unit had operated uninterrupted at its full design output level throughout the period concerned.[22]

Capacity factors of operating plants have been much poorer than forecast. The assumption by vendors and those promoting the technology has been that nuclear plants would be extremely reliable with the only interruptions to service being for maintenance and refueling, giving capacity factors of 85-95 percent. However, performance was poor, and around 1980, the average capacity factor for all plants worldwide was about 60 percent. To illustrate the impact on the economics of nuclear power, if we assume fixed costs represent two-thirds of the overall cost of power if the capacity factor is 90 percent, the overall cost would go up by a third if capacity factor was only 60 percent. To the extent that poor capacity factors are caused by equipment failures, the additional cost of maintenance and repair would further increase the unit cost of power. In a competitive market, a nuclear generator contracted to supply power that is unable to fulfill its commitment is likely to have to buy the "replacement" power for its customer, potentially at very high prices.

However, from the late 1980s onwards, the worldwide nuclear industry has made strenuous efforts to improve performance, and capacity factors now average more than 80 percent, for example, the United States now has an average of nearly 90 percent, compared to less than 60 percent in 1980, although the average lifetime capacity factor of America's nuclear power plants is still only 70 percent.

Operating Costs.

Many people assume that nuclear power plants are essentially automatic machines requiring only the purchase of fuel and that they have very low running costs. The cost of fuel is relatively low and has been reasonably predictable. However, the assumption of low running costs was proved wrong in the late 1980s and early 1990s when a small number of U.S. nuclear power plants were retired because the cost of operating them (excluding repaying the fixed costs) was found to be greater than cost of building and operating a replacement gas-fired plant. It emerged that nonfuel operation and maintenance (O&M) costs were on average in excess of $22/MWh, while fuel costs were then more than $12/MWh.[23] Strenuous efforts were made to reduce nonfuel nuclear O&M costs, and by the mid

1990s, average nonfuel O&M costs had fallen to about $12.5/MWh and fuel costs to $4.5/MWh. However, it is important to note that these cost reductions were achieved mainly by improving the reliability of the plants rather than actually reducing costs. Many O&M costs are largely fixed—the cost of employing the staff and maintaining the plant— and vary little according to the level of output of the plant, so the more power that is produced, the lower the O&M cost per MWh. The threat of early closure on grounds of economics has now generally been lifted in the United States.

It is also worth noting that British Energy, which was essentially given its eight nuclear power plants when it was created in 1996, collapsed financially in 2002 because income from operation of the plants barely covered operating costs.

Fuel costs have fallen because the world uranium price has been low since the mid-1970s. U.S. fuel costs average about $5/MWh, but these are arguably artificially low because the U.S. Government assumes responsibility for disposal of spent fuel in return for a flat fee of $1/MWh. This is an arbitrary price set more than 2 decades ago and is not based on actual experience.

Decommissioning and Waste Disposal Costs.

These costs are difficult to estimate because there is little experience with decommissioning commercial-scale plants, and the cost of disposal of waste (especially intermediate or long-lived waste) is uncertain. However, even schemes which provide a very high level of assurance that funds will be available when needed will not make a major difference to the overall economics. For example, if the owner was required to place the (discounted) sum forecast needed to carry out decommissioning at the start of the life of the plant, this would add only about 10 percent to the construction cost.

The problems come if the cost has been initially underestimated, the funds are lost or the company collapses before the plant completes its expected lifetime. All of these problems have been experienced in Britain. The expected decommissioning cost has gone up several-fold in real terms over the past couple of decades. In 1990, when the Central Electricity Generating Board (CEGB) was privatized, the accounting provisions made from contributions by consumers were not passed on to the successor company, Nuclear Electric. The subsidy that applied from 1990-96, described by Michael Heseltine[24] as being to "decommission old, unsafe nuclear plants" was, in fact, spent as cash flow by the company owning the plant, and the unspent portion has now been absorbed by the Treasury. The collapse of British Energy has meant that a significant proportion of their decommissioning costs will be paid by future taxpayers.[25]

Insurance and Liability.

There are two international legal instruments contributing to an international regime on nuclear liability: The International Atomic Energy Agency's Civil Liability for Nuclear Damage (1963 Vienna Convention) and the Organization for Economic Cooperation and Development's (OECD) Third Party Liability in the Field of Nuclear Energy (1960 Paris Convention) together with the linked Brussels Supplementary Convention of 1963. These conventions are linked by the Joint Protocol, adopted in 1988. The main purposes of the conventions are to:

1. Limit liability to a certain amount and limit the period for making claims;

2. Require insurance or other surety by operators;

3. Channel liability exclusively to the operator of the nuclear installation;

4. Impose strict liability on the nuclear operator, regardless of fault, but subject to exceptions (sometimes incorrectly referred to as absolute liability); and,

5. Grant exclusive jurisdiction to the courts of one country, normally the country in whose territory the incident occurs.

In 1997, a Protocol was adopted to amend the Vienna Convention, which entered into force in 2003, and in 2004, a Protocol was adopted on the Paris Conventions. These changed the definition of nuclear damage and changed the scope. For the Brussels Convention, new limits of liability were set as follows: operators (insured) €700 million; installation state (public funds) €500 million; and collective state contribution €300 million; a total liability of €1500 million. These new limits have to be ratified by all contracting parties and are currently not in force.

The scale of the costs caused by, for example, the Chernobyl disaster, which may be in the order of hundreds of billions of euros, means that conventional insurance coverage would probably not be available and, even if it was, its coverage might not be credible because a major accident would bankrupt the insurance companies.

It has been estimated that if Electricité de France (EDF), the main French electric utility, was required to fully insure its power plants with private insurance but using the current internationally agreed limit on liabilities of approximately €420 million, it would increase EDF's insurance premiums from €0.017/MWh, to €0.19/MWh, thus adding around 8 percent to the cost of generation. However, if there was no ceiling in place and an operator had to cover the full cost of a worst-case scenario accident, it would increase the insurance premiums to €5/MWh, thus increasing the cost of generation by around 300 percent.[26]

A SHORT HISTORY OF THE BRITISH NUCLEAR POWER PROGRAM

The policy announced by the UK government in January 2008 will be the fifth attempt to relaunch the UK nuclear power program. The first generation nuclear power plants in Britain were of an indigenous design known as magnox. Between 1956 and 1971, 11 magnox stations were completed, but by the early 1960s, it was clear this design could never be economic. The magnox stations are generally portrayed as reliable workhorses and, if they had been followed by successful new designs, they would probably have been retired at the end of their 20-year design lifetime. However, the failure of subsequent programs has meant that they have operated long beyond their design lifetime, up to 40 years, and in 2008, two units remain in service. They have suffered corrosion problems, their reliability has been mediocre, and they represent a very expensive source of electricity.

In 1965, the UK government chose another British design to succeed the magnoxes, the advanced gas-cooled reactor (AGR), and five stations, each of about 1,200MW, were ordered. Instead of the 4 years forecast for building the plants, these took from 10-24 years from start of construction to commercial operation. None of the plants ever operated as designed, and all operate significantly below their design maximum output rating.

By 1970, the problems with the design were clear, and after a further 3 years of investigations, in 1973 the government chose another UK design, the Steam generating heavy water reactor (SGHWR). By 1977, the developers had to acknowledge that this design could not be built on a commercial scale and thus was abandoned. In 1977, the government adopted a dual reactor policy, two more AGRs were to be built, and the steps taken to be in a position to order a U.S. designed reactor, the pressurized water reactor (PWR) from Westinghouse. In 1979, the two AGR orders were confirmed, and the government announced a 10 reactor order program of Westinghouse PWRs, with the first order to be placed in 1981, and the others to follow at yearly intervals. By 1987, when the first order (Sizewell B) was actually placed, the program had been reduced to four units. At the same time, the government announced its intention to privatize the UK electricity industry and operate the generation sector as a competitive market.

In 1989, the government acknowledged that, after 2 years of effort, a plan could not be devised that would allow the privatization of the nuclear power plants. The main problem appeared to be the economic risk associated with building and operating the four new proposed PWRs (including Sizewell B). The operating plants were uneconomic, but their costs were largely known, and subsidies could be used to cover these. However, the risk of overrunning construction times and costs and poor operating reliability were much more open-ended for the new PWRs. The Energy Minister at the time claimed that "unprecedented guarantees were being sought. I am not willing to underwrite the private sector in this way. . . ."[27]

Studies preparing for privatization had revealed that, far from being cheap sources of generation, as had always been claimed, the operating cost alone of the magnox and the AGR stations was double that of the expected wholesale price of electricity. The construction cost, normally expected to account for more than two-thirds of the total generation cost from a nuclear power plant, had to be written off. The nuclear power plants were transferred to two new publicly owned companies, Nuclear Electric, Scottish Nuclear, and a huge consumer subsidy was introduced raising £1 billion per year simply to allow the companies to break even. The four unit PWR program was abandoned, although work was allowed to continue on Sizewell B, despite the clear evidence it would be hopelessly uneconomic.

In 1996, a year after the completion of Sizewell B, at a cost in excess of £3 billion when its costs were known and it seemed likely that its reliability would be reasonable, the government sold the seven AGRs and Sizewell B for about £1.7 billion to a new company, British Energy. The reliability of the AGRs had improved sufficiently that there appeared a reasonable expectation that their running costs could be met from the income from sales of electricity. While the company was required to make some contribution to the cost of decommissioning, the largest part of the cost was left to be met from British Energy's cash flow at the time decommissioning was carried out.

The privatization meant that eight nuclear stations, each of about 1200MW and paid for by consumers, were sold for about half the cost of building Sizewell B. Much of the cost of building Sizewell B was paid for from the £1 billion per year consumer subsidy, applied from 1990-96, money which consumers had been told would go to pay for decommissioning and waste disposal.

The UK wholesale electricity price remained unreasonably high from privatization in 1990 until 2001, when it fell sharply. British Energy quickly got into difficulties, and by September 2002, it had collapsed. The government eventually managed to force through a package of measures to save the company by assuming some of its liabilities and subsidizing its costs (for example on reprocessing), and the company was relaunched in 2005, with the government taking 64 percent share of ownership as the price for saving the company. In June 2007, the government sold 25 percent of the shares, and it expects to sell a further 10 percent, leaving the government with a 30 percent holdings. When the wholesale price of electricity falls again, the reliability of the plants deteriorates as they age and, as the impact of having to retire the oldest AGRs takes effect, it seems likely that the company will fail with taxpayers again having to take on the financial burdens it leaves behind.

Ironically, the main asset the company now has is ownership of the sites where many of the existing plants are. It is generally acknowledged that, in any new nuclear program in the UK, the first plants will be built on existing sites as it might be expected that public opposition here would be much less than at new sites. British Energy has neither the resources nor the credibility to build new nuclear plants, but it could earn significant income from the use of its existing sites, and a new nuclear program may be British Energy's best hope of survival, albeit essentially as a real estate company.

Lessons.

Even when the evidence is overwhelming that mistakes have been made, as happened with the AGR program, the SGHWR, and Sizewell B, the government will not abandon misconceived programs until long after they should have been cut and at great cost to taxpayers and electricity consumers. The failed attempts to relaunch nuclear power programs were based on hopelessly optimistic forecasts of construction costs and times, reliability, and operating cost.

However, the main outcome of this experience is the huge opportunity cost of these largely fruitless programs. They consumed the vast majority of government and electricity industry research and development (R&D) budgets, they dominated the attention of civil servants involved with the electricity industry, and they influenced UK industry to try to develop nuclear capabilities instead of more productive and profitable capabilities in renewable energy sources and energy efficient technologies.

OLKILUOTO AND THE U.S. NUCLEAR POWER 2010 PROGRAM

Olkiluoto.

The Olkiluoto order is currently the only live new order in Western Europe or North America, and the first to be placed since the Civaux 2 order in France in 1993, which was coupled to the grid in 1999. It is the first plant of a new design, the European pressured water reactor (EPR), developed by the Franco-German company, Areva. The EPR is a 1,600MW pressurized water reactor (PWR) evolved from designs supplied by the two main owners of Areva NP, Areva (France) and Siemens (Germany). The customer is a company called Teollisuuden Voima Oy (TVO), owned by the large electric-intensive industries of Finland.

Olkiluoto is often portrayed as the exemplar of the capabilities of current designs. It is predicted to be cheaper to build and operate, and safer than its predecessors. It is also seen as a demonstration that nuclear power orders are feasible in liberalized electricity markets. Many commentators claimed that nuclear power orders were unfeasible in liberalized markets because consumers would no longer bear the full risk of building and operating new power plants. It is therefore important to examine the circumstances of the Olkiluoto order to see how far it really can be seen as a commercial order chosen in a free market and without subsidies and guarantees.

Before examining the specifics of the order, it is worth noting that Finland's experience with nuclear power has been much better than that of the UK. Finland ordered four relatively small nuclear power plants from 1971-75. Two of these at Loviisa (both 440MW net) used the first generation Russian design (VVER-440) but were upgraded to Western standards with the assistance of Siemens. The two at Olkiluoto (both 660MW net) use a Swedish BWR design similar to plants built in Sweden. The reliability of all four plants has been high, and, even today when reliability is much higher in the rest of the world than it was in the 1980s, all four Finnish units are in the top 20 percent in the league table of nuclear power plants ordered by lifetime capacity factor. So, the track record of Finland as a nuclear operator is better than that of the UK.

Construction Cost and Time.

To reduce the risk to the buyer, Areva offered the plant under turnkey terms:

> It is a fixed price contract, with the consortium having total responsibility for plant equipment and buildings, construction of the entire plant up to and including commissioning (excluding excavation), licensability, schedule and performance. The overall project cost has been estimated by TVO at around €3bn.[28]

The turnkey terms fixed the price TVO would have to pay and allowed for fines to be levied on the contractors if the plant was late. The schedule allowed for a 48-month period from pouring of first concrete to first criticality.

From the start, the construction period has gone seriously wrong, so that after 18 months of construction in December 2006, the plant was 18 months behind schedule, and the vendor, Areva, was suffering severe losses.[29] This was not the result of a particular problem, but the result of a range of failures, including welding, delays in detailed designs, problems with concrete, and with the quality of some equipment. More generally, it seemed that none of the parties involved, including the vendor, the customer, or the safety regulator, had a clear enough understanding of the requirements that building a nuclear plant placed on them.

In December 2006, the French Ministry of Industry (the French government owns more than 90 percent of Areva) said that the losses to Areva had reached €700 million on a contract fixed at €3 billion. The turnkey contract should ensure that this cost escalation is not passed on to the customer, although the deal appeared to be under strain. Philippe Knoche, an Areva representative stated:

> Compensation principle. TVO did not accept this interpretation and the TVO project manager, Martin Landtman, when asked about Knoche's statement, said: 'I don't believe that Areva says this. The site is in the contractor's hands at the moment. Of course, in the end, TVO is responsible for what happens at the site. But the realisation of the project is Areva's responsibility.'[30]

Compensation for delays has already reached the limit of €300 million that would be payable for a delay of 18 months. The buyer will not receive compensation for further delays beyond those already incurred by September 2006.

Further problems were announced in August 2007, although these were not fully quantified in terms of delays to completion or additional costs. It was reported that the delays were partly due to problems meeting the requirement that the plant should be able to withstand an aircraft crashing into it, and partly because the volume of documentation required had been underestimated by the vendor.[31] One report stated that Areva NP was going to take an additional provision €500-700 million on top of the €700 million provision already made for losses.[32] In December 2007, Areva announced that the plant was not expected to be completed until summer 2011.

Finance.

The details of how the plant would be financed have not been published, but the European Renewable Energies Federation (EREF) and Greenpeace separately made complaints to the European Commission in December 2004 that they contravened European State aid regulations. The Commission did not begin to investigate the complaints until October 2006, and in September 2007, the Competition Commission dropped the case. According to EREF, the Bayerische Landesbank (owned by the state of Bavaria) led the syndicate (with Handelsbanken, Nordea, BNP Paribas, and J. P. Morgan) that provided the majority of the finance. It provided a loan of €1.95 billion, about 60 percent of the total cost at an interest rate of 2.6 percent. It is not clear if this is a real or a nominal rate. If it is a nominal rate, the real rate is effectively zero. Two export credit institutions are also involved: France's Coface, with a €610 million export credit guarantee covering Areva supplies, and the Swedish Export Agency SEK for €110 million.

The Customer.

The buyer, TVO, is an organization unique to Finland. PVO, the largest shareholder, holds 60 percent of TVO's shares. PVO is a not-for-profit company owned by Finnish electric-intensive industry that generates about 15 percent of Finland's electricity. Its shareholders are entitled to purchase electricity at cost in proportion to the size of their equity stakes. In return, they are obliged to pay fixed costs according to the percentage of their stakes and variable costs in proportion to the volume of electricity they consume. The other main shareholder in TVO is the largest Finnish electricity company, Fortum, with 25 percent of the shares. The majority of shares in Fortum are owned by the Finnish Government. This arrangement is effectively a life-of-plant contract for the output of Olkiluoto 3, at prices set to fully cover costs.

Analysis of the Olkiluoto Experience.

Turnkey contracts have been few and far between in the history of nuclear power and have generally resulted in huge losses to the vendor. Nuclear power plants are immensely complex requiring a great deal of on-site work and input from a large number of organizations. It is therefore difficult for any one company to feel that they have sufficient control over the process so that they can guarantee the price to the customer. The most famous turnkey orders were the 12 placed in the United States in 1963-66.[33] The vendors lost huge amounts of money on these orders, but they achieved their objective. They convinced utilities that the vendors were confident of their designs and that buying a nuclear plant was no greater risk than buying a fossil fuel plant. Subsequent U.S. orders did not contain this protection for the buyer.

If the Olkiluoto order does accentuate the EPR technology, thereby opening the way for further orders, the losses incurred by Areva and Siemens might appear justifiable to their shareholders. However, experience has been so poor that, far from convincing new buyers, it might put them off, and potential buyers of the EPR in India and China are reported to be perturbed by the problems.[34] However, it seems unlikely that the owners of Areva could contemplate offering turnkey terms again until there is very clear evidence that the probability of cost and time overruns for an EPR had become extremely low.

The unique nature of the plant owner means that, far from competing in an open market, the owners have been able to insulate it very fully from the market by contracting for the lifetime's output of the plant at whatever cost is incurred. There is risk to the owners. The plant is likely to be at least 2 years behind in completion, and the owners will have to buy power from the market for that period, potentially at high prices. If the cost of power from Olkiluoto proves to be significantly higher than the wholesale market price, the owners will have to buy expensive power and, for the electric-intensive industry where the cost of power purchase could make up about half of the total costs, this could be catastrophic.

The European Commission has found that the finance did not involve unfair state aids. However, it is bizarre to find that loans to a prosperous Western European country have to be backed by export credit guarantees, and the cost of borrowing is blatantly far below commercial rates. The Olkiluoto order therefore does not provide any evidence that nuclear orders are feasible in a liberalized market without substantial public subsidies and guarantees. Experience so far reinforces the very high economic risks of cost and time over-runs involved in the construction of a nuclear power plant.

THE U.S. NUCLEAR POWER 2010 PROGRAM

The Program.

The Bush administration made a concerted effort to revive nuclear ordering with its 2002 Nuclear Power 2010 program. It has yet to achieve a new order. Under the program, the U.S. Department of Energy (DoE) expects to launch cooperative projects with the industry to:

> . . . obtain NRC approval of three sites to assure the availability of these potential locations for new nu-

> clear power plants under the Early Site Permit (ESP) process . . . develop application preparation guidance for the combined Construction and Operating License (COL) and to resolve generic COL regulatory issues. (The COL process is a 'one-step' licensing process by which nuclear plant public health and safety concerns are resolved [prior to commencement of construction,] and before the NRC approves and issues a license to build and operate a new nuclear power plant.)[35]

A total of up to $450 million in grants is expected to be available for at least three projects. Two main organizations initially emerged to take advantage of these subsidies and have signed agreements with the DoE to develop COLs. Nustart, launched in 2004, was the first utility grouping to express an interest. It comprises a consortium of eight U.S. utilities including Constellation Energy, Entergy, Duke Power, Exelon, Florida Power & Light, Progress Energy, Southern Company, and the Tennessee Valley Authority (TVA), providing staff time, not cash).[36] EDF, and the vendors, Westinghouse and General Electric (GE) are members but have no voting rights.

This was followed up by the nuclear provisions of the U.S. Energy Policy Act of 2005 (EPACT 2005). The Bush program is best understood as an effort to reverse the power market lessons of the 1980s and 1990s. Since investors have proven unwilling to assume the risks of building new nuclear units, even after the improving of designs and the streamlining of the licensing process, EPACT 2005 reverts to the 1960s and 70s by reassigning risk back to those who are given no choice, this time the taxpayers instead of the customers.

The most important nuclear provisions of EPACT 2005 offered three types of support.[37] First, a limited number of new nuclear power plants can receive a

$18/MWh production tax credit for up to $125 million per 1000MW (or about 80 percent of what the plant could earn if it ran 100 percent of the time). The second benefit is a provision for federal loan guarantees covering up to 80 percent of the debt involved in the project (not the total cost). The third benefit provides up to $500 million in risk insurance for the first two units and $250 million for units 3-6. This insurance is to be paid if delays that are not the fault of the licensee slow the licensing process of the plant.[38]

By 2007, it was clear that the loan guarantees were not sufficient to reassure financiers. In April 2007 the U.S. Nuclear Energy Institute (NEI), the trade body for the nuclear industry, in a meeting with the U.S. Office of Management and Budget (OMB) lobbied for 100 percent debt coverage for up to 80 percent of the project cost. Subsequently, DoE proposed 90 percent of debt coverage by loan guarantees up to a maximum of 80 percent of total project cost, but this still did not satisfy the nuclear industry, which wanted guarantees for 100 percent of the debt. In August 2007, the OMB appeared to allow DoE the discretion to guarantee 100 percent of the debt.[39] In addition, it emerged that a provision in an Energy Bill passed by the Senate allowed a provision for up to $50 billion in loan guarantees for new nuclear power plants.[40] If we assume that a nuclear plant would cost $4 billion and that guarantees would apply up to the maximum 80 percent of project cost allowed, this would provide guarantees for at least 15 units.

Analysis of the Program.

The publicly-stated basis for the Finnish and UK nuclear programs was that nuclear orders did not need subsidies and guarantees, albeit the reality was very different for Finland. However, the basis of the U.S. program was that subsidies and guarantees for about four projects would be enough to kick-start ordering. The changes made in 2007 to the provisions mean that the support is much more extensive and open-ended than originally planned.

The provisions in Finland and the United States provide a good indicator of where UK companies wanting to build nuclear power plants will look for support. The largest elements are the loan guarantees and the market support. Comprehensive guarantees for the loans are vital because, as with Olkiluoto, this will dramatically reduce the cost of capital by shifting risk to taxpayers. Especially in regions where some form of wholesale electricity market exists, some form of price guarantee is necessary so that the nuclear plant is not exposed to the uncertainties of the market. The provisions on insuring against regulatory delays are also important, but their cost is significantly less.

Loan guarantees and regulatory insurance lower the price of nuclear power without lowering its cost, at least not for many years. This reduction occurs because some of the costs and risks are removed from the price charged to customers and onto the shoulders of taxpayers. For example, the production tax credit deprives the U.S. Treasury of funds that must be made up from other sources. Whether the benefit flows through to customers or is retained by investors will vary with the economic regulatory approach used but, either way, prices can be kept lower than would be the case if the credit did not exist. Similarly, the loan guarantees assure lenders that they will be repaid no matter what happens at the power plant. Essentially, their guaranteed loans are converted into government obligations. This lowers both the interest rate and the amount of more expensive equity capital that must be raised, as was the case for Olkiluoto in Finland.

Taken together and combined with other benefits recently conferred on the U.S. industry (such as the 20-year extension of the law limiting nuclear power plant exposure to liability for the costs of a serious accident), the benefits in the recent U.S. law have substantially increased the likelihood of a new U.S. nuclear power plant order in the next few years. Indeed, the incentives are structured to provide maximum benefit to plants ordered before the end of 2008.

During a conference in 2006, three U.S. electric utility CEOs made it clear that without the 2005 congressional action there was no possibility of nuclear orders, but even the extensive support now envisaged might not be sufficient to ensure new nuclear orders:

> [TXU CEO John Wilder] said there were now projects totaling about 26 gigawatts lining up for limited federal incentives, which could provide 'anywhere from a $2 per megawatt-hour advantage to a $20 per megawatt-hour advantage.' He said he didn't believe it would be known which companies would receive those benefits until about 2012. 'Quite frankly, that's all the difference between these projects working or not working.'[41]

NRG Energy President/CEO David Crane, also speaking on a September 26, 2006, conference panel with Wilder, said the measures in the Energy Policy Act of 2005 were key to his company's decision to pursue potential construction at South Texas Project. "I do think those are absolutely necessary to get nuclear plants under way," he said. "In fact, until I actually knew what they were, we would not have even contemplated it."[42]

Exelon Nuclear's President, Christopher Crane, said that the incentives were a key factor in his company's decision to prepare a COL. But other factors would influence whether Exelon commits to building a new reactor.[43]

Can Use Of Financial Instruments Overcome the Problem of Risk?

Some commentators have suggested that the issues of economic risk can be dealt with by innovative use of insurance and financial instruments. David Newbery claimed that using these instruments, nuclear power plants could be built in the UK without use of government subsidies or other forms of government support.[44] Newbery's claim was based on the assumption that the main risk was market risk. Specifically identified are three risks: (1) with large amounts of intermittent renewables being built, at windy times, the energy spot price would occasionally crash; (2) the carbon price, set in the European Union (EU) Energy Trading Scheme (ETS) was uncertain; and, (3) in the future, the spot price of gas, which has a close relationship with the spot electricity price, was likely to be much less stable than it has been due to geo-political reasons.

Newbery proposed to deal with this risk by issuing bonds to small consumers so that the amount they paid for a specified amount of electricity was fixed. He gives an example under which a consumer would purchase a bond for £9 to buy 100kWh of electricity. If the retail price is higher than this, consumers would receive a larger dividend and, if it was lower, the dividend would also be lower, but consumers would have lower electricity bills. Given that a large proportion of small consumers do not understand how to switch electricity suppliers, much less understand the details of financial bonds, it seems highly unlikely consumers would see it as worthwhile to buy these bonds.

However, the main problem with Newbery's proposal is that he does not understand where the main issue of economic risk with nuclear power plants lies. Newbery says "suppose that construction, operating and regulatory risk can be insured, leaving only market price risk."[45] Why does Newbery assume that it will be cheaper to cover this risk through insurance rather than for it to be reflected in a high cost of capital? Insurers have access to the same information as financiers, and there is no reason to assume they will assess the risk differently.

Newbery assumes that any additional costs from the regulatory risk would be guaranteed by the government (taxpayers). This would be a subsidy and probably a rather large one. However, this figure is dwarfed by the risks arising from construction and operation. Olkiluoto, the Finnish nuclear power plant now under construction, was supposed to be the show-case for new nuclear technologies, but it is now 60 percent over budget (€1.5 billion) and 2.5 years late, with ample probability of additional cost and time overruns. If we assume the value of the output of a nuclear plant is €50/MWh, then the annual value of the output of a plant like Olkiluoto would be about €600 million, if it was reliable (achieving 90 percent of its maximum feasible output over the year). A nuclear company that cannot fulfill its contracts because the completion of the plant is late will have to buy replacement power from the market at the highest prices on offer. The delay of 2.5 years would result in losses of at least €1.5 billion from the energy not produced. An insurer that had covered Olkiluoto would therefore have to pay out €3 billion for cost and time overruns. What level of premium would be needed for an insurer to be willing to cover such a risk?

However, once the plant is complete, the technical risk does not end. Nuclear plants are not always reliable and, if we look at the four most recently completed plants in France, they averaged an availability of 45 percent in their first 4 years of operation. So if an insurer had insured these plants to operate at 90 percent availability, they would have had to pay out somewhere in the order of €4 billion, if we assume the replacement power could be bought at only average market price.

The reality is that using financial instruments cannot make risk disappear. Ultimately, the cost of bearing that risk has to be paid for and, in this case, it will be the public that pays for it, either taxpayers or electricity consumers.

A UK PROGRAM

Corporate Strategies.

On the basis of experience in Finland and the United States, it seems implausible that a nuclear power program can be launched in Britain without the support of public subsidies and guarantees. British Energy's financial collapse of 2002 probably means it is not plausible for it to pursue an application to build new nuclear power stations independently, although the sites it already owns mean that anyone hoping to build new nuclear capacity in the UK will probably have to involve British Energy. All of the six main UK electricity companies have expressed interest in participating in plans to build new nuclear plants. EDF is usually seen as the most aggressive advocate of new nuclear capacity and has plans to build at least four new nuclear power plants (of the EPR design) in the UK. E.ON, also an experienced nuclear operator, is potentially an owner-operator, but has not yet specified the extent of its ambitions. RWE, like E.ON a German-based company with significant nuclear experience, has also stated its intention to invest in new nuclear capacity as an owner-operator. Centrica has said that it hopes to invest more than £3 billion (equivalent to one new unit) in new nuclear capacity in collaboration with other companies.[46] Scottish Power has not made a strong commitment to participating in new nuclear build, but Iberdrola, its Spanish owner, was reported to be in talks with British Energy in January about building a 1,600MW plant in the UK. In January 2008, EDF acknowledged that it was considering launching a takeover bid for Iberdrola and hence Scottish Power. Scottish power and Southern Energy have also held talks with British Energy about participating in new nuclear capacity.

This apparently united front in favor of nuclear seems hard to explain, given the implausibility of orders without subsidy and the government's apparently firm commitment not to provide subsidies and guarantees. However, while the companies are unwilling to use the words subsidies and guarantees, this appears to be due to a rather questionable view of what represents a subsidy or guarantee. For example, even the most aggressive of UK nuclear utilities, EDF, emphasized the need for some support: Plants could be built without subsidy "provided that there was agreement on the funding of decommissioning and waste disposal, a clear licensing and consent road map, and a credible carbon price."[47]

Unless the UK government is very naïve about the attractiveness of nuclear investment, or it does not actually expect any nuclear orders to be placed, there must be suspicions that the government and the companies are indulging in semantic distinctions about what constitutes a guarantee or a subsidy. The government expects it will take 7 years to pilot one or more designs through the expensive and time-consuming process of obtaining safety approval. This will be a major challenge for the nuclear safety body, the Nuclear Installations Inspectorate (NII), which is already understaffed and struggling to replace its aging workforce. There must be strong suspicions that, if after this effort no orders are forthcoming, the government of the day, by then with significant distance from today's government, will be tempted to introduce guarantees and subsidies. This will avoid the embarrassment of a UK government yet again diverting resources away from other energy options to a fruitless nuclear program.

On the face of it, utilities would seem to have no interest in building uneconomic facilities. However, for such utilities, nuclear orders would only be placed if there were clear provisions taking the plant out of the market. So, the more nuclear capacity a company owned, the less exposed to the market it would be. Companies cannot be held to statements by today's executives, so playing along with the government today simply puts them at the head of the queue for any subsidies that are made available. If the subsidies do not materialize or they are inadequate, the company can simply step out of the queue at no cost.

Subsidies and Guarantees.

Experience from Finland and the United States shows where these might be required.

Decommissioning and Waste Disposal Cost.

As argued above, if decommissioning and waste disposal costs are accurately estimated from the start of operation, the delay from close of plant to completion of decommissioning and waste disposal is accurately forecast, provisions are invested securely and the rate of return the provisions can make is also accurately estimated, making provisions for decommissioning and waste disposal should not have a major impact on nuclear economics. Decommissioning and waste disposal take place so far in the future, the cost is effectively "discounted" away. However, if during the life of the plant, it emerges that the decommissioning and waste disposal costs have been underestimated, the provisions are lost or the return is less than expected, making up the additional money could be a major burden to the owner. Given the limited experience of decommissioning and waste disposal, and the rapid rise in decommissioning estimates, companies are likely, as noted by Vincent de Rivaz, to seek some cap on the contribution they have to make to pay for decommissioning and waste disposal.

The UK government quickly acceded to this pressure and, in a consultation published in February 2008, is offering to guarantee owners of nuclear power plants a fixed cost for decommissioning and waste disposal (intermediate- and high-level). However, the government is still claiming that subsidies and guarantees are not being offered:

> The Energy Bill and the guidance published today make clear that companies are liable by law to meet their full costs. 'Let me be clear—full means full.

> Funds will be sufficient, secure and independent, it will be a criminal offence not to comply with the approved arrangements and we are taking powers to guard against unforeseen shortfalls.'[48]

It is not clear that such guarantees would have been needed, given that such comprehensive guarantees were not required in Finland and are not being discussed in the United States. Clearly, the companies will gratefully accept any additional guarantees they are offered but, given how far away these costs are, it seems unlikely that financiers would see them as a major risk.

In the United States, the government has taken title to spent fuel since 1978 and levies a fixed charge on utilities of only 0.1c/kWh for disposal of spent fuel. There is no "intermediate-level" U.S. category, and all waste that is not high-level is categorized as low-level. No cost guarantees exist for U.S. low-level waste.

Decommissioning funds are also not guaranteed in the United States. Costs estimates must be continually updated and, if a shortfall is anticipated, either because costs have escalated or the fund has not earned as much interest as expected, contributions must be increased.

Construction Costs and Loan Guarantees.

The key to the Finnish order was the availability of a turnkey contract that seemed to place the risk of cost and time overruns on the vendor rather than the buyer. The UK would be a prestigious prize for any nuclear vendor, but at present it seems highly unlikely that any vendor could take the risk of offering any more than one unit on turnkey terms and probably then only if subsequent orders were committed and on less stringent terms to the vendor. Both the U.S. and Finnish programs have been based on loan guarantees paid for by the public, albeit in the Finnish case, the French and Swedish public. In addition, in some U.S. states, wholesale competition is being reined in and nuclear plants may be built under the traditional model of making them part of a regulated rate base. Under this, the company owning the plant would be guaranteed a fair rate of return on its investment. Publicly funded loan guarantees would appear to be essential if loans are to be offered at reasonable rates of interest unless nuclear plants are completely removed from the market.

Market Guarantees.

For the U.S. program, huge production tax credits are being offered that mean there is a high chance costs will be covered. For Olkiluoto, the plant's output is covered by an effective life-of-plant power purchase agreement at full cost recovery terms. Market guarantees would be likely to violate EU unfair state aids legislation, so some creative thinking, like a high guaranteed carbon price might be used to effectively provide support.

Operating Costs and Reliability.

The Finnish nuclear industry has always had a good record of reliably operating nuclear power plants, and the U.S. industry has turned around a very poor record of reliability over the past 15 years so that U.S. plants are now among the most reliable in the world. So both countries have a good track record of operation. However, while the UK nuclear industry has improved its performance since 1990, the reliability of its plants is probably worse than that of any other developed country. Whether investors would assume that the poor British record was not relevant, given that the operating companies would probably be French or German, remains to be seen. No vendor would guarantee the operating cost of a plant it sold nor would insurance coverage be available, so this is a risk it would be hard to assume.

Regulatory Delays.

The Finnish regulator has been blamed, not necessarily justifiably, for some of the delays at Olkiluoto, and the U.S. program offers some insurance coverage against delays resulting from the regulatory process. Coverage might therefore be needed for UK plants, as envisaged by the EDF UK CEO, Vincent de Rivaz.

Other Issues.

There are a number of other costs attached to building any new power plant that could be the subject of requests for subsidy. These include:

- Cost of connection to the transmission network. Particularly if the plant is built on a new site, or if it replaces a much smaller unit, there could be significant transmission reinforcement costs. National Grid Transco estimated that if all existing nuclear power stations were to be replaced, the cost of reinforcements to the transmission network would be £1.4 billion.[49]
- Spinning reserve costs. New nuclear power plants, especially if the EPR was chosen would represent the largest units in the system, up to

1,700MW. Spinning reserve is the amount of plant that must be kept in readiness for operation in case of the failure of the largest unit. PB Power noted that the current UK system is designed to allow the failure of two 660MW units. This was a standard derived in the 1970s when 660MW units were the largest units on the UK system. PB Power estimated that if an EPR was built with output of 1,580MW, an additional 260MW of spinning reserve would be needed at a cost, if supplied by a gas-fired plant of £1.3/MWh, or £2.1/MWh if supplied by a coal-fired plant. The EPR design is now likely to have a rating of about 1,700MW, so this cost may be an underestimate if 400MW of additional spinning reserve was needed. Of the other potential designs, the AP-1000 and the ACR-1000 would not need additional spinning reserve, while the ESBWR (1,520MW) would require about 200MW additional reserve.

CONCLUSIONS

Politically, it seems that subsidies and guarantees are an anathema to a significant proportion of Members of Parliament. So if a new nuclear program is to go ahead in the UK, it has to be on the basis that no subsidies and guarantees will be given.

However, given the time-scale for new orders, which does not anticipate any orders being placed for 7 years or more, it is doubtful whether today's commitments from companies and government are worth anything. Energy market circumstances will change continuously for the next 7 years, and a commercial company operating in a competitive market will be able to claim that their commitment not to need subsidies had been overtaken by changes in energy markets. Equally, in 7 years the government will have little connection to today's government and will not feel bound by today's commitments. The suspicion must therefore be that statements by government and companies are only possible because those involved know they will not have to deliver on these commitments.

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APPENDIX I

DISCOUNTING, COST OF CAPITAL, AND REQUIRED RATE OF RETURN

A particularly difficult issue with nuclear economics is dealing with and putting on a common basis for comparison the streams of income and expenditure at different times in the life of a nuclear power plant. Under UK plans, the time from placing a reactor order to completion of decommissioning could span more than 200 years.

Conventionally, streams of income and expenditure incurring at different times are compared using discounted cash flow (DCF) methods. These are based on the intuitively reasonable proposition that income or expenditure incurred now should be weighted more heavily than income or expenditure earned in the future. For example, a liability that has to be discharged now will cost the full amount, but one that must be discharged in, say, 10 years can be met by investing a smaller sum and allowing the interest earned to make up the additional sum required. In a DCF analysis, all incomes and expenditures through time are brought to a common basis by "discounting." If an income of $100 is received in 1 year's time and the discount rate is 5 percent, the net present value of that income is $95.23—a sum of $95.23 would earn $4.77 in 1 year to make a total of $100. The discount rate is usually seen as the "opportunity cost" of the money, in other words, the rate of return (net of inflation) that would be earned if the sum of money was invested in an alternative use.

While this seems a reasonable process over periods of a decade or so and with relatively low discount rates, over long periods with high discount rates, the results of discounting can be very powerful, and the assumptions that are being made must be thought through. For example, if the discount rate is 15 percent, a cost incurred in 10 years of $100 would have a net present value of only $12.28. A cost incurred in 100 years, even if the discount rate was only 3 percent, would have a net present value of only $5.20, while at a discount rate of 15 percent, costs or benefits more than 15 years forward have a negligible value in an normal economic analysis (see Table 7-1).

Discounting period (years)	3%	15%
5	0.86	0.50
10	0.74	0.25
15	0.64	0.12
20	0.55	0.061
30	0.41	0.015
50	0.23	0.00092
10	0.052	-
150	0.012	-

Source: Author's calculations.

Table 7-1. Impact of Discounting: Net Present Values.

If we apply this to nuclear plants operating in a competitive market where the cost of capital will be very high, this means that costs and benefits arising more than, say 10 years in the future, will have little weight in an evaluation of the economics of a nuclear power plant. Thus increasing the life of a plant from 30 years to 60 years will have little benefit, while refurbishment costs incurred after, say, 15 years will equally have little impact.

For decommissioning, for which under UK plans the most expensive stage, is not expected to be started until 135 years after plant closure, this means very large decommissioning costs will have little impact even with a very low discount rate consistent with investing funds in a very secure place with a low rate of return, such as 3 percent. If we assume a magnox plant will cost about $1.8 billion to decommission and the final stage accounts for 65 percent of the total (undiscounted) cost ($1.17 billion), a sum of only $28 million invested when the plant is closed will have grown sufficiently to pay for the final stage of decommissioning.

The implicit assumption with DCF methods is that the rate of return specified will be available for the entire period. Give that even government bonds, usually seen as the most secure form of investment, are only available for 30 years forward and that a period of 100 years of sustained economic growth is unprecedented in human history, this assumption seems difficult to justify. So, with nuclear power, there is the apparent paradox that, at the investment stage, a very high discount rate (or required rate of return) of 15 percent or more is likely to be applied to determine whether the investment will be profitable, while for decommissioning funds, a very low discount rate is applied to determine how much decommissioning funds can be expected to grow.

The key element resolving this paradox is risk. Nuclear power plant investment has always been risky because of the difficulty of controlling construction costs, the variability of performance, the risk of the impact of external events on operation, and the fact that many processes are yet to be fully proven (such as disposal of high level waste and decommissioning). In a competitive environment, there are additional risks because of the rigidity of the cost structure. Most of the costs will be incurred whether or not the plant is operated. Thus while nuclear plants will do well when the wholesale price is high (as was the case with British Energy from 1996-99), they will do poorly when the wholesale price is low (2000-02). The fact that the plant has made good profits for a decade will not protect it from bankruptcy in the bad years, and financiers will therefore see investment in nuclear power as extremely risky and will apply a very high interest rate reflecting the risk that the money loaned could easily be lost.