DECOMMISSIONING OF NUCLEAR POWER STATIONS

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With the sale of British Energy plc pending, the decommissioning of the UK's nuclear reactors is a pertinent issue. This paper describes briefly the history of the development of nuclear reactor technology in the UK; the physical and financial arrangements for the decommissioning of reactors; spent fuel management and dry store siting; and financial provision for decommissioning in other countries.

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Decommissioning of Nuclear Power Stations

The Government has offered British Energy plc for sale. This company operates the UK's AGR and PWR reactors, the most modern in the nuclear inventory. The older Magnox stations run by Magnox Electric plc will remain in the public sector.

This paper briefly describes the history of development of the UK nuclear industry including details of the main differences between the three principal reactor types - Magnox, AGR and PWR stations. Current strategy, both physical and financial, for decommissioning at the end of their economic lives is presented. Arrangements are outlined for spent fuel management from the AGRs and PWR, including possible arrangements for the siting of dry stores for spent fuel prior to reprocessing. Information about methods for dealing with the liabilities of radioactive waste disposal and decommissioning in other countries is also included.

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I Introduction

The UK was in the forefront of developing nuclear power for civil use. Calder Hall in Cumbria was the first industrial scale nuclear power station in the world. It was commissioned by the United Kingdom Atomic Energy Authority (UKAEA) in 1956 and was the initial member of a family of gas-cooled Magnox reactors named after the magnesium alloy used to make the fuel cans which contain the uranium fuel elements. The forerunners of these reactors had been designed for military purposes and as the programme of Magnox-type reactors proceeded for commercial energy use it became clear that their engineering and economic limitations were so great that a new reactor design was required. In total eleven Magnox stations were built, eight are still operational and three - at Berkeley, Trawsfynydd and Hunterston A - are currently being decommissioned. The remaining Magnoxes are coming to the end of their operating life and are unlikely to be kept running much beyond the early part of the next century. Although problems with corrosion of reactor parts have led to a reduction in operating temperatures, and therefore a lowered efficiency, overall the Magnox reactors have performed well.

Since 1 April 1996 six Magnox stations at Bradwell, Oldbury, Wylfa, Hinkley Point A, Dungeness A and Sizewell A have been run under the auspices of Magnox Electric plc (the two plants at Calder Hall and Chapelcross are operated by British Nuclear Fuels plc (BNFL)). It has been recognised for some time that it would not be practicable to privatise the Magnox stations mainly because they will not generate enough cash over their remaining lifetimes to meet their liabilities for spent fuel reprocessing, disposal of nuclear waste and decommissioning when closed. The Government's plan is to keep these stations running for as long as is safely possible. This makes economic sense because their generation costs are low and it defers expenditure on decommissioning[1]. The eventual aim is to integrate Magnox Electric with BNFL which would then run all Magnox stations. The Government's objectives for Magnox Electric were stated in an answer to a recent written parliamentary question.[2]:

> **Mr. Eggar:** Yes. The Government wish Magnox Electric plc to be a robust public sector entity which will enhance competition in the electricity market and secure the best possible value for the tax payer from its operations. The company must operate in a commercial manner, judging any investment by commercial rates of return. In doing so, it must:
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> 1. demonstrate in all its activities that safety is at the foundation of its business;
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> 2. have full regard to the environmental impact of all its operations;
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> 3. maximise net revenue from electricity sales by operating its generating plant as fully, and for as long, as is consistent with safety requirements;

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[1] *The Prospects for Nuclear Power in the UK: Conclusions of the Government's Nuclear Review* Department of Trade and Industry and the Scottish Office Cm 2860 May 1995
[2] HC Deb 10 June 1996 c14w

4. meet all its nuclear liabilities as cost effectively as possible;

5. maintain and develop its core skills and capabilities to meet its current and future operational needs. Magnox may exploit these skills and capabilities in appropriate new business areas, as agreed with the Government; and

6. seek a basis for integration with the British Nuclear Fuels which will provide the combined company with a clear incentive to maximise the net revenues from Magnox generation and to minimise all Magnox-related reprocessing and other back end costs.

The second generation of UK nuclear reactors that superseded the Magnox stations were the Advanced Gas Cooled Reactors (AGRs). The principle difference between AGRs and Magnox reactors is that the former are more efficient at converting heat generated by nuclear fission into electricity by virtue of their much higher core operating temperature. (Both are gas-cooled reactors the cooling being accomplished by means of carbon dioxide gas.) To choose the type of reactor to follow the Magnox stations a competition was held to decide whether the British designed AGR or an American design would be most suitable. In 1965 the choice was announced. The success of the British designed AGR over its American competitor was heralded as a triumph for British nuclear technology. These stations appeared to have great advantages over the Magnox design and it was hoped that they would provide a competitive alternative to the Pressurised Water Reactor (PWR) which was popular elsewhere. The use of a pre-stressed concrete pressure vessels for AGRs brought fewer worries than those associated with the PWR reactor pressure vessels which were of steel.

In the event the AGR building programme turned into a disaster[3] for the British nuclear industry. The bankruptcy of contractors followed design changes and construction problems. The completion of stations was often behind schedule[4,5]. By 1980 only two of the ordered stations had been completed. These were at Hinkley Point B and Hunterston B. The problems of Dungeness B became legendary-begun in 1966 and scheduled for completion in 1970, it was not fully operational by 1990. In retrospect the construction programme was hopelessly mismanaged through the aim of keeping several construction consortia in business and also by changing designs between each AGR. In all seven AGR stations were commissioned between 1976 and 1988 at Heysham 1 and 2, Hartlepool, Hinkley Point B, Dungeness B, Hunterston B and Torness. Since 1 April 1996 these stations have been operated by British Energy plc. Historically many of the AGRs have had a poor performance record[6]. Comparing their performance with that of five years ago, however, their output has improved by around 50% due to several factors[7] including:

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[3]*The Energy Question* Gerald Foley
[4]*ibid*
[5]*Nuclear Power:Its Development in the UK* R F Pocock
[6]*Nuclear Engineering International* July 1996 p34
[7]*The British Energy Share Offer: Offer Brochure* June 1996

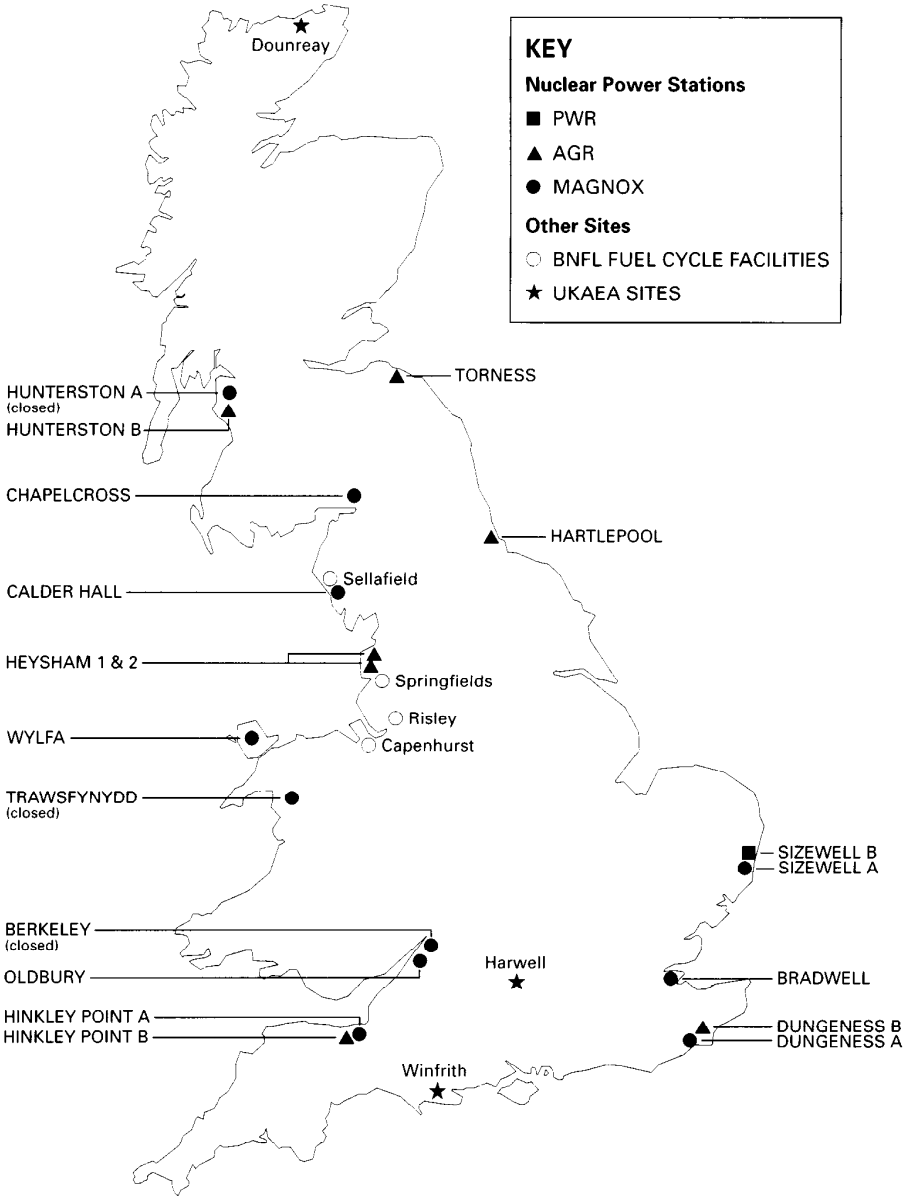
> investment in developing refuelling plant and enhancing fuel efficiency leading to a reduction in down time for refuelling;
>
> shut down for statutory inspection and maintenance - the average length of these statutory outages has been reduced and the periods between them increased at some stations; and
>
> improved procedures, increased operator training and investment in more advanced reactor control systems.

In addition to the AGR stations British Energy also operates the only member of an aborted third generation of nuclear stations, the PWR at Sizewell B in Suffolk. The PWR is the most popular operating reactor worldwide, comprising about two-thirds of the total. It is of a totally different design from the Magnox and AGR stations making use of water under very high pressure both as a coolant to transfer energy to the electricity generating plant (turbine), and as a moderator to slow down neutrons to aid nuclear fission. Sizewell B was completed in 1994 and began to supply electricity to the grid on 14 February 1995. Further information about UK reactor design is contained in Library Research Paper 94/31 *The Nuclear Review.*

It is British Energy, comprising the eight most modern UK stations (7 AGRs plus 1 PWR) that the government is about to privatise. A map showing the geographical location of UK commercial nuclear power stations and principal UKAEA and BNFL sites is reproduce below[8].

[8]*The Prospects for Nuclear Power in the UK: Conclusions of the Government's Nuclear Review* Department of Trade and Industry and the Scottish Office Cmnd 2860 May 1995

UK Commercial Nuclear Power Stations and Principle UKAEA and BNFL sites



II Decommissioning

Decommissioning of nuclear power stations should be considered in two parts. First the physical decommissioning strategy and second the means to pay for it. These will be discussed in turn.

A. Decommissioning Strategy

Decommissioning strategy for nuclear power stations in the UK currently comprises three stages[9]:

(i) Immediately after shutdown the reactor is defuelled;

(ii) After 5-10 years the buildings external to the reactor shield are removed;

(iii) 100 years after shutdown the reactor is demolished.

As an alternative the gas-cooled reactors could be decommissioned using a "safestore" method. This would be identical to the above strategy at point (i) but diverge in points (ii) and (iii) as follows

(iib) After 5-10 years non-radioactive buildings are removed and radioactive buildings are prepared for an extended period of care and maintenance. Thirty years after shutdown, the existing buildings are placed in "safestore" by sealing openings such as doors and covering walls with high integrity materials. The aim is that no further maintenance should be required over a period of a further 100 years although routine surveillance would be carried out throughout the period.

(iiib) At the end of the safestore period of about 135 years after shutdown all the buildings and the reactor are demolished.

A variation on safestore would be to proceed to it immediately after shutdown instead of 30 years later.

There are arguments both for and against safestore. It would allow more time for radioactive decay and further advances in technology. It is also more cost-effective and would enhance the UK's position in advising and assisting with decommissioning in other countries. Those against safestore argue that stations should be decommissioned as soon as possible to be in line with the concept of sustainable development, and that plant decommissioned early does

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[9] *Review of Radioactive Waste Management Policy:Final Conclusions* Cm 2919

not have time to deteriorate. In addition if decommissioning is carried out soon after shutdown the knowledge and experience of those who worked on the site during its operational life are still available.

The use of safestore has recently become topical with regard to Trawsfynydd station which is one of three Magnox stations currently being decommissioned. It is reported[10],[11] that an application for planning permission to safestore the plant will be made later this year and that it has been delayed so as not to upset the sale of British Energy.

The Government intends to require all nuclear operators to prepare strategies for decommissioning of their stations on a case-by-case basis[12]. These will include justification of proposed timetables and financial provisions. Such plans will be reviewed quinquennially by the Health and Safety Executive (HSE) in consultation with the environment agencies[13] to ensure that they remain soundly based.

B. Nuclear Liabilities and the Segregated Fund

The transfer of AGR and Sizewell B liabilities to British Energy was one of the main issues studied by the Trade and Industry Select Committee (TISC) which reported on 14 February 1996[14]. It was recognised in their report that

> 26. The unique feature of the economics of nuclear power is the nuclear liabilities - for the reprocessing of spent fuel, the management and disposal of radioactive waste and the decommissioning of stations. They are unique because of their vast size, dominating the balance sheet, the significant element of uncertainty about some of them and the fact that some of them will not fall due for a century or more, long after the existing stations have closed.

With this in mind the report recommended that "whatever the level of liabilities, the liabilities should follow the assets from which they arose" (para 67). The Government has repeated its commitment to this on numerous occasions. Most recently in the Opposition debate about nuclear privatisation[15] the Minister for Industry and Energy, Mr Tim Eggar MP, said:

> I must repeat again that liabilities have followed assets in the proposals for the sale of British Energy. We have made it clear in the past that that will happen, and I repeat quite categorically and unreservedly that liabilities will follow assets and that British Energy is responsible and will remain responsible for the liabilities that are associated with its stations.

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[10] *Western Daily Mail* 11 June 1996 p1
[11] *Financial Times* 10 June 1996 p7
[12] *Review of Radioactive Waste Management Policy:Final Conclusions* Cm 2919
[13] The Environmental Agency in England and Scotland,the Scottish Environmental Protection Agency in Scotland.
[14] *Nuclear Privatisation* Trade and Industry Select Committee HC 43 1995/6
[15] HC Deb 18 June 1996 c 742-786

The TISC[16] also recommended (paragraph 55) "The government should establish more reliable arrangements to ensure that long-term liabilities arising after stations close are discharged", and with regard to the Segregated Fund to meet the liabilities (Paragraph 56) "The Government should establish the Segregated Fund and appoint its trustees as soon as possible".

Mr Eggar announced[17] on 27 February 1996 that the Segregated Fund would be established on 31 March 1996 and come into effect on privatisation. The Fund is intended to cover the post-closure costs of decommissioning British Energy's nuclear power stations and their sites, excluding the cost of defuelling, and two other major long-term liabilities: the management and disposal of spent waste off site; and British Energy's share of BNFL decommissioning. It will be managed by an independent trust known as the Nuclear Trust[18]. At the official opening of Sizewell B on 25 March 1996 Mr Ian Lang MP, the President of the Board Trade, announced[19] that the Fund would receive "an initial endowment of about £230 million from British Energy and they will pay about £16 million a year initially". The source of these funds from a company in the public sector and their apparent insufficiency have been the subject of much debate and speculation. Margaret Beckett, MP, raised these issues recently in the Opposition debate about nuclear privatisation:

> To begin with, there is obscurity about the issue of the segregated fund itself. The last Red Book shows a cost to the Exchequer in respect of the industry of some £230 million - precisely the sum that has appeared on the balance sheet of British Energy, and will be the dowry it provides to start off the fund.
>
> It is presumably on the basis of the scale of the dowry from public funds that the level of yearly contribution from the privatised company is assessed at a mere £16 million a year, compared to previous estimates from City analysts that funding would have to be about £30 million to £50 million a year - more than double, at the very least. I say "presumably", because the Government have, up to now, failed to publish or place in the Library of the House the report that they claim provides the justification for such a low contribution, on the spurious grounds that it is not yet completed. However, that does not seem to have prevented the Government from reaching a judgment on the report.

Environmental groups have also expressed dissent. An example of these are the views of the Consortium of Opposing Local Authorities (COLA) and Friends of the Earth (FOE). They have set out their concerns about liabilities that will be exempt from the Segregated Fund, and the adequacy of the Fund given their claim that a 3.5% real annual growth rate up to the year 2130 has been asssumed when a 2% rate might be more prudent[20]:

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[16]*Nuclear Privatisation* Trade and Industry Select Committee HC 43 1995/6
[17]DTI Press Notice P/96/147
[18]DTI Press Notice P/95/845
[19]DTI Press Notice P/96/240
[20]*Privatisation: The Liability Burden on the Public Sector Special Briefing* No 23 COLA June 1996

However, despite Government assurances, two possible types of AGR liability exemption emerged during evidence to TISC:

'operational' exemptions - primarily concerned with the reprocessing of spent AGR fuel already delivered to BNFL, stored at station sites, or currently in reactor cores; and

'post-shutdown' exemptions - liabilities which will not be paid for by the BE segregated fund because the level of contributions has been set far too low.

With regard to 'operational' exemptions, the total of pre- 1996 AGR reprocessing liabilities (as defined above) was estimated to TISC at an *undiscounted* £4 billion. There has subsequently been a debate about how much of this total BE might be exempted from[18]. The new COLA/FOE research takes the debate forward significantly by developing a method for estimating likely 'operational' exemptions in the years 1996-2005. It does this by comparing public statements of planned fuel cycle payments to BNFL, with estimates derived from published front and back end fuel cycle costs. The results are disturbing: it appears that the likely 'operational' exemption is a minimum of £1.7 billion[19].

With regard to 'post-shutdown' exemptions, the previous briefing outlined the results of research on the required and proposed levels of annual payments by BE into a segregated fund [20]. It showed that at the proposed level of £16 million a year there is very little reassurance for the taxpayer that several categories of long-term AGR liability will be met. These 'post-shutdown' exemptions include four liability categories: AGR final core reprocessing; AGR stage I decommissioning; AGR intermediate and high level waste disposal; and the decommissioning of AGR-related facilities at Sellafield. They total £3.6 billion.

In addition, there is potential for the BE segregated fund to default further liabilities, because fund performance might be less than has been assumed (3.5% real annual growth to 2130). If a more prudent assumption of 2% is made beyond 30 years, the BE segregated fund would fail in 2117, leaving £1.6 billion of decommissioning costs to fall to the public sector. Although less certain than the first two exemptions, this represents a real further risk to the taxpayer.

[18]D Lascelles, 'British Energy Landed with £1 bn Bill', *Financial Times*, 2 March 1996.
[19]M J Sadnicki, '*Nuclear Privatisation: Liabilities left in the State Sector*', June 1996, p17-18
[20]COLA, '*British Energy Segregated Fund: the Inadequacy Exposed', Special Briefing* No 22, April 1996.

The "new COLA and FOE commissioned research" by Mike Sadnicki mentioned in the text which amplifies concerns about the level of provision for the Segregated Fund has led to an ongoing public disagreement with the Government.[21,22]

Information about financial strategies to meet nuclear liabilities in other countries is presented in Section IV.

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[21]HC Deb 19 June 1996 c 868
[22]*Guardian* 25 June 1996 p19

III Spent Fuel Management

Both during the operation of a nuclear power station and at decommissioning the spent fuel is the most radiologically hazardous material to be dealt with. The Segregated Fund does not cover the defuelling cost of AGRs and the PWR[23] .

A. Strategy

Spent fuel from AGRs and PWR reactors can either be reprocessed soon after removal to extract uranium and plutonium for reuse or held in storage at a dry store for direct disposal or reprocessing at a later date. The Government's view is that the method chosen should be a matter of commercial judgement for the owner as long as regulatory requirements are met[24].

B. Siting of Dry Stores

Scottish Nuclear Ltd (SNL) originally planned to build a dry store as an alternative to reprocessing spent fuel at Torness in East Lothian. At a public enquiry into the proposals it was recommended that the Government should consider the need for a national strategy on the siting of dry stores.

The options are:

* a single-store strategy with one or more stores at a *single* site or
* a multi-store strategy with one or more stores at a *number* of sites.

A Government appraisal of these alternatives, particularly with regard to safety, concluded that there were no obvious benefits to either strategy. Decisions about the type and siting of dry stores will be matters for the commercial judgement of operators taking into account the necessary planning and regulatory requirements. Given the public dissent over the NIREX proposal for the siting of a Rock Characterisation Facility for low and intermediate- level radioactive waste near Sellafield in Cumbria the siting of dry stores could run into considerable problems.

SNL's plan to build a dry store at Torness has been abandoned following more recent reprocessing contracts with BNFL[25], but the issue may arise in the future.

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[23]HC Deb 22 May 1996 c 535w
[24]*Review of Radioactive Waste Managemfent Policy:Final Conclusions* Cm2919
[25]*Financial Times* 'Long-standing nuclear foes kiss and make up' 7 March 1995

IV Financial arrangements in other countries

In other countries nuclear liabilities are essentially funded in one of two ways, although the details are many and varied. In some countries it has been considered unnecessary for there to be regulatory controls, other than acceptable accounting standards, over funds to pay for liabilities. This is often the case, as in France, where the state effectively owns the nuclear power industry. The position in France is particularly interesting since the country will face a substantial decommissioning bill as it has such a large nuclear power programme. In other countries funds to meet nuclear liabilities have been established, often with legislative backing, either associated with the nuclear power companies themselves, or separate from them.

The following extract from *Future Financial Liabilities of Nuclear Activities*[26] provides information about funding for radioactive waste disposal and the decommissioning of nuclear plants in other countries:

> While there are countries where no specific government requirements exist, other than accepted accounting standards, some have rules established by the government for creating funds to pay the liabilities and for creating companies to undertake waste disposal and decommissioning work.
>
> In countries where the State owns industrial groups operating a large number of power plants or fuel cycle facilities, it has not generally been considered necessary to impose a requirement for such funds. For example, this is the case of France where EDF is the sole operator of nuclear power plants and Cogema the fuel cycle company...
>
> In the case of Japan, even though the State does not act as owner, the nuclear share of the utilities, added to their size, has given enough guarantee for the government to be able to rely primarily on accounting standards. Legislation has established rules controlling the funds reserved for decommissioning of power plants and reprocessing spent fuel.
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> Other countries such as Belgium, Finland, Korea, Spain, Sweden and the United States have created, by law, funding systems so as to assure that outside the regular balance sheet of the operators, i.e. not directly accessible to them, funds are available for the safe handling and final disposal of some or all of the waste arising and in some cases the decommissioning of the nuclear facilities. In Korea and Belgium the fund is envisaged only for the disposal of the waste and does not include the dismantling of the nuclear facilities which remains under the financial responsibility of the utility; in these two cases this fund is managed by a State-owned organisation.
>
> In Belgium, the State and the utilities reached an agreement in 1985 by which the utilities constitute the necessary provisions to cover dismantling and decommissioning costs. The provisions are under the supervision of the "Control Committee for Gas and Electricity". The annual appropriations are revised every five years.

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[26] *Future Financial Liabilities of Nuclear Activities* Nuclear Energy Agency of the Organisation for Economic Co-operation and Development 1996

In Canada, the utilities operating nuclear power plants are owned by the provincial governments, and note in their financial statements the estimated costs for decommissioning and disposal of radioactive waste. The Atomic Energy Control Board, the competent authority, has issued a Regulatory Policy Document by which licencees must identify costs for decommissioning as early as the planning and design stage of a nuclear facility. A new regulation is expected to be introduced soon to replace the existing Atomic Energy Control Act. The new Act and the supporting regulations will include the need for the generator of liabilities to provide financial assurance for decommissioning to the satisfaction of prevailing regulations. For the case of uranium and thorium mining, a revised regulation was promulgated in 1994 in order to ensure that sufficient funds will be available for decommissioning.

In Finland and Sweden, the holder of a power plant licence is responsible for ensuring that all measures are adopted for the safe handling and final disposal of nuclear waste, (or nuclear material which is not to be reused) generated by the activities, and for the safe decommissioning of facilities. This has led in Sweden, to the Financing Act of 1981, and in Finland to the Nuclear Energy Act of 1988. These laws are intended to guarantee that funds are available when different measures in the nuclear waste management programme are carried out. To achieve this, the reactor owners pay to the State a fee related to the energy supplied from each reactor. The fund is administered by the central government authority: in Finland through the Ministry of Trade and Industry with the State Nuclear Waste Management Fund (VYR); in Sweden, through the Swedish Nuclear Power Inspectorate, SKI. VYR refunds assets in its fund which exceed the defined liabilities. The liabilities cover all waste types and all waste management measures including R & D. Guided by the Financing Act, SKI decides on reimbursement to the nuclear power utilities of costs relating to management of spent nuclear fuel, the decommissioning of nuclear plants, and for R & D on these activities.

In Germany, the "Endlagervorausleistungverordnung" (Repository, Advance Payment Ordinance) of 1982 establishes a funding mechanism which entitles the Bundesamt fur Strahlenschutz (BfS, Federal Bureau for Radiation Protection) to collect advance payments from the waste producers to cover future costs for repository R & D, land purchase and legal actions, repository planning, construction and operation. Concerning decommissioning costs, the "German Commercial Law" requires that money is set aside annually during the operating life-time of the facility. Responsibility for the fund is retained by the owner of the facility who has to follow accepted accounting standards in preparing annual accounts. The operator/owner of the facility has to justify the provisions to supervision boards, e.g. supervisory auditors, certified public accountants.

In Spain, the law considers that the cost for disposal of the waste arising from nuclear power plants and their decommissioning is an external cost, and thus not the liability of the licence holder. Those responsibilities for radioactive waste disposal and decommissioning of nuclear power plants rest with a State-owned company. To ensure funding of that company, the government approves a General Radioactive Waste Plan which includes both technical actions to be taken and the financial requirements during the expected life of the power plants. These external costs, revised annually, are reflected in the electricity prices paid bv the consumers.

In the United States there are funding mechanisms for the management of spent fuel and decommissioning of the power plants. In the case of spent fuel the operator has to pay the Department of Energy (DOE) a levy on each kWh (kilowatt-hour) produced, while a financial assurance must guarantee the decommissioning of the radioactive portion of a nuclear power plant.

V Further Reading

1) *Review of Radioactive Waste Management Policy* Final Conclusions Cm 2919 July 1995

2) *The Prospect for Nuclear Power in the UK* Cm 2860 May 1995

3) *Nuclear Privatisation* Trade and Industry Select Committee Second Report HC 43-I and II 1995/96

4) *Government Observations on the Second Report from the Trade and Industry Committee (session 1995-96) on Nuclear Privatisation* HC-383

5) *Nuclear Privatisation: Liabilities Left in the State Sector* Mike Sadnicki Commissioned by the Consortium of Opposing Local Authorities and Friends of the Earth 5 June 1996

6) *The Nuclear Review - Some Technical Issues* Parliament Office of Science and Technology June 1994

7) *The Cost of Decommissioning Nuclear Facilities* Report by the Comptroller and Auditor General National Audit Office 4 June 1993

8) *Nuclear Energy Programmes in OECD/NEA Countries* OECD/NEA 1995

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