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DRAFT	October 2000	H G LEWIS	R I WRIGHT	R I WRIGHT
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SUMMARY:

In 1997, RM Consultants Ltd (RMC) was contracted by Health and Safety Executive (HSE) to carry out a review of international approaches to decommissioning redundant nuclear facilities. A report was produced which covered an assessment of International Atomic Energy Agency (IAEA) safety series documentation on decommissioning and a review of UK and overseas approaches to the decommissioning of both nuclear power reactors and chemical plant. The report also discussed the reasons for earlier decommissioning, which were being increasingly adopted overseas, as compared to the delayed decommissioning options such as Safestore favoured by the UK nuclear industry.

NSD have now requested that the initial report should be updated. This revised report provides an update of the status of international standards relating to the decommissioning of nuclear facilities and legally binding conventions agreed to by Member States of the IAEA. It also covers the present situation within the UK, and summarises developments on decommissioning in Western Europe, the USA and Japan.

FORM RM 11B

DRAFT

INTERNATIONAL APPROACHES TO DECOMMISSIONING NUCLEAR FACILITIES

By H G LEWIS
(RM Consultants Ltd)

ABSTRACT

This report provides a detailed description of the various approaches to decommissioning nuclear facilities that have been adopted internationally. It covers the International Atomic Energy Agency (IAEA) safety series documentation on decommissioning with particular reference to the Radioactive Waste Safety Standards (RADWASS) Fundamentals principles of radioactive waste management and the recently concluded legally binding convention on the safety of spent fuel and radioactive waste management.

UK and overseas approaches to the decommissioning of both nuclear power reactors and chemical plants are compared and contrasted. It is noted that whereas the UK nuclear industry has adopted delayed decommissioning options such as Safestore, internationally there is an increasing trend towards earlier decommissioning of redundant facilities. The reasons for these different approaches are discussed and possible future impacts on UK decommissioning policy and strategy are assessed.

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CONTENTS

1. INTRODUCTION

In 1997, RM Consultants Ltd (RMC) was contracted by Health and Safety Executive (HSE) to carry out a review of international approaches to decommissioning redundant nuclear facilities. The purpose of this review was to ensure that the Nuclear Safety Directorate of the HSE remained fully aware of changes in policy and/or strategy overseas with respect to decommissioning.

A report was produced which covered an assessment of International Atomic Energy Agency (IAEA) safety series documentation on decommissioning and a review of UK and overseas approaches to the decommissioning of both nuclear power reactors and chemical plant.

The report also discussed the reasons for earlier decommissioning that were being increasingly adopted overseas, as compared to the delayed decommissioning options such as Safestore favoured by the UK nuclear industry.

NSD have now requested that the initial report should be updated to include recent developments internationally.

This revised report provides in Section 2 an update of the status of international standards relating to the decommissioning of nuclear facilities and legally binding conventions agreed to by Member States of the IAEA. Section 3 covers the present situation within the UK, while Section 4 summarises developments on decommissioning in Western Europe, the USA and Japan. A comparison of UK and overseas approaches to decommissioning nuclear facilities is presented in Section 5. Possible future developments are discussed in Section 6.

2. IAEA SAFETY STANDARDS AND CONVENTIONS

2.1 Background

The IAEA, which was founded in 1957, has a mandate to promote the safe and peaceful use of atomic energy. It is an autonomous, intergovernmental organisation of 130 Member States.

As Part of its Statute, the IAEA is authorised to establish or adopt standards of safety, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with specialised agencies in the subject areas covered.

The IAEA has during the past 40 years been involved in developing appropriate safety documentation for use by Member States and which provide a basis for or complement national regulations. These cover the four broad areas of safe transport of radioactive materials, radiation protection, safety of nuclear power reactors and the safety of radioactive waste management.

The IAEA safety standards reflect best international practice, and are consistent with regulatory documents of Member States having developed nuclear industries and of major international bodies. In addition to employing the services of international experts in specific subject areas, the IAEA has established its Safety Series documents on the basis of advice provided by international bodies. These include the International Nuclear Safety Advisory Group (INSAG), the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), and a number of non-governmental international bodies such as the International Commission on Radiological Protection (ICRP).

The safety standards clearly state the safety objectives, concepts, principles and requirements and provide guidance as a basis for national regulations or as indications of how safety requirements may be attained. These documents are issued pursuant to the IAEA's statutory function to establish safety standards. Within the safety standards there are three hierarchical levels, Safety Fundamentals, Safety Requirements and Safety Guides.

The Safety Fundamentals state the basic objectives, concepts and principles, while the Safety Requirements detail the basic requirements that must be satisfied in order to ensure safety for particular activities or applications. The Safety Guides contain recommendations, on the basis of international experience, related to the fulfilment of the basic requirements.

The written style used in the Safety Fundamentals and Safety Requirements ('shall' statements) accords with that of regulatory documents since the basic principles and requirements which they establish, and which are mandatory as far as the IAEA's own operations are concerned, may be adopted by Member States for use in national regulations to be applied in respect of their own activities. The recommendations contained in the Safety Guides are expressed as 'should' statements.

While these safety standards have been widely accepted by Member States, as reflecting best international practice, they are not legally binding.

Since 1973 the IAEA has addressed itself to providing guidance on decommissioning. It has carried out this task by reviewing current scientific, technological and regulatory information, and disseminating it as internationally acceptable good practice in the form of safety fundamentals, standards and guidelines. References [1-3] are examples of high level IAEA Safety Series publications on decommissioning.

2.2 **Phased Decommissioning**

The term 'decommissioning', as used in the nuclear industry world-wide, is understood to mean the set of actions taken at the end of a facility's useful life to retire that facility from service while protecting the health and safety of workers and the public and, at the same time, the environment. These actions can range from, on the one hand, merely closing down the facility with minimal removal of radioactive material and continuing maintenance and surveillance to, on the other, complete removal of radioactivity to levels acceptable for unrestricted use of the facility and its site.

Decommissioning may be carried out in one continuous operation following shutdown of a nuclear facility, or in a series of discrete operations separated by one or more periods of time. This second alternative is referred to as phased decommissioning.

The IAEA had, in the past (1,2), defined three discrete stages of decommissioning which became widely used internationally for clarity and ease of comparison. The first stage, which preferably should be carried out as soon as possible after final closure of the nuclear facility, involved the removal of radioactive material and operational wastes but retention of the first contamination barrier. The second stage consisted of dismantling of active and non-active plant to leave the building structure and in the case of nuclear power plants the reactor shield. The final stage consisted of demolishing the building structure or dismantling the reactor core and bio-shield, site clearance and removal of all radioactive material to allow release of the site for unrestricted use.

However, over the past few years as a result of decommissioning experience, an increasing number of countries now use different terminologies and approaches. To reflect these changes the IAEA in developing its Safety Standard on decommissioning of nuclear facilities, as part of the Radioactive Waste Safety Standards (RADWASS) programme, has decided that it will no longer be appropriate to refer to three distinct stages of decommissioning.

While the ultimate goal of decommissioning is unrestricted release of the site, the time required for a decommissioning programme will be facility specific and may range from a few years to many decades. Decommissioning may be accomplished in a continuous programme or by intermittent phases. It may therefore include periods of safe storage with surveillance and reuse of the site or parts of it for new facilities.

2.3 **Nuclear Power Reactors**

As explained in Section 2.1, the highest level IAEA safety document in a particular subject area is the Safety Fundamentals, which provides basic objectives, concepts and principles to ensure safety. For the safety of nuclear power reactors, the Safety Fundamentals document is entitled 'The Safety of Nuclear Installations' (4). The six major stages of the licensing process are delineated as siting, design, construction, commissioning, operation and decommissioning. The definition of decommissioning is very succinct, namely 'the process by which a nuclear installation is permanently taken out of operation'. It is interesting to note that the UK Government's White Paper 'Review of radioactive waste management policy' (5) has a similar definition, 'the process whereby a nuclear facility, at the end of its economic life, is taken permanently out of service and its site made available for other purposes'.

The Safety Fundamentals document emphasises the need to minimise the generation of radioactive wastes from decommissioning of nuclear installations. The need to limit radiation exposure to site personnel and of release of radioactive material to the environment during dismantling, and a requirement for regulatory approval of the decommissioning programme are also set out. Two principles relate to decommissioning:

1. The generation of radioactive waste, in terms of both activity and volume, shall be kept to the minimum practicable by appropriate design measures and operating practices.

2. The design of an installation and the decommissioning programme shall take into account the need to limit exposures during decommissioning to as low as is reasonable achievable. Prior to the initiation of decommissioning activities, the regulatory body shall approve the decommissioning programme.

2.4 **Chemical Plants**

Decommissioning is defined in the RADWASS programme (see Section 2.5) as the administrative and technical actions taken at the end of the useful life of a nuclear facility in retiring it from service and ultimately removing it from regulatory control. These actions typically involve conducting assessments, developing plans, performing monitoring and surveillance, as well as dismantling and removing radioactive materials, wastes, components and structures.

As discussed further in Section 2.5, the main safety objective for decommissioning is to protect human health and the environment from the radiological and non-radiological hazards resulting from the shut down facility, while limiting the burdens on future generations. This implies that, at all phases of decommissioning, workers, the public and the environment are properly protected from hazards resulting from the decommissioning process.

The ultimate goal of decommissioning any nuclear facility is unrestricted release of the site. The time period to achieve this goal may typically range from a few years to several decades (for example, to allow for radioactive decay). However, subject to national legal and regulatory requirements, a nuclear facility or its remaining parts may also be considered decommissioned if incorporated into a new or existing facility, or even if the site in which it is located is still under regulatory or other institutional control. This could apply, for example, to the decommissioning of a nuclear chemical plant located on a multi-facility site.

The safety principles described in Section 2.3 also apply to nuclear chemical plant. Whether decommissioning is a continuous process or is carried out in stages separated by periods of surveillance, care and maintenance, it is common practice to carry out post operational clean out (POCO) along with initial decommissioning/decontamination to remove all loose radioactivity. This is followed by dismantling and demolition.

In most Member States the decommissioning of non-reactor nuclear facilities is performed under much the same regulatory framework as that used to cover construction, operation and maintenance. Reference 3 describes in general terms the approach that may be used in regulating decommissioning and the considerations that may be taken into account in

developing decommissioning regulations and guides. It also describes the responsibilities of the regulatory body and of the decommissioning licensee.

2.5 RADWASS Safety Series Programme

The RADWASS Safety Fundamentals document (6) contains nine principles for safe management of radioactive waste. These are:

1. **Protection of human health:** Radioactive waste shall be managed in such a way as to secure an acceptable level of protection for human health.

2. **Protection of the environment:** Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment.

3. **Protection beyond national borders:** Radioactive waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will be taken into account.

4. **Protection of future generations:** Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today.

5. **Burdens on future generations:** Radioactive waste shall be managed in such a way that will not impose undue burdens on future generations.

6. **Legal framework:** Radioactive waste shall be managed within an appropriate national legal framework including clear allocation of responsibilities and provision for independent regulatory functions.

7. **Control of radioactive waste generation:** Generation of radioactive waste shall be kept to the minimum practicable.

8. **Radioactive waste generation and management interdependencies:** Interdependencies among all steps in radioactive waste generation and management shall be appropriately taken into account.

9. **Safety of facilities:** The safety of facilities for radioactive waste management shall be appropriately assured during their lifetime.

All these principles are consistent with the overall objective of ensuring that radioactive waste is managed in a manner that protects human health and the environment now and in the future without imposing undue burdens on future generations.

In order to apply the principles set out in the Safety Fundamentals document, Member States need to have an established national legal system for radioactive waste management. Such a system must specify the objectives and requirements of a national strategy for radioactive waste management and the responsibilities of the parties involved.

In the RADWASS programme, decommissioning is considered to be part of the pre-disposal subject area, since wastes arising from decommissioning have to be treated, conditioned and stored prior to disposal. During the last two years various RADWASS documents have been prepared. A Safety Requirement on the pre-disposal management of radioactive waste, including decommissioning, has recently been published in August 2000 (7). This document describes basic requirements for safely decommissioning nuclear facilities with the ultimate aim of unrestricted release or use of the site. It also emphasises the importance of adequate advanced planning, including designing nuclear facilities for ease of decontamination and dismantling, and developing and using methods to reduce public and occupational exposures during decommissioning. An essential requirement in the planning stage is the need to minimise the creation of radioactive wastes during decommissioning operations.

A requirement for preparation by the operator of an initial decommissioning plan has been noted, along with regular review at appropriate intervals and after any significant events as required by the regulatory body. At final shutdown of the facility, a detailed decommissioning plan would be required for approval by the regulatory body. This detailed

plan should include arrangements for minimising generation of secondary wastes and for careful segregation of waste with a view to possible release from regulatory control of large volumes containing extremely low levels of activity in accordance with established clearance criteria.

The basic requirements have been elaborated in three Safety Guides on decommissioning. Two of these Guides, decommissioning of nuclear power plants and research reactors (8) and decommissioning of medical, industrial and research facilities (9), were published in November 1999, while the third Guide on decommissioning of nuclear fuel cycle facilities is due to be published in the next few months.

2.6 **Regulatory Requirements**

The regulatory requirements for decommissioning nuclear facilities are outlined in Reference 3. It is acknowledged that in most Member States the body established to regulate decommissioning of nuclear facilities is also responsible for regulating their operation. The responsibilities of the regulatory body, as described in reference 10, are to:

- enforce compliance with legal requirements;
- implement the licensing process;
- advise the Government.

This safety requirement states that the regulatory body shall take appropriate steps to ensure that activities which generate radioactive waste are not started without provision for suitable and sufficient storage capacity while awaiting the availability of relevant disposal routes. It also requires the regulatory body to ensure that adequate records of radioactive waste management facilities or sites are maintained for an appropriate period of time.

The decommissioning safety requirements (7) and safety guides (8,9) describe in some detail the specific responsibilities of the regulatory body relating to decommissioning. They state that the regulatory body should enforce legislation and regulations related to

decommissioning, in co-operation with other government agencies and departments where appropriate. The specified activities of the regulatory body include:

(a) making recommendations to the appropriate government authority regarding the implementation of laws, regulations, subsidiary legal provisions and other administrative measures as well as policy and strategy for the safe decommissioning of nuclear facilities;
(b) collecting and evaluating information required to establish the laws, regulations and subsidiary legal provisions as well as the administrative measures needed for decommissioning and to make related regulatory decisions;
(c) developing regulations and subsidiary legal provisions, e.g. guides required to put into effect the decommissioning policy and strategy, including the establishment of clearance criteria for materials, equipment, buildings and sites;
(d) reviewing the selected decommissioning option, decommissioning plans, quality assurance programmes and other submissions related to the decommissioning of a nuclear facility;
(e) issuing licences or other authorisations for decommissioning of a nuclear facility and ensuring compliance with requirements and regulations;
(f) ensuring that decommissioning activities are appropriately planned and safely implemented by the operator,
(g) conducting inspections to ensure compliance with regulatory requirements and implementing enforcement where necessary;
(h) ensuring that the existing operator transfers records and documentation relevant to the decommissioning process to any new operator; and
(i) ensuring maintenance of records and documentation for an appropriate period of time following completion of decommissioning, including key data such as the final monitoring survey.

The importance of adequate record keeping is also described in another IAEA Safety Series document (11). This states that the regulatory body shall ensure that records are maintained for nuclear facilities that have been decommissioned. The regulatory body may choose to take responsibility for the long-term retention of such records.

2.7 Spent Fuel and Waste Management Convention

In September 1997, delegates from 62 Member States adopted the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management at a Diplomatic Conference held at the IAEA in Vienna. This joint convention is the first legally binding international instrument to address the safety of management and storage of radioactive wastes and spent fuel, and the decommissioning of nuclear facilities.

The convention aims to ensure that during all stages of spent fuel and radioactive waste management, including decommissioning, effective defences are established to protect workers, public and the environment against harmful effects of ionising radiation both now and in the future. The UK was one of the first signatory nations to the convention. In this convention, decommissioning is defined as 'all steps leading to the release of a civilian nuclear facility, other than a disposal facility, from regulatory control. These steps include the processes of decontamination and dismantling'.

It is important to note that for both spent fuel and radioactive waste management the safety requirements set out in the RADWASS Fundamentals principles (6) have been reiterated with particular emphasis on the avoidance of imposing undue burdens on future generations. There is also specified a requirement that decommissioning plans for a spent fuel management facility or a waste management facility are prepared and updated, as necessary, using information obtained during the operating lifetime of that facility, and are reviewed by the regulatory body.

The convention also states that the Contracting Parties shall take appropriate steps to ensure the safety of decommissioning of a nuclear facility. Such steps shall ensure that:

i. qualified staff and adequate financial resources are available;

ii. radiation exposure of workers and the public shall be kept as low as reasonably achievable (ALARA), discharges shall be limited to keep exposures to radiation ALARA and that appropriate corrective measures are implemented to control and mitigate the effects of unplanned or uncontrolled releases of radioactive materials;

iii. appropriate emergency preparedness arrangements (on site and, if necessary, off site emergency plans) are applied; and

iv. records of information important to decommissioning are kept.

The convention establishes a binding reporting system whereby Contracting Parties shall submit at regular intervals a national report addressing all measures taken to implement the convention's obligations. This report shall include details of all nuclear facilities in the process of being decommissioned and the status of decommissioning activities at these facilities.

3. UK APPROACHES TO DECOMMISSIONING

3.1 Policy and Regulation

The lead government department in the formulation of the UK's radioactive waste management policy is the DETR. Decommissioning is recognised as an important aspect of this policy. DTI generally represents the views of the nuclear industry in this process, and other government departments and the regulators are also involved.

Regulation of radioactive waste management, including decommissioning, is undertaken by both the Health and Safety Executive (HSE) and the Environment Agency (EA). HSE's statutory powers arise from the Health and Safety at Work etc Act 1974 (12) and the Nuclear Installations Act (NIA) 1965 (as amended) (13). HSE has delegated its roles under the NIA to the Nuclear Installations Inspectorate (NII). The EA's regulatory powers are provided by the Radioactive Substances Act 1993 (14).

Nuclear sites are licensed under the NIA by the NII, who attach conditions to the site licence in the interests of safety and in respect of the handling, treatment and storage of radioactive materials. The conditions relating to waste management and decommissioning require

arrangements to ensure that generation of wastes is minimised, that wastes are properly contained and that wastes are stored in a controlled manner. When a nuclear licence is granted, the operator is required to make arrangements to comply with the conditions attached to the licence. As part of this compliance, the licensee has to demonstrate the safety of the facility at all stages of its operation, from the start of construction through to the completion of decommissioning, in a sequence of safety reports. These safety reports have to be periodically reviewed and updated.

In addition, the licensees have to prepare decommissioning plans that:

- define the operator's strategy for decommissioning and managing the waste produced at each stage; and
- consider all practical options for managing each waste arising, including any secondary waste from the decommissioning operations.

If the decommissioning strategy does not provide for the return of the whole site to unrestricted use appropriate arrangements must be made for:

- the maintenance of active safety systems (e.g. containment and ventilation) in effective operation;
- measurements and inspection to ensure that contamination control systems are functioning properly;
- monitoring radiation and contamination (surface and airborne) levels inside the remaining plant and in the area around the plant; and
- control of access to the site.

Discharges to the environment and the disposal of wastes arising during decommissioning activities are regulated by the EA. The EA also requires licensees to prepare a 'Radioactive Waste Management Document' for any major decommissioning project, and this document needs to justify the operator's overall choice of options, in terms of the best practicable environmental options (BPEO) for each waste arising.

3.2 Nuclear Reactors

The UK's current strategy for decommissioning nuclear power stations (as stated in the 1995 Government White Paper on radioactive waste management policy (5)) is that it should be done in three stages - Stage I defuelling immediately on shutdown; Stage II dismantling buildings external to the reactor shield 5 - 10 years later; and stage III demolishing the reactor itself 100 years after shutdown.

However, Magnox Electric, Nuclear Electric and Scottish Nuclear proposed a 'Safestore' strategy for Magnox and Advanced Gas Cooled reactors (15). This strategy was based on a long term three stage approach which provides optimal time for radioactive decay prior to intervention and so reduces radiation dose to staff and minimises waste disposal volumes. Three stages are involved as follows:

Stage 1 Removal of fuel following shutdown, over a 3 year period, followed by a 1-2 year preparation of the site for Care and Maintenance (C&M) period of approximately 30 years. This preparation period involves the removal, where economic, of various non-radioactive plant and buildings and putting the remaining buildings including the reactor building in a suitable state for C&M.

Stage 2 Construction of an intruder-proof and weather-proof structure around buildings containing active plant. This is called a "Safestore", takes from 2 to 4 years to complete, and permits minimum maintenance over the next 100 years or so during which time routine surveillance would be undertaken.

Stage 3 Complete dismantling and removal of Safestore structures and all plant and buildings to return to a "greenfield" site. This commences approximately 135 years after shutdown and will take about 10 years to complete.

The 1995 White Paper (5) concluded that in general, the process of decommissioning nuclear power plants should be undertaken as soon as it is reasonably practical to do so, taking account of all the relevant factors. Since regulatory approval will continue to be required on a case-by-case basis, it would be unwise for the operators of nuclear power stations to take steps which would foreclose technically or economically the option of

completing Stages II and III on an earlier timescale should that be required. Nevertheless, the Government believed that there were a number of potentially feasible and acceptable decommissioning strategies for nuclear power stations including Safestore.

The White Paper also stated that nuclear operators would be asked to draw up strategies for decommissioning their redundant plant and these would be reviewed quinquennially by HSE in consultation with the EA.

BNFL, UKAEA and the Ministry of Defence (MOD) also have responsibilities for operating and/or decommissioning redundant nuclear reactors. BNFL's reactor decommissioning procedures are currently based on the IAEA three stages but with the final demolition stage being delayed for 85-90 years to allow decay of activation products. This approach would result in a total decommissioning duration of about 110 years. Two alternatives to this procedure are now being considered. Firstly deferment of stage 3 until 135 years after shutdown leading to a total programme of 145 to 150 years. Secondly construction of Safestore 35 years after shutdown, which as with Magnox Electric, Nuclear Electric and Scottish Nuclear would be expected to last for about 100 years. Similarly UKAEA plan to defer Stage 2 and 3 decommissioning in order to minimise costs. While Stage 1 defuelling is normally carried out immediately after shutdown of the reactor, post stage 1 there will be long term care and maintenance periods.

The present status of redundant nuclear reactors in the UK is that large power reactors such as the Magnox stations at Berkeley, Hunterston and Trawsfynydd, the Dounreay DFR and PFR, Winfrith SGHWR and Windscale AGR have either been or are currently being defuelled. Apart from WAGR where stage 2 dismantling is about to commence, all these reactors are in stage 1 or long term post stage 1 care and maintenance. Small research reactors such as Dounreay DMTR, Harwell Dido, Pluto, BEPO and GLEEP, Winfrith ZEBRA and Nestor, and Aldermaston HERALD and Merlin have also been defuelled, but only GLEEP and ZEBRA are at stage 2 decommissioning. It is considered unlikely that any of these smaller reactors will start stage 3 decommissioning until after 2050. However, it should be noted that the Manchester and Liverpool Universities Reactor at Risley has been successfully decommissioned and delicensed.

3.3 Chemical Plants

Many nuclear chemical plants such as those that which were operated by UKAEA at Harwell and Dounreay, by BNFL at Capenhurst, Springfields and Sellafield and by MOD at Aldermaston have been wholly or partly redundant for a number of years. The Safestore concept is of little practical benefit because of the problems of contamination spread. In addition these chemical plants tend to have less robust containment structures than reactors, and as a result there is a greater emphasis on earlier dismantling to meet safety requirements and to minimise increasing care, maintenance and surveillance costs. Specifically for plutonium plants, early decommissioning can restrict the ingrowth of americium which results in increased dose uptake to workers, so there is a particular incentive to remove plant equipment as soon as possible.

The decommissioning process for BNFL's chemical plants consists of three operational and two dormancy phases:-

- Initial Decommissioning (ID)
- Surveillance and Maintenance (S&M)
- Dismantling (DS)
- Care and Maintenance (C&M)
- Demolition (DM)

The three operational phases (ID, DS and DM) are broadly consistent with the IAEA three stages of decommissioning.

ID is defined as an extension of Post Operational Clean Out (POCO) with the aim of removing or fixing all loose radioactivity and to place the plant in a condition where further decommissioning may be safely deferred at minimum cost. For plants which are already redundant, POCO is planned to take place alongside ID. For presently operational and future plants, POCO is assumed to take 6-12 months after the end of operations; ID will then commence immediately following POCO.

S&M is the period between ID and DS and ensures the plant is kept in a safe condition. It may include filter changing, fan replacement, building repairs, radiological checks and maintenance of surveillance and containment equipment.

Dismantling is defined as the removal of all radioactive plant to leave the building structure with no contamination above LLW. C&M is the maintenance of the building structure post DS, while DM involves the final building demolition using predominately conventional techniques.

BNFL currently programme extended periods of S&M and C&M for process plants. Dismantling will only be undertaken on a timescale consistent with the effective utilisation of waste treatment facilities, manpower and equipment resources. However, dismantling will be completed within 50 years of the end of plant operations. For plutonium plants DS is planned to immediately follow ID to minimise increased dose uptake from americium ingrowth. Nevertheless building demolition (for both process and plutonium plants) is not scheduled to commence until after 2050.

UKAEA and MOD have similar stages of decommissioning for chemical plants. However, an important difference is that stage 2 dismantling involves disassembly and removal of all contaminated plant, equipment and structures (i.e. all radioactivity, not just ILW, is removed). As with BNFL, UKAEA and MOD envisage extended quiescent periods between stages 1 and 2 and stages 2 and 3.

A significant amount of experience has been gained from decommissioning of chemical plants by BNFL (Capenhurst diffusion plant, Sellafield plutonium plants), UKAEA (Harwell and Dounreay) and MOD at Aldermaston.

The present status of UK nuclear facilities undergoing decommissioning is shown in Table 1.

TABLE 1 STATUS OF UK DECOMMISSIONED FACILITIES

Plant/ Installation	Name	Type*	Operating Period	IAEA Decommissioning Stage
Large power Reactor	DFR Dounreay	FBR	1963-77	1
	WAGR Windscale	AGR	1962-81	2
	SGHWR Winfrith	HWR	1968-90	1
	PFR Dounreay	FBR	1975-94	1
	Berkeley 1	GCR	1961-89	1
	Berkeley 2	GCR	1961-88	1
	Hunterston A1	GCR	1964-90	1
	Hunterston A2	GCR	1964-89	1
	Trawsfynydd 1	GCR	1965-93	1
	Trawsfynydd 2	GCR	1965-93	1
Small reactor Plant	Windscale Pile 1	GR	1950-57	1/2
	Windscale Pile 2	GR	1951-58	1/2
	Merlin Aldermaston	PR	1959-62	1
	BEPO Harwell	GR	1948-68	1
	DMTR Dounreay	HWR	1958-69	1
	Dragon Winfrith	HTR	1965-76	1
	ZEBRA Winfrith		1967-82	2
	DIDO Harwell	HWR	1956-90	1
	PLUTO Harwell	HWR	1956-90	1
	GLEEP Harwell	GR	1947-90	2
Other installation	B212 Caesium plant (S)	-	1956-58	3
	B206 solvent recovery plant (S)	-	1952-63	3
	B29 fuel storage plant (S)	-	1952-64	1
	B207 uranium purification plant (S)	-	1952-73	3
	Uranium enrichment (diffusion) plant (C)	-	1953-82	3

(S) Sellafield (C) Capenhurst

* Key FBR = Fast Breeder Reactor GCR = Gas Cooled Reactor
AGR = Advanced Gas-cooled Reactor GR = Air Cooled Graphite Reactor
HWR = Heavy Water Moderated Reactor PR = Pool-type Reactor
HTR = High Temperature Reactor

4. INTERNATIONAL APPROACHES

4.1 National Decommissioning Policies

Although the contents of national decommissioning policies vary among overseas countries, they in general include the following:

- **A framework of laws and regulations** within which a decommissioning programme can be developed. In some countries, this framework is fairly specific, in most others it is base on broad requirements, already in existence. A method of dealing with residual radioactivity in decommissioned facilities and material and equipment that are to be released for restricted or unrestricted use is particularly relevant. The IAEA has provided guidance on this subject (16).

- **The recycling and reuse of material recovered in decommissioning work.** This may be an attractive alternative to waste disposal. It is being strongly advocated in Germany, but otherwise few countries have issued firm criteria for applying this alternative (17,18).

- **The responsible organisations** and the role given to them;

- **Waste Management.** The availability of storage and/or disposal facilities for the spent fuel and waste arising from decommissioning can significantly affect the overall decommissioning strategy.

- **Financial Assurance.** Provisions for assuring that sufficient funds are available for performing the necessary decommissioning work are required by most countries.

Originally, atomic energy laws in many countries only covered siting, design, construction, commissioning and operation of nuclear facilities and there were often no specific requirements regarding decommissioning. It was, however, implied that decommissioning would require regulatory approval since decommissioning is an important, safety related stage in the life cycle of the facility.

At present, many countries still regulate decommissioning on a case-by-case basis using the same legislation that they use to regulate operations. However, as decommissioning activities have become more frequent and now include large nuclear facilities, there is an increasing tendency to develop specific guidance and/or regulations.

A wide range of legal and regulatory frameworks exists in which decommissioning requirements are addressed. In some countries the atomic energy laws specifically address decommissioning e.g. Germany (19), in others regulations have been enacted (e.g. the USA (20)), in yet others decommissioning is covered by conditions in the operating licence (as is the case in the UK).

4.2 **European Developments**

The approaches to decommissioning nuclear installations vary within the different continental European countries with significant nuclear capabilities, and they in turn have noticeable differences from the UK approach. This sub section describes the decommissioning plans and policies for different countries, and also provides information on the specific organisations charged with the responsibility of overseeing such important aspects as safety and radioactive discharges arising from decommissioning activities.

4.2.1 France

Most French nuclear facilities are owned by the government through various public companies and organisations such as Electricitié de France (EDF) and the Commissariat à l'Energie Atomique (CEA) together with its subsidiaries, in particular the Compagnie Générale des Matières Nucléaires (COGEMA) and the Agence Nationale pour la Gestion des Déchets Radioactifs (ANDRA). The only nuclear materials which may be owned by private companies are radiation sources for industrial applications and radiography.

The Ministry of the Environment and the Ministry of Industry (MOI) are the governmental authorities responsible for the safety of nuclear installations. The regulatory responsibilities of the governmental authorities in the area of nuclear safety are as follows:

- establishment and application of general safety rules;
- issue of licences to each installation after in-depth technical appraisal of the safety case; and
- surveillance.

The Nuclear Installations Safety Directorate (DSIN) is a specialised department in the Ministry of Industry. Its services are also available to the Ministry of the Environment. It licenses the construction, operation and decommissioning of nuclear installations.

Licences for the construction and operation of nuclear facilities are granted by ministerial decree after due consideration of the views of the Ministries concerned and a public hearing. The Commission Inerministérielle des Installations Nucléaires de Base (CIINB) prepares the licensing decree for signature by the Prime Minister.

DSIN was set up by a decree of the Council of State in May 1991 to take over the responsibilities of SCSIN which had existed since 1973. DSIN makes use of the Institut de Protection et de Sûreté Nucléaire (IPSN), a major branch of CEA, as a source of technical support.

DSIN's main duties are:

- to look into problems arising from the choice of sites for nuclear installations,
- all authorisation procedures relating to nuclear installations including radioactive releases,
- organisation and carrying out of surveillance of nuclear installations,
- to formulate general technical regulations and to check on their application,
- to set up an organisation to deal with an incident or accident at a nuclear installation,
- to set up public relations channels in order to communicate with the media and the outside world generally, and
- observation of research and development work in the field of nuclear safety carried out by organisations reporting to the MOI, such as CEA and EDF.

The Office for Protection against Ionising Radiation (OPRI) was created by means of a decree in July 1994. It is a public organisation, whose role is to provide expertise and control on behalf of the ministries of health and labour. OPRI carries out measurements and analysis of radioactivity or ionising radiation, and ensures that there is a very strict control over liquid and gaseous discharges from nuclear installations. OPRI has established an effective network of sampling points throughout the country and about 50000 samples are collected annually. Quality of measurement is guaranteed by comparison with an international network of the World Health Organisation.

With regard to decommissioning of redundant nuclear facilities, French policy states that safety controls must continue from shutdown of a nuclear installation until all radioactive materials have been removed.

Decree 90-78 (January 1990) modified decree 63 - 1228 (December 1963) by creating a new article 6 which specified the decommissioning obligations of a nuclear plant operator, and defined the different decommissioning phases. An operator wishing to shut down an installation must inform DSIN of:

- the status chosen for the installation after final shut-down, showing how it fits into the plan for possible future decommissioning,
- the way in which he intends to achieve this status,
- general rules for surveillance and maintenance which will enable the installation to be kept in a satisfactory condition in the chosen status.

The first phase comprises operations which can be carried out under the regulatory framework of the initial licence decree (operating licence). These operations include defuelling, removal of nuclear materials and waste, and equipment decontamination. They are performed in accordance with the operating rules and conditions attached to the initial safety report. Six months before final shutdown, the operator is required to present a safety study describing these operations to DSIN.

The next phase concerns the achievement of safe storage conditions. These operations include:

- dismantling of non radioactive equipment and structures;
- maintenance or strengthening of containment barriers; and
- performing site radiological characterisation.

According to Article 6 of the Decree of January 1990, these operations need a licence decree from the Ministries of the Environment and of Industry. This Safe Storage Decommissioning Decree can only be issued after approval that it complies with the requirements of the Ministry of Health, and following consultation with CIINB.

The third decommissioning phase is dismantling which can be started at the end of the operations required for achieving safe storage or deferred to take advantage of radioactive decay. A new decree is required to obtain a dismantling licence. The administrative and technical conditions are similar to those described above. Issue of the new decree allows the start of dismantling operations, at the end of which either IAEA Stage 2 or Stage 3 will have been reached.

In some cases, when the dismantling operations modify the installation beyond a point at which it becomes no longer recognisable as described in its previous licence a new nuclear installation has been created. This must be the subject of a new licence. The new licence may be issued simultaneously with the dismantling licence. A good example is the Pegase reactor at Cadarache, which operated from 1963 to 1974. It has been decommissioned, and since 1990 it has operated as a radioactive waste storage facility.

Article 6 of decree 90-78 does not address decommissioning scheduling, which is based exclusively on economic and social considerations consistent with optimising protection of the workers and the environment. While it is possible, as explained above, to delay the dismantling phase of decommissioning, a significant number of nuclear installations have already been decommissioned in France.

CEA (which has the responsibility for most nuclear installations already, or currently, being decommissioned) has a stated policy to undertake prompt decommissioning whenever possible. Deferred dismantling is only considered if a significant reduction in radioactivity

is expected over time, and there are no safety reservations regarding the condition of the shut-down facility. A recent review of CEA decommissioning experience (21) noted the importance of taking advantage of the knowledge of the plant operating personnel, and in not underestimating the costs of monitoring facilities awaiting dismantling.

The current status of decommissioning French nuclear facilities is shown in Table 2.

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TABLE 2 STATUS OF FRENCH DECOMMISSIONED FACILITIES

Plant/ Installation	Name	Type*	Operating Period	IAEA Decommissioning Stage
Large power reactor	G1 Marcoule	GCR	1956-68	2
	G2 Marcoule	GCR	1959-80	2
	G3 Marcoule	GCR	1960-84	2
	Chinon A1	GCR	1963-73	1
	Chinon A2	GCR	1965-85	
	Chinon A3	GCR	1966-90	1
	Chooz A	PWR	1967-91	
	Saint Laurent A1	GCR	1969-90	1
	Saint Laurent A2	GCR	1971-92	
	EL4 Monts d'arrée	HWR	1969-90	2
Small reactor plant	EL2 Saclay	HWR	1952-65	2
	EL3 Saclay	HWR	1957-79	2
	PEGASE Cadarache	PWR	1963-74	3
	RAPSODIE Cadarache	FBR	1967-83	2
	TRITON Fontenay	PR	1959-82	2
	MELUSINE Grenoble	PR	1958-88	3
	MINERVE Saclay	PR	1954-76	3
	ZOE Fontenay	HWR	1948-75	2
	NEREIDE Fontenay	PR	1959-82	3
	PEGGY Cadarache	GCR	1961-75	3
	CESAR Cadarache	CA	1964-74	3
	MARIUS Cadarache	CA	1960-83	3
Other installation	Elan II B La Hague, Source fabrication plant	-	1970-73	3
	Elan II A La Hague, Pilot plant for Elan II B	-	1968-70	3
	AT1 La Hague, Fuel reprocessing plant	-	1969-79	3
	PIVER Marcoule, Waste vitrification plant	-	1966-80	3
	ATTILA, Dry processing pilot cell	-	1968-75	3
	RM2, Radiometallurgy lab, 13 cells	-	1964-85	3
	Building 19 Fontenay, Plutonium metallurgy	-	1957-84	3

* Key GCR = Gas Cooled Reactor FBR = Fast Breeder Reactor
PWR = Pressurised Water Reactor CA = Critical Assembly
HWR = Heavy Water Moderated Reactor PR = Pool-type Reactor

4.2.2 Belgium

In Belgium, the general framework of nuclear safety and radiological protection is set by the Royal Decree of February 1963, as amended. This lays down the basis for the protection of workers and the population against ionising radiation. The decree also covers the siting, design, construction and commissioning of nuclear facilities. An amendment is in preparation to specifically require a decommissioning licence.

In 1980, the Government passed a law creating the National Agency for Radioactive Waste and Fissile Material, ONDRAF-NIRAS, to manage radioactive waste and fissile materials. Details were set out in the Royal Decree of March 1981.

In 1991, the Government passed a new law and Royal Decree extending the mission of ONDRAF-NIRAS and entrusting it with specific tasks in the field of decommissioning nuclear installations. This Decree requires, for each new facility and plants still operating, that the operator/licensee must provide information about future decommissioning programmes collected together in a decommissioning plan. The initial decommissioning plan has to be approved by ONDRAF-NIRAS, and should include the equipment and radiological inventory of the plant, the strategy proposed, the estimations of waste types and quantities, and the decommissioning cost evaluation.

At least three years before the final shutdown of the facility, the licensee must prepare a final decommissioning plan. The final plan confirms the preferred strategy and defines the decommissioning programme in detail. After approval by ONDRAF-NIRAS, the licensee is responsible for carrying out the decommissioning programme.

The selected strategy for nuclear plants already shutdown is dismantling to IAEA Stage 3. No benefit was expected from deferred decommissioning of the Eurochemic reprocessing plant, and dismantling of the main process building to IAEA Stage 3 started after an intensive in situ decontamination of the process equipment. The dismantling of the first European PWR prototype reactor BR3 started shortly after its final shutdown in 1987 with a demonstration programme covering the dismantling of highly activated reactor components.

The new Belgian government, elected in Summer 1999, has proposed that nuclear power plants should be phased out within a specified timeframe. Under the proposals, all reactors would be closed and decommissioned such that the latest plant decommissioning would commence in 2015 and be completed by 2025.

4.2.3 Germany

In Germany, the Federal Minister of the Environment, Nature Protection and Nuclear Safety (BMU) is responsible for nuclear safety and radiological protection and issues acts and ordinances as well as rules, guidelines and criteria, and supervises the States, which act on behalf of the Federal Government in the licensing procedure. BMU can give directives to the States to ensure a legally consistent regulatory framework. BMU receives advice on all issues concerning nuclear safety and radiation protection from the Reactor Safety Commission (RSK) and from the Commission for Radiological Protection (SSK).

The States act on behalf of the Federal Government as the licensing authorities for construction, commissioning and decommissioning of all nuclear installations. The licensing authorities consult expert organisations for assessment of the Safety Analysis Reports and independent evaluations of all safety issues arising during construction, operation and decommissioning.

The legal basis for the use of nuclear energy, radiological protection, and related activities is the Atomic Energy Act (AEA) of December 1959, as amended February 1986 and further amended December 1992. Section 7, para (3) of the AEA is the central statement on the post-operational phase of land-based installations for the production, treatment, processing or fission of nuclear fuel or for the reprocessing of irradiated nuclear fuel and reads as follows:

The decommissioning of a nuclear installation as well as the safe enclosure of a finally decommissioned installation or the dismantling of the installation or parts thereof shall require a licence.

Section 9, para (1) of the AEA states: "Any person who constructs, operates, otherwise holds, materially modifies, decommissions or disposes of installations in which nuclear fuel is handled shall make provisions to assure that radioactive residues as well as disassembled or dismantled radioactive components are utilised without harmful effects or are disposed of as radioactive wastes in an orderly manner if utilisation is not possible (because of economic or safety considerations)".

Two other legal provisions deal with radiation exposure. These are:

(1) Act on the Precautionary Protection of the Population against Radiation Exposure (Precautionary Radiological Protection Act) as promulgated December 1986.

(2) Ordinance on the Protection against Damage and Injuries Caused by Ionising Radiation (Radiological Protection Ordinance - RPO) as promulgated June 1989 and amended August 1994.

The aspects relating to radiation exposure are governed by the RPO, which applies to the operating phase as well as to the decommissioning phase. Any unnecessary radiation exposure or contamination of persons, property or the environment has to be avoided. All types of radiation exposure or contamination, even below the established limits, have to be kept as low as possible. Details of the calculation of the public exposure are prescribed in an Administrative Ordinance. Furthermore, there are guidelines for the radiological protection of occupationally exposed people.

Finally, an Ordinance Relating to the Procedure for the Licensing of Facilities in Accordance with Section 7 of the Atomic Energy Act (Nuclear Licensing Procedures Ordinance - NLPO) as promulgated February 1995, provides statements on the extent of public involvement in the licensing procedures. The NLPO also covers the need for public notification and access to application documents submitted by licensees for decommissioning a nuclear facility and/or safe enclosure of a decommissioned facility.

A decommissioning concept (not a plan) is necessary for initial licensing of nuclear installations, in compliance with RPO. Criterion 2.10 of the Safety Criteria for Nuclear Power Plants (issued by the Federal Minister of the Interior October 1977) states:

"Nuclear power plants shall be in such a condition that they can be decommissioned in compliance with the Radiation Protection Regulations. A concept for the removal of the plant after its final shutdown in compliance with Radiation Protection Regulations shall be provided".

Decommissioning projects have to comply with RPO. Before the start of decommissioning, the applicant for a licence has to submit a number of documents. These are a safety analysis report comprising a description of the plant, an outline decommissioning plan, plant location, drawings, discussion of possible hazards and safety measures. This material is intended to enable the general public to decide if its rights are affected by the decommissioning plan.

Further, more detailed decommissioning plans will be required together with a description of the measures to be taken against disturbances and other interference by third parties, qualifications of personnel, financial provision to cover compensation for damage, and prevention of contamination of water, air and soil.

Separate licenses are needed for:

(a) withdrawal from service, i.e. shutdown of a nuclear installation
(b) safe enclosure, following defuelling
(c) complete dismantling.

At present, there are proposals to amend the AEA with respect to decommissioning so that requirements are established to ensure:

(1) complete dismantling of all radioactive components in due time after final shutdown; and

(2) sufficient financial means to dismantle the plant even in the case of an unplanned early final shutdown.

A major review of German nuclear power generation and waste management policy has recently taken place following the election of a new government in 1998. An agreement was reached between the Federal Government and the nuclear industry in June 2000 to shut down all existing reactors at the end of their design lives and to proceed with their decommissioning.

There are two possible strategies for decommissioning; (1) immediate dismantling after the removal of all supply materials, or (2) deferred dismantling after a delay not exceeding 30 years.

The current status of decommissioning of German nuclear installations is shown in Table 3. It may be seen that most redundant facilities have been, or are being, decommissioned to the equivalent of IAEA Stage 3. A small number of facilities (the Lingen BWR and the two HTRs) have been completely defuelled, and the operators have been granted a safe enclosure licence. This allows the nuclear installation to be kept in a Care and Maintenance (C&M) state, but only for a specified (20-30 years) limited timescale. However, the merits of this approach have been questioned (22); the author describing new evaluations suggesting that immediate dismantling to a green field site would be cheaper and easier than deferred decommissioning.

TABLE 3 STATUS OF GERMAN DECOMMISSIONED FACILITIES

Plant/ Installation	Name	Type*	Operating Period	IAEA Decommissioning Stage
Large power reactor	HDR Karlstein	BWR	1969-71	3
	KKN Niederaichbach	HWR	1973-74	3
	KRB A Gundremmingen	BWR	1966-77	3
	KWL Lingen	BWR	1968-77	1
	MZFR Karlsruhe	HWR	1966-84	3
	VAK Kahl	BWR	1961-85	3
	AVR Jülich	HTR	1967-88	1
	THTR 300 Hamm-Uentrop	HTR	1985-88	1
	KKR Rheinsberg	PWR	1966-90	3
	KGR1 Greifswald	PWR	1973-90	3
	KGR2 Greifswald	PWR	1974-90	3
	KGR3 Greifswald	PWR	1977-90	3
	KGR4 Greifswald	PWR	1979-90	3
	KGR5 Greifswald	PWR	1989-90	3
	KNK-II Karlsruhe	FBR	1978-90	2
Small reactor plant	Otto-Hahn ship reactor	PWR	1968-79	3
	FR-2 Karlsruhe	HWR	1962-81	2
	FRJ-1 Merlin Jülich	PR	1962-85	2
	RFR Rossendorf	PR	1957-90	3
	FRG-2 Geesthacht	PR	1963-95	3
Other installation	Nukem-Alt fab plant Hanau		1960-88	3
	WAK reproc plant Karlsruhe		1971-90	3
	Hobel fab plant Hanau		1962-92	3

* Key BWR = Boiling Water Reactor PWR = Pressurised Water Reactor
HWR = Heavy Water Moderated Reactor PR = Pool-type Reactor
HTR = High Temperature Reactor

4.2.4 Spain

In Spain, the legal basis for regulating the peaceful use of nuclear energy and radioactive materials was established by Act 25 in 1964. The licensing process is governed by the Regulation on Nuclear and Radioactive Installations, approved by Decree in 1972, which is currently under review.

Act 15 of 1980 established the Nuclear Safety Council (CSN) and considerably modified established responsibilities within the licensing process that is now conducted by the Ministry of Industry and the CSN. Authorisations are granted by the Ministry; however, before this can be done, the Ministry must receive a legally binding report (i.e. a report which cannot change once issued and which includes legally binding recommendations) from CSN on all matters relating to radiological protection and nuclear safety (objectives, criteria, limits and conditions). According to the provisions of this Act, the CSN must issue a safety report not only prior to granting of siting, construction and operational permits and licences, but also prior to any decommissioning. It is therefore inferred that decommissioning requires a specific licence.

The Spanish radiological protection regulations (latest version issued January 1992), fully comply with the EEC Directives of 1980 and 1984 and the IAEA Basic Safety Standards (23). These regulations apply to all decommissioning activities.

Royal Decree 1522 published in 1984 established the Spanish National Waste Management Company (ENRESA) and defined its responsibilities within the nuclear fuel cycle. As part of its responsibilities, ENRESA is charged with the management (preparation and implementation) of the activities required for the decommissioning of nuclear facilities.

Decommissioning is regarded as just another step in the lifecycle of a nuclear facility, subject to virtually the same licensing framework as that applied to siting, construction and operation. Although there is no national policy on decommissioning, it is believed that a considerable degree of harmonisation and general optimisation of the whole process can be achieved since ENRESA now manages all decommissioning projects for the Spanish nuclear facilities.

Since 1983, Spanish legislation has provided for the creation of a national waste management fund from a fee on electricity. This fee includes the cost of decommissioning activities up to complete dismantling.

According to the Ministerial Order issued by the Ministry of Industry and Energy in July 1990, a "Dismantling and Decommissioning Plan" has to be approved by the competent Authority before a nuclear installation may be shut down. In addition, it is necessary for the fuel to have been unloaded and removed from the site and for the unloading and removal of operating wastes to have been completed, prior to the start of decommissioning.

Up to the present time, only one large nuclear power reactor, Vandellos 1, has been shutdown in Spain. This GCR operated from 1972 to 1989 and is currently undergoing Stage 2 decommissioning. ENRESA drew up the Dismantling and Decommissioning Plan which was approved by CSN and included:

- Safety Study: Description of the installation, General Project, Safety Study and Environmental Impact study;
- Technical Specifications;
- Plan organisation and schedule;
- Quality Assurance Manual;
- Dismantling Waste Management Plan;
- Radiological Protection Manual;
- Emergency Plan & Physical Safety Plan.

4.2.5 Italy

The lack of specific national regulations concerning licensing of decommissioning activities and the absence of a final repository for radioactive waste severely affects the planning of decommissioning of Italian nuclear power plants. Nonetheless, a general strategy to carry out decommissioning has been established and is based on two main points:

1 - the plants will be brought in a relatively short time to a "passive safe enclosure" state, known as CPP;

2 - the final dismantling and the subsequent possible unrestricted release of the site will be delayed for several years.

The CPP is meant to be an inherently safe state, thus ensuring personnel and general public radiological and conventional protection without the necessity of any action by operating personnel, with only periodic inspections being required. The main activities to be performed to bring the plant in line with a CPP state are:

- defuelling of the reactor and off-site shipment of irradiated and fresh fuel;
- treatment and conditioning of operational waste;
- confinement and containment of the residual radioactivity in a limited number of buildings, with partial dismantling of contaminated systems and components; the systems, components and materials containing the radioactivity have to be protected to reduce their deterioration with time.

Despite the absence of official legislation, a significant number of Italian nuclear installations have ceased operating and their owners have requested permission to commence decommissioning (specifically to place the plants in CPP). The Ministry of Industry, following consultation with the Ministries of Environment and Health and regional authorities, have granted limited authorisations to carry out phase 1 activities to bring the facilities into a CPP state. When completed, the facilities will then be at a stage somewhere between IAEA stages 1 and 2. For the Latina GCR and Gargliano BWR plants the authorisation licences state that the CPP state should be reached within 10 years of final plant shutdown.

4.2.6 Sweden

Nuclear safety and radiation protection in Sweden are governed by two laws namely (i) the Act on Nuclear Activities, (February 1984), and (ii) the Act on Radiation Protection, (July 1988).

These acts place the responsibility for safe operation and decommissioning of nuclear facilities, including management of the waste generated, on the licensee. The Act on Nuclear Activities assigns the financial responsibility for management of all wastes generated, including spent fuel and decommissioning wastes, to the licensee.

Two separate regulatory bodies have been established; the Swedish Nuclear Power Inspectorate (SKI) for nuclear safety and the Swedish Radiation Protection Institute (SSI) for radiation protection. Both bodies have mandates to inspect nuclear sites and installations and to issue and enforce regulations.

Other than placing waste management responsibility on the licensee, there is as yet no specific decommissioning policy in Sweden. The decommissioning which has been carried out so far (small research facilities) has been regulated on a case-by-case basis. Nuclear fuel cycle facilities remain under an operating licence until the competent authorities have issued decommissioning approval.

Non-nuclear fuel cycle installations are normally not subject to regulatory control during decommissioning. In some cases, however, specific installations such as laboratories, in which alpha emitting radionuclides have been used, and large particle accelerators have been subject to regulation by SSI even during decommissioning.

There is no specific licence required for decommissioning activities, but since all changes in construction and operation must be reviewed and approved, decommissioning activities are in fact reviewed by the regulatory bodies.

Nuclear reactor owners are required to pay an annual fee to the State covering future expenses for waste management and decommissioning. This fee is in proportion to the electricity produced by the reactor, and is determined annually by the Government on recommendation from SKI.

4.3 USA Developments

In the United States of America, the Nuclear Regulatory Commission (NRC) is responsible for licensing and regulating commercial nuclear facilities and commercial uses of radioactive materials. NRC also conducts research in support of the licensing and regulatory process. NRC's legal authority is provided by the Atomic Energy Act of 1954, the Energy Reorganisation Act of 1974, the Nuclear Proliferation Act of 1978, the National Environmental Policy Act of 1969, and other applicable statutes. These responsibilities include protecting public health and safety, protecting the environment, protecting and safeguarding nuclear materials and plants in the interest of national security, and assuring conformity with antitrust laws.

NRC policy on decommissioning has been codified in the NRC regulations. Decommissioning had been defined therein as safe removal of nuclear facilities from service and reduction of residual radioactivity to a level that permits release of property for unrestricted use and termination of licence. The Environmental Protection Agency (EPA) has the authority to establish generally applicable standards for residual radioactivity.

The NRC does not license Government owned nuclear installations which are operated by the Department of Energy (USDOE), except as specifically required by law. Most USDOE decommissioning is conducted according to EPA regulations. The Defense Nuclear Facility Safety Board (DNFSB) is responsible for ensuring safety during decommissioning operations at defence plants.

NRC has amended its regulations to provide specific requirements for the decommissioning of nuclear facilities and recently published them in the US Federal Register as amendments to Title 10 of the Code of Federal Regulations (CFR), Parts 30, 40, 50, 51, 70 and 72. The closure of high level waste, low level waste and mill tailings disposal sites are covered under other parts of the regulations. Under NRC regulations, removal of the last core of nuclear fuel from the reactor site is considered part of the final stage of reactor operation and is not considered to be part of decommissioning.

The US decommissioning regulations, in general, require applicants and licensees to provide a plan for completion of decommissioning. Reactor facility licensees are required to supply three plans: at time of application for licence, five years prior to projected end of operations and at termination of operations. The first plan contains information that demonstrates reasonable assurance of funds for decommissioning. The second is a preliminary decommissioning plan containing a site-specific cost estimate and an up-to-date assessment of the major technical factors that could affect planning for decommissioning. After operations cease, the licensee has to submit a Post Shutdown Decommissioning Activities Report (PSDAR) which includes:

- the identification of the chosen decommissioning option with a description of activities involved;
- a description of controls and limits on procedures and equipment to protect occupational and public health and safety;
- a description of the planned final radiation survey;
- an updated cost estimate for the chosen alternative for decommissioning, comparison of that estimate with present funds set aside for decommissioning, and plan for assuring the availability of adequate funds for completion of decommissioning; and
- a description of technical specifications, quality assurance provisions and physical security plan provisions in place during decommissioning.

Within 90 days of receipt of the PSDAR, the NRC holds a public meeting in the vicinity of the reactor. This part of the NRC policy encourages public participation in the regulatory process.

Within 30 days after the public meeting, the licensee may begin major decommissioning activities without specific NRC approval. However, these major activities must not:

1) Foreclose release of the site for unrestricted use;
2) Significantly increase decommissioning costs;
3) Cause any unreviewed environmental impact;
4) Violate the terms of the licensee's existing license.

Before completing decommissioning, and within a maximum period of 60 years, the licensee must submit a Termination Plan two years prior to termination of the licence. The Termination plan must contain:

1) Locations, types, and amounts of radioactivity;
2) Remaining activities to be performed;
3) Plans for site cleanup;
4) Detailed plans for final radiation survey;
5) Planned end use of the site;
6) Updated cost estimate for the remaining activities; and,
7) A supplement to the environmental report listing any changes.

At this point the NRC again holds a public hearing in the vicinity of the reactor, which provides further opportunity for public input to the regulatory process. Upon satisfactory accomplishment of the Termination Plan activities, the NRC may terminate the licence.

For power reactors, the US regulations provide for three decommissioning options: (1) dismantling (DECON), which is started soon after the final plant shutdown and completed without delay; (2) safe storage (SAFSTOR), which allows for a delay of up to 60 years for completion of decommissioning (i.e. licence termination); and (3) entombment (ENTOMB), which allows radioactive contaminants to be encased in a structurally long lived material, such as concrete.

The 60 year SAFSTOR period is based on technical studies that show there is no significant benefit to delaying dismantling beyond 60 years.

In the ENTOMB option, the entombed structure would be appropriately maintained and continued surveillance carried out until the radioactivity decays to a level permitting unrestricted release of the property within about a hundred year period. For most Nuclear Power Plants, the ENTOMB option would be impractical due to the presence of long lived activity. However, there may be smaller reactors, reactors which do not run to the end of their lifetime, or other situations where long lived nuclides are not present at significant levels, for which the ENTOMB option may be viable.

For non-power reactors and materials licensees, DECON is the only acceptable decommissioning option. SAFSTOR is not allowed for these licensees because technical studies show that there is no significant benefit to delaying the dismantling of these facilities.

In recent years there has been a noticeable move towards earlier decommissioning of redundant nuclear installations in the USA, with a consequent preference for DECON as compared to SAFSTOR. A good example is the 330MW Fort St Vrain HTR which operated from 1979 to 1989. In 1990 it was decided that following removal of fuel from the reactor, the DECON option should be pursued. Dismantling started in 1992 and decommissioning was completed within time and cost in 1996; the nuclear licence has now been terminated. The dose uptake to decommissioning workers was less than predicted even though radiation levels on some components were greater than originally anticipated. The reactor owners quoted two main reasons for choosing earlier decommissioning; firstly rapidly increasing waste disposal costs and secondly that they could not afford the long term insurance liabilities associated with the SAFSTOR option.

Other US utilities have also recently favoured the DECON option and have reported successful progress in decommissioning the Shoreham, Yankee Rowe and Trojan nuclear plants. In addition, the Rancho Seco plant which was shut down in 1989 was originally placed in SAFSTOR, but it has now been decided to proceed with decommissioning with a scheduled completion date of 2011. Decommissioning has already started on the Connecticut Yankee plant, shut down in December 1996, and at the Big Rock Point plant, which ceased operating in 1997.

There has also been a marked increase in earlier decommissioning of non-power reactors at universities, research facilities and isotope production plants (24).

At USDOE sites there have been significant developments in the decommissioning of fuel cycle facilities during the last few years. Demolition of redundant facilities at Hanford and Rocky Flats have been completed ahead of schedule, reflecting a greater urgency to carry out early DECON wherever feasible.

As a result of these developments, NRC and the state public utility commissions (who regulate the electricity rates charged to customers within each state) are now encouraging earlier decommissioning. The regulators have also endorsed proposals that nuclear plant owners should set aside adequate funds to pay for decommissioning in external trusts. Separately, USDOE recently asked the US Congress to advance additional money for decommissioning and environmental restoration activities.

4.4 **Japan**

The Atomic Energy Basic Law (1955) established the Atomic Energy Commission (AEC) and the Nuclear Safety Commission (NSC) to implement national policy and to administer the development and utilisation of atomic energy. The AEA is responsible for promotion, development and utilisation of atomic energy. The NSC covers safety.

Atomic Energy Safety Regulations are governed by the Nuclear Reactor Regulations Law (1957). The actual regulations for construction, operation and decommissioning are made by the relevant Competent Ministries, which for commercial nuclear power plants is the Ministry of International Trade and Industry (MITI) and for research reactors, reprocessing plants and waste management facilities is the Science and Technology Agency (STA).

The basic philosophy on decommissioning of power reactors was established by the AEC in 1982. This stated that dismantling of reactors should be performed as soon as possible after shutdown taking into account safety, societal issues and reutilization of the site. It was also considered that existing technology was sufficiently developed to allow reactors to be dismantled, but that development of new technologies would be desirable to reduce costs and radiation exposure to workers.

The Nuclear Reactor Regulations Law requires that prior to starting decommissioning a nuclear reactor licensee should submit a decommissioning plan. This document must address the decommissioning methods and schedule and also the means of disposal of nuclear fuel and radioactive waste. When a reactor ceases operation the licensee must

within 30 days initiate removal of nuclear fuel materials, and submit a report to MITI after completion of defuelling. This defuelling stage is normally followed immediately by decommissioning which consists of system decontamination and a safe storage period prior to dismantling.

In 1985 MITI proposed a standard process by which nuclear power plants would be dismantled after a safe storage period of five to ten years. A supporting MITI study compared occupational radiation exposure per year during the dismantling period (estimated at about four years) with that incurred during the operation and maintenance of the plant concerned. In the case of five to ten years safe storage, occupational radiation exposure per year during the dismantling period was found to be almost the same as, or lower than, that of operation and maintenance. In addition, the quantities of radioactive waste generated did not decrease significantly even for safe storage periods of 20 to 30 years. This strategy has since become the accepted policy for decommissioning Japanese reactors, i.e. defuelling immediately following termination of reactor operation, system decontamination followed by 5-10 years safe storage and then dismantling and demolition.

In Japan the reactor licensee is wholly responsible for decommissioning, and is also responsible for managing the radioactive wastes generated at the reactor site. Prior to completion of dismantling, the licensee must make arrangements to manage all radioactive waste arising from dismantling by transferring it to interim storage or a final disposal site.

Nuclear power reactor decommissioning experience in Japan is fairly limited, but Japan Atomic Energy Research Institute (JAERI) has successfully completed the first demonstration programme by decommissioning the Japan Power Demonstration Reactor (JPDR). This 12.5 MW power reactor (BWR type) operated from 1963 to 1976. Decommissioning started in 1981 and was completed in 1996 when total site clearance to a green field site was achieved.

The Tokai 1 gas cooled reactor operated from 1966 to 1998. The spent fuel is now being removed (scheduled to be completed by 2002), and will be immediately followed by the standard decommissioning process, as described above.

Since 1985, the operators of commercial nuclear power plants in Japan have had to set up reserved funds to cover decommissioning costs which are estimated on the basis of reactor type and power output.

5. COMPARISON OF UK AND INTERNATIONAL APPROACHES

Sections 3 and 4 have shown that there are noticeable differences in the approaches that have been adopted to decommissioning of nuclear installations in the UK and overseas. Furthermore, the recent and increasing tendency world-wide to carry out decommissioning of redundant facilities as soon as possible is in marked contrast to the British philosophy of delaying complete decommissioning for many decades (up to 150 years after shut down of nuclear reactors). This Section provides a comparison of these approaches both generally (policy, regulatory, funding and public issues) and technically.

5.1 General Aspects

The differences in decommissioning approaches do not appear to be a function of national policy, regulations or guidance. While there are no specific decommissioning laws or regulations issued in the UK, this is not a unique situation. However, the acceptance by the UK Government of the Safestore option for decommissioning nuclear power reactors (albeit with the proviso that steps to foreclose earlier completion of Stages II and III should not be undertaken) is undoubtedly the clearest endorsement of long term deferred decommissioning of any country with a significant nuclear power programme.

The 1995 UK White Paper (5) stated that segregated funds for decommissioning should be established for those parts of the nuclear industry which are privatised. Accordingly HSE/NII now require licensees to provide cost and funding estimates for their decommissioning programmes as part of the quinquennial reviews of decommissioning strategy. This approach has brought the UK into line with other developed nuclear countries.

Finally, issues concerned with public perception and involvement may be considered. In the UK there has been very little public involvement specifically with respect to decommissioning activities, either planned or operational, apart from Trawsfynydd (see Section 6 below). From a regulatory viewpoint, the site licence applies to decommissioning as it does for any other phase of the lifetime of a nuclear power plant. Therefore, there is no requirement for a public enquiry, and public interest in the licensee's long term plans for a particular site and the facilities contained thereon appear to be minimal. In contrast, most foreign countries encourage public involvement, as a result of the laws, decrees or regulations specifically dealing with decommissioning which require public consultation at various stages (particularly when the decommissioning plan is submitted and before a dismantling licence is issued).

However, it is important to note that in the UK the Environmental Impact Statement Directive has now come into force (25) (see Section 6). In addition, any future requirements for revised waste disposal authorisations will entail public consultation. These factors are therefore likely to increase public awareness in the UK.

5.2 **Technical Issues**

Considering that the UK has been at the forefront of the development of nuclear power during the past 40 years, it is noticeable that only a small number of nuclear installations have been fully decommissioned. No power reactors or small reactor plants have yet been completely decommissioned, apart from the Manchester and Liverpool Universities research reactor, and the majority of redundant facilities have only reached IAEA stage 1 (i.e. they have been defuelled and then placed in a care and maintenance state). This is in marked contrast to the situation in France, Germany and the USA where many nuclear plants (including reactors) have already been decommissioned to IAEA Stage 3.

5.2.1 Nuclear Reactors

For nuclear power plants, UK waste producers have put forward the Safestore concept, under which complete decommissioning will be deferred until 100-150 years after shutdown. The advantages that have been expressed for Safestore are:

1. it will allow more time for decay of radioactivity,
2. it will allow further advances in technology, and
3. the strategy is more cost effective.

The reduction of dose rate with time after reactor shutdown, and the consequent increase in allowable working time inside a Magnox reactor has been quantified in Reference 10. Mainly as a result of decay in cobalt 60, the dose rates are estimated to reduce by a factor of 10^5 after 100 years and by 10^6 after 135 years. However, technical studies in the USA in support of the SAFSTOR options (see Section 4.3) indicate that after 60 years delay there is no significant reduction in dose uptake to operators. In addition a comparative analysis of decommissioning options for the Fort St Vrain HTR (26) showed that while the total radioactivity in the reactor vessel would decrease by a factor of about 10^3 after 60 years, this decreased radioactivity would not contribute significantly to a reduction in disposal costs since total waste volumes were not greatly affected. Spanish regulators have calculated that 30 years is the optimum delay, taking account of radioactive decay, whilst France has opted for a 40 year delay. 30 years is also the maximum delay authorised by the German authorities.

It is almost certain that there will be technological advances over the next century, which could significantly benefit decommissioning activities. The nature and extent of these advances and consequent cost savings are, however, almost impossible to quantify. The alternative view of European and USA analysts (e.g. (24)) is that present technology is perfectly adequate to decommission even the most complex nuclear installations, while maintaining high safety standards.

A definite advantage of deferred decommissioning is that costs, particularly on a discounted basis, will be reduced. In other words, given adequate financial provision, the earnings on invested funds will exceed the costs of delayed decommissioning. Discounting over periods in excess of 100 years allows relatively low provisions for decommissioning to be made in

the present. Earlier decommissioning would result in increased cash having to be raised to set aside now.

However, the NRC in the USA carried out a detailed cost analysis for decommissioning of the Trojan plant (27). This analysis discovered that early decommissioning soon after reactor shutdown was cheaper than waiting decades for radiation to decay, when all costs were taken into account. A more recent review of USA decommissioning experience (28) also concluded that DECON was less expensive than SAFSTOR, mainly because of the annual commitment of resources needed during SAFSTOR to maintain the nuclear facility in regulatory compliance.

The perceived disadvantages of deferred decommissioning as expressed by overseas countries are as follows:

- increased waste disposal costs
- increased burdens on future generations
- loss of technical know how and expertise
- more restrictive legislative and radiological standards
- long term care and maintenance costs

Long term deferral of decommissioning would undoubtedly result in higher waste disposal costs. In the USA disposal costs have increased by 12% per annum over the past 10 years (26), and similar increases have been observed or are being predicted in Europe. Perhaps of even more concern is the current uncertainty regarding future waste disposal facilities. Many existing facilities are likely to reach their full capacity within the next 20-50 years. In addition significant delays in obtaining approval for new waste disposal sites are leading to growing uncertainty as to future availability of such disposal facilities. If disposal facilities are unavailable then wastes necessarily generated during decontamination and dismantling operations will have to be stored at the sites of the nuclear installations being decommissioned, and this will further increase costs.

Adoption of the Safestore strategy would also result in the imposition of burdens on future generations, who unlike the present generation had not benefited from the use of nuclear

power from installations to be decommissioned. One of the RADWAS Safety Fundamentals principles (6) states that radioactive waste shall be managed in such a way that will not impose undue burdens on future generations. The principle is based on the ethical consideration that the generations that receive the benefits of a practice should bear the responsibility to manage the resulting waste. The responsibility of the present generation includes developing the technology, constructing and operating facilities, and providing a funding system, sufficient controls and plans for the management of radioactive waste. Deferred decommissioning may therefore not be compatible with this principle, which has been endorsed by the UK Government (5) and has recently been reiterated in the legally binding waste management safety convention (see Section 2.7).

It may also be argued that delaying decommissioning contradicts the concept of sustainable development. Reference 29 states that UK Government policy is to ensure that radioactive waste is managed safely and that the present generation, which receives the benefit of nuclear power, meets its responsibilities to future generations. In addition, Safestore implies making financial provision over periods of 100-150 years and this could prevent future generations from taking earlier action to decommission a particular installation unless they were prepared to bear additional costs.

Loss of technical know-how and expertise following deferred decommissioning is difficult to quantify. While there are obvious advantages in utilising the specific knowledge and experience of staff who have previously worked on a particular nuclear plant when it is being decommissioned, it may be sufficient to ensure that this expertise is retained in the 'corporate memory' and can be readily accessed in the future. For plants that commenced operation during the past 20 years such an approach should be feasible, but the 'corporate memory' may not be adequate for older plants. It is also important to note that regulatory controls will continue in force throughout the Safestore period, and therefore the licensee must ensure that licence documents are maintained and where appropriate updated.

Regulators must ensure that a licensee maintains day-to-day control of the facility being decommissioned and that its staff manage all operations and processes even if experienced consultants/contractors are employed. The licensee must demonstrate that an adequate organization will be in place to discharge its responsibilities until the facility is finally

removed from regulatory control. Thus there has to be a sufficient number of suitably qualified and experienced personnel (SQEP) throughout the duration of decommissioning. An important aspect will be the need for continuing staff training. Concern has been expressed that with deferred decommissioning, 22nd century trainers will have no practical experience to pass on to those who will have to finally undertake the facility decommissioning.

There is almost unanimous agreement internationally that radiological standards for protection against ionising radiation will be tightened in the future. Based on experience over the past 30-40 years, it is very unlikely that dose rate limits for radiation workers will remain unchanged during the next century. Stricter annual dose limits will result in reduced allowable exposure times for staff carrying out decommissioning activities, and this is seen as a disincentive to delayed decommissioning. It is also believed that legislative and regulatory pressures will increase the necessity for more and improved safety documentation with time. Environmental agencies are also likely to impose stricter discharge authorisations, particularly into groundwater, as a result of international agreements such as the OSPAR Convention (30).

Another consequence of deferred decommissioning is perceived as long term care and maintenance requirements that may prove to be a significant cost. Any delays in decommissioning run the risk that plant will deteriorate, and it is essential to prevent leakage with subsequent spread of radioactivity. Care and maintenance has to be carried out on installations which are in a quiescent state between decommissioning stages to ensure that health and safety of operating staff and general public, as well as the environment, are protected. Routine and regular surveillance of building structures and ventilation and sampling of their contents could prove costly. As an example, UKAEA have estimated that the annual costs for care and maintenance of their facilities undergoing decommissioning will be £14M, and a Care and Maintenance Strategy Project (CMSP) has recently been set up by DRAWMOPS to reduce these costs. In the USA, NRC require that licensees have adequate property and liability insurance which would have to be maintained for the entire decommissioning period. This is estimated to cost nuclear reactor owners an average $1M per year for each plant. In addition, the Price-Anderson Act requires US nuclear licensees to pay an insurance surcharge in the event of a major accident at any nuclear station in the

USA. The US utilities/plant owners consider that this is another disadvantage with deferred decommissioning.

Although less than 10% of nuclear reactors in the USA have been decommissioned to date, attempts are already being made to record the lessons learned (24, 28). The main points that have emerged are:

- decommissioning is simplified by using off-the-shelf tools, and that the technologies presently exist to decommission even complex facilities;
- utilisation of experienced staff with knowledge of the plant when it operated can result in significant cost savings;
- the need to archive operating records and ensure that they are easily retrievable is fundamental;
- early decommissioning has resulted in positive public reaction.

5.2.2 Fuel Cycle Facilities

For non-reactor fuel cycle facilities, the Safestore concept is not considered to be feasible, and as a result there is less incentive world-wide to delay decommissioning. In particular early dismantling (approximating to IAEA stage 2) is encouraged to ensure that safety of the redundant chemical plants may be assured. In the case of redundant plutonium plants early decommissioning is necessary to minimise americium ingrowth with subsequent higher dose rates.

A significant number of chemical plants have been completely decommissioned in the UK such as BNFL's diffusion plant at Capenhurst, various plutonium plants at Sellafield, R&D facilities at Aldermaston, and UKAEA plants/laboratories at Harwell and Dounreay. However, despite the valuable experience that has been gained, there is no UK policy for early decommissioning. In fact both BNFL and UKAEA future decommissioning programmes favour deferred dismantling and demolition with extended periods of care and maintenance between decommissioning stages. Put simply, both BNFL and UKAEA's decommissioning strategy for non-reactor fuel cycle facilities aims to achieve the lowest overall discounted cost consistent with achieving the necessary level of safety (31). As a

result, dismantling will only be carried out when effluent/waste treatment facilities, equipment and manpower resources are available, and demolition (stage 3) will not commence until the latter half of the next century with the overall decommissioning programmes planned to extend into the 22nd century.

In continental Europe there is a greater emphasis on early decommissioning. Redundant chemical plants at the German Karlsruhe and Hanau sites are being decommissioned, and in France both CEA and COGEMA aim to carry out prompt decommissioning. In Belgium, a detailed assessment concluded that the Eurochemic reprocessing plant should be dismantled immediately following equipment decontamination. A similar approach is being adopted in the USA where DECON is the only acceptable decommissioning option. This entails immediate dismantling of contaminated and activated structures and components to a level allowing the plant to be released for unrestricted use.

In summary, for nuclear reactors most developed countries originally favoured deferred decommissioning to allow for decay of radioactivity and because this option was more cost effective. The Safestore strategy adopted in the UK results in the longest time delay (up to 150 years to complete decommissioning), whereas in other countries the safe storage periods are significantly less. For example, in Germany safe enclosure licences have a time limit of 20-30 years and the US SAFSTOR strategy allows for a maximum delay of 60 years. In addition over the past few years, there has been an increasing concern that deferred decommissioning runs the risks of higher waste disposal costs, imposition of burdens on future generations, care and maintenance expenditure and insurance liabilities.

For chemical plants, the advantages of deferred decommissioning lies mainly with lower discounted costs. The extent of the advantage is dependent on the chosen discount rate. The UKAEA use a 6% discounted rate and this high figure outweighs concerns over long term care and maintenance and waste disposal uncertainties/costs. Overseas countries generally favour early dismantling of non reactor installations.

6. POSSIBLE FUTURE DEVELOPMENTS

It is obviously difficult to predict what changes are likely to occur in the future with respect to international approaches to decommissioning nuclear installations. However during the past few years there has been a definite trend in overseas countries away from deferred decommissioning, and it appears probable that this trend will intensify. Another imponderable is what effect, if any, these international developments will have on UK decommissioning policies and strategies.

As described earlier in this report there are various advantages and disadvantages to deferred decommissioning, and the balance between these conflicting pressures is in many cases influenced by country specific factors such as legal/regulatory requirements and financial constraints. Nevertheless there appear to be two main generic factors supporting earlier dismantling and demolition of nuclear installations, (i) concerns about the management of waste streams arising from decommissioning activities, particularly the rising costs and uncertainties regarding waste disposal, and (ii) a growing awareness of the long term costs associated with surveillance, care and maintenance.

Waste management/disposal concerns have resulted in a significant change in the perception of decommissioning by USA utilities. In previous years the economic argument that delaying decommissioning so that it could be paid for with cheaper inflated dollars held sway. Recently these economic arguments have been outweighed by the growing awareness that in future waste disposal site availability is going to become increasingly limited and expensive. US nuclear plant owners are now accelerating their decommissioning schedules to take advantage of existing disposal site availability.

The growing cost of insurance liabilities and concerns regarding future litigation have also affected sentiment in the USA. As a result decommissioning activity has increased significantly over the past 3-4 years, and it is predicted to rise even more rapidly in future. US nuclear licensees are increasingly adopting a philosophy that when a facility ceases operating, decommissioning money should be spent immediately in order to ‘cut losses’.

Decreasing interest rates in developed countries may also have an effect on the timing of decommissioning activities. Japanese interest rates are now effectively zero, and as a result early decommissioning is favoured since the work involved is seen as stimulating the local

economy, while there are no cost advantages for deferred decommissioning from using zero discount rates.

There is a growing awareness that long-term care and maintenance, necessary during deferred decommissioning, does not just consist of checking building structures and ventilation and carrying out radiation monitoring at routine intervals. Even when all operational facilities at a site have ceased, the licensee must ensure that an adequate organisation exists to oversee facilities at various stages of decommissioning. This means that security, access control, fire protection and emergency response planning must be maintained. In addition, record keeping and the retention of local plant knowledge has to be ensured, and be readily accessible. International regulators are increasingly insisting that any nuclear installation which is undergoing deferred decommissioning (particularly if it is in a care and maintenance state between decommissioning stages) will have to meet modern standards for a nuclear storage facility. The rationale for this approach is that any facility containing contamination or radioactive components has to be considered as a store, even though in many cases the buildings were not designed or constructed to such standards. Therefore there is a strong likelihood that in future improvements/modifications to any facility in a care and maintenance state will be demanded of the licensee.

In addition, the issue of public awareness, which to date has not been a major factor, is in the near future likely to increase pressure for earlier decommissioning.

There is an increasing public awareness internationally of the back end of the nuclear fuel cycle, and in particular of decommissioning programmes. Laws and regulations specifically relating to decommissioning in countries such as Germany and USA require public hearings, and these are being increasingly used by intervenors to support earlier decommissioning rather than as in previous years to object to any decommissioning per se. Ethical objections to deferred decommissioning have been increasingly expressed, but to date the general public do not appear to have realised the implications of the RADWASS fundamentals principle relating to burdens on future generations. However, during this year international bodies such as the IAEA have become aware that non-governmental organisations such as Greenpeace and Friends of the Earth have begun to use public concerns about decommissioning as part of their anti-nuclear strategy. Specifically these NGOs have raised

objections to the construction of new nuclear power plants and expansion of the industry on the grounds that the back end of the nuclear fuel cycle consists of expensive and unresolved liabilities with serious safety implications. Greenpeace, both in USA and Europe, have stated that delays in decommissioning, particularly of non-reactor chemical plant and research reactors, indicates that the nuclear industry lacks confidence in dealing with the wastes produced and do not have safe/viable options for its disposal.

While it is true, as stated in Section 5, that public awareness of decommissioning issues is fairly limited in the UK, there are indications that awareness and possible opposition to current policies may increase in future. Prior to publication of the waste management policy review (5) the Department of the Environment issued a consultation document. In response, some individuals and anti-nuclear groups argued against Safestore quoting concerns about plant deterioration, loss of expertise and that the strategy conflicted with sustainable development. Although these arguments were not accepted by the UK Government, such reservations will undoubtedly be repeated in future particularly as and when objectors become aware of international developments. It should also be noted that on the one occasion when the UK public were consulted on decommissioning of a nuclear power reactor, namely the Trawsfynydd Magnox reactor, a change in policy resulted. At the time of shutdown announced in July 1993, the preferred decommissioning strategy was declared to be deferred Safestore. In recognition of the particular location of Trawsfynydd in Snowdonia National Park, however, a public consultation exercise was carried out in 1994 prior to confirming the strategy. As a result of that exercise, it was agreed that the strategy would be amended to prompt Safestore requiring the reactor buildings to be reduced substantially in height thereby reducing the long-term environmental impact of the station.

The European Union Directive 97/11/EC requires assessments to be carried out of the potential effects on the environment before nuclear reactors can be decommissioned. The UK has implemented the provisions of this Directive by means of the Nuclear Reactors (Environmental Assessment for Decommissioning) Regulations, 1999 (25). The HSE has been identified as the Competent Authority for enforcing these regulations, and have delegated their duties in this respect to the NII.

Environmental Impact Assessment (EIA) is the process by which the licensee produces an Environmental Statement (ES) in support of its application for consent and a Competent Authority comes to a conclusion on whether to grant consent. The ES describes the potential environmental impact of the decommissioning.

The regulations will require licensees at reactor sites to seek consent from HSE before they start decommissioning or dismantling work on reactors or nuclear power stations. Even non-nuclear work, on turbine halls for example, will require prior consent from HSE. Licensees will be required to submit an ES to HSE before the start of decommissioning and to make this available to the public. NII will consult with statutory consultees, including the environment agencies, and others as appropriate and consider the comments received in coming to a decision on granting consent for decommissioning. NII may only grant consent, on behalf of HSE, after it is satisfied that an adequate EIA has been performed. The results of the EIA may require that conditions are attached to the consent. It is important to note that as a result of these new regulations, public consultation will be required as a precursor to the decommissioning of nuclear power reactors.

In addition, the present UK Government is committed to providing opportunities for public participation in decisions relating to waste management and decommissioning. It has signed the Aarhus Convention (32), an international convention on environmental information and public participation, under which it is obliged to involve the public in decisions concerning radioactive wastes.

The impact on UK decommissioning strategies of moves towards earlier decommissioning overseas is difficult to predict. Waste management and disposal issues have, to date, not been considered to be of great significance. However the rejection of Nirex's proposal for a rock characterisation facility at Sellafield have raised uncertainties about the availability of an underground repository, and this will result in increased costs for storage of wastes arising from decommissioning. The importance of care and maintenance costs has been recognised, particularly by UKAEA. It is probable that in future regulators will make licensees more aware of the consequences of considering facilities undergoing care and maintenance as de facto stores. The imposition of burdens on future generations, retention of records and knowledge specific to plants being decommissioned, and the possibility of

more restrictive legislative and radiological standards will also have to be considered by licensees, in addition to public acceptance issues discussed above. Whether these factors will be considered sufficient to overcome the advantages of deferred decommissioning, particularly the discounted cost benefits, remains to be seen.

7. CONCLUSIONS

This report has discussed the IAEA safety series documentation on decommissioning relating to both nuclear power reactors and chemical plants. The RADWASS Safety Fundamentals principles of radioactive waste management, and the recently concluded legally binding convention on the safety of spent fuel and radioactive waste management, with specific references to decommissioning have been described. The report has also reviewed UK and international approaches to decommissioning redundant nuclear facilities.

Originally most developed countries favoured deferred decommissioning, particularly for nuclear reactors, to allow for decay of radioactivity and because this option was perceived to be less costly. However during the past few years various factors have contributed to the growing trend in overseas countries towards earlier decommissioning and a shortening of the total time from facility shutdown to termination of the licence. The main contributory factors have been concerns that deferred decommissioning runs the risks of higher waste disposal costs, imposition of burdens on future generations, care and maintenance expenditure and insurance liabilities. These overseas approaches have been compared and contrasted to the delayed decommissioning/Safestore options which have been adopted in the UK.

Finally, possible future developments, including growing public awareness of decommissioning activities, have been discussed and their potential impact on UK decommissioning policy and strategy assessed.

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