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Applying Decommissioning Experience to the Design and Operation of New Nuclear Power Plants

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NUCLEAR ENERGY AGENCY
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FOREWORD

This report provides an overview of the current approaches and views in applying experience from decommissioning to the design and licensing of third generation reactor systems. The study on which it is based was undertaken due to the increased level of interest in several OECD countries in launching new nuclear construction programmes incorporating such reactor systems.

The report is intended primarily for decision makers in this field who wish to be informed about enhancements made in relation to requirements and design features, and about areas where further work may be desirable. It was developed based on information received from regulatory authorities, electricity producers and reactor design organisations concerned with the development and implementation of new reactor systems, either as responses to a questionnaire on the above topic or during a topical session held at the annual meeting of the NEA Working Party on Decommissioning and Dismantling (WPDD) on 12-13 November 2008 at Senec in the Slovak Republic. The topical session was structured such that the presentations and discussions covered issues of common interest to designers, utilities and regulators.

The International Atomic Energy Agency (IAEA) Waste Technology Section has participated in this work from the outset and contributed to the above topical session.

Acknowledgement

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TABLE OF CONTENTS

KEY FINDINGS

1. **Decommissioning is being recognised increasingly by those involved in the development of new nuclear power plants as an important aspect of plant management, playing a role during the whole life cycle of the plant and deserving consideration from the outset of design and planning activities. This represents a marked change of approach from earlier generations of nuclear power plants.**

The information collected during this study suggests that third generation nuclear plants will incorporate many improvements that will be beneficial to plant dismantling. Several design improvements that are driven by objectives other than decommissioning, e.g. facilities for promoting ease of maintenance and to enable replacement of large components during plant operation are nevertheless helpful to decommissioning. Some design features meant to reduce dose to the workforce during operation and maintenance – such as avoidance of traps for radioactive contamination in pipework and improved primary coolant filtration – will also reduce doses during decommissioning. By the same token, many design features that will be helpful during decommissioning, especially relating to radiation protection and waste management, will also be useful during normal plant operation.

2. **It is now a universal requirement that a preliminary decommissioning plan be developed early in the licensing process, which is helpful in focusing attention on decommissioning and dismantling aspects at the design stage.**

Decommissioning plans need to be sufficiently detailed so as to facilitate the development of reliable and credible estimates of decommissioning costs, e.g. as, typically, the funds for decommissioning have to be collected from early in plant operation. Elaborating the dismantling sequence at the design stage may be very beneficial in identifying design improvements beneficial to decommissioning and then in reducing uncertainties on dismantling costs.

In addition, the requirement to update decommissioning plans periodically and to introduce requirements for archiving the associated records should ensure that better documentation is available for future decommissioning efforts. Putting such requirements into effect requires diligence on the part of the operators of the plant and, in particular, a rigorous application of configuration management systems in recording design changes made during construction and operation.

3. **An important priority for utility organisations is that the design provides for optimal operation and maintenance (O&M) of the facility. Design features to support O&M work will invariably also be beneficial for later decommissioning tasks**.

Good design practices for both O&M and decommissioning include: providing ample space for the activities being undertaken, minimisation of the doses during these activities, minimisation of waste quantities, and making provision for replacement of components. A related issue concerns the minimisation of waste arisings, e.g. through careful selection of materials and by incorporating features to limit the spread of potential contamination. Careful optimisation of design provisions for decommissioning with those of "downstream" waste management may be expected to yield benefits in terms of reducing radiation exposure of the workforce and decommissioning costs.

In addition to consideration being given to the nuclear island plant, it is recommended that attention is also given to the balance of the reactor plant, on the basis that areas which are difficult to access could give rise to later problems during decommissioning. In general, it is good practice to submit the entire plant to a structured review from the perspective of decommissioning.

4. **Although many design requirements aimed at improved O&M will also be beneficial for decommissioning there are nonetheless design considerations that need to focus directly on plant decommissioning and dismantling.**

Design provisions specific to decommissioning include designing structures for long-term stability minimising infiltration, containing spills and releases, and retarding contaminant transport. Decommissioning experience to date suggests that greater consideration should be given to identifying the key components of particular reactor systems that are directly related to decommissioning and to delineating the boundaries of these systems.

Current good practice is to implement technical provisions that circumvent the use of embedded piping. This is to be commended and should be implemented as widely as possible. Leaks in embedded piping are difficult to locate and may lead to larger amounts of waste and longer outages during plant operation. At the same time, potential radiation doses from unshielded piping need to be addressed in designing the provisions for radiation protection.

5. **Early consideration should be given to the needs of plant configuration management, including developing systems for maintaining records of the physical configuration of the plant on an ongoing basis, as well as maintaining records of leaks and other contamination incidents.**

It is essential that plant management systems incorporate requirements for records management, including material specifications and records from the siting, design, construction, operation, and shut down. Experience from recent decommissioning projects suggests that plant records may sometimes be incomplete or inaccurate, e.g. they may not reflect the final plant configuration. It is important that such systems include, in addition to those records that are directly relevant to operation, other records that might be important for decommissioning, e.g. information on temporary openings made during construction may facilitate the reuse of these accesses during decommissioning.

The development of 3-D models as part of the design process provide a useful management tool throughout plant operation, including for showing how configuration control can be maintained during sequential dismantlement and for visualising the locations of sources of activity to help assess where samples should be taken for radiation monitoring.

6. **Monitoring systems for the early detection of leaks and contamination, including leaks from underground piping (environmental monitoring), should be provided and maintained. It is also good practice to provide means for monitoring of plant chemistry parameters, against an objective of minimising corrosion of metallic components.**

Plant management systems should ensure that updates of decommissioning plans should be based on records of environmental monitoring, and site history records of incidents, spills or releases. Past experience suggests that plant operators need to give special attention to the collection and preservation of information on contamination events, as such contamination may otherwise only be identified during demolition of the concrete structure.

7. **Guidance on ensuring that dismantling and decommissioning considerations are reflected in the design requirements for new generation plant is increasingly being addressed at multinational level by electricity producers and by regulators, albeit with different end-goals.**

The requirements of utility organisations on the decommissioning aspects of new designs tend to have greater coherence as a result of the work of groups such the EUR group in Europe, and EPRI in the United States. The approach taken by EUR of categorising requirements according to: feasibility using current technologies; nuclear and conventional safety; waste minimisation and dose minimisation, is to be commended. It may be helpful if there were a more quantitative approach – perhaps a target-driven approach – to issues such as waste reduction, worker doses and provision of space during decommissioning for lay-down, decontamination and waste storage. The EUR document specifies requirements on aspects such as material selection for reduced dose rates, good surface finishing to facilitate decontamination of materials and providing easy accessibility for removal of plant components.

Regulatory guidance on design requirements for decommissioning new generation plant is primarily directed towards funding provisions, waste minimisation and the protection of workers and the environment during dismantling operations. Relatively little guidance is provided concerning "designing for decommissioning" i.e. the provision of facilities and equipment that will be needed for dismantling or for the management of the waste arisings. Regulatory authorities tend to refer to more general guidance such as the IAEA safety guides, and the applicant has wide discretion about how these requirements are met. This may lead to different approaches being taken in different countries to issues such as plant configuration management, record keeping and the provision of facilities and equipment.

8. **The need to incorporate dismantling lessons both at the design stage and during the whole life cycle of a facility could be better fulfilled if dismantling experience were systematically collected, analysed and recorded.**

It is clear that design organisations are making positive efforts to take greater account of decommissioning needs in the design of new plant. At the same time, with some important exceptions such as the USNRC, it seems that there have been few systematic attempts to capture the lessons from dismantling experience and it is not clear that there is a systematic process to feed these lessons in the design of new plant. The study indicates that a more comprehensive and systematic approach to collecting and promulgating lessons learned from decommissioning would be generally welcomed, perhaps facilitated by the international organisations such the NEA and the IAEA.

An important consideration here is that, within utility and regulator organisations, the areas of design, operation and dismantling and decommissioning are often handled by different departments. Indeed, sometimes, the responsibility is assigned to completely different organisations, requiring special attention to be given to co-ordination of information transfer between the different groups. The present study has provided an opportunity for regulators, utilities and design organisations to share and discuss their differing perspectives on how requirements for decommissioning should be reflected in new plant designs.

1. INTRODUCTION

In recent years, the nuclear industry has being developing a third generation of reactors, whose design provides improved levels of safety and better cost effectiveness, including shorter construction times and increased lifetimes (typically 60 years, currently). Several countries are giving consideration to building reactors of this type and a number of plants are currently under construction, reflecting satisfactory preliminary reviews by the relevant regulatory authorities.

It has been evident for some years that the decommissioning of earlier generations of nuclear plants could have been made easier if greater consideration had been given to this plant management aspect at the design stage and during operation of these plants. Better forward planning for decommissioning could have resulted in lower worker doses and reduced costs. This has led electricity producers and national authorities to demand that decommissioning needs be addressed from the design stage and that preliminary decommissioning plans be provided as an input to the licensing process. These plans, as well as providing a basis for preliminary estimates of the cost of decommissioning and of waste management, are expected to address, at an appropriate level, the necessary design provisions to:

- Minimise the creation of radioactive waste by:
  - Limiting and controlling activation and contamination.
  - Facilitating decontamination.
- Simplify dismantling and equipment handling.
- Enable onsite management of materials and waste.
- Facilitate site release.

When appropriate design measures are not taken at an early stage, their introduction later in the project becomes increasingly difficult, and therefore their early consideration may be expected to lead eventually to smoother and more effective decommissioning.

The information presented in this report was obtained from a study on the same topic conducted by the NEA Working Party on Decommissioning and

Dismantling during 2008. The study began with a survey of reactor design organisations, electricity producers and regulatory authorities concerned with the development and implementation of new reactor systems. The preliminary findings were discussed at a special meeting of the survey respondents, together with policy makers, decommissioning organisations and waste management organisations, in November 2008. This report takes account of the discussions at that meeting and on subsequent comments provided by the interested parties.

This report begins by describing the perspectives and requirements of regulators (Chapter 2) and utilities (Chapter 3) on these issues. Chapter 4 discusses what is currently being done in terms of incorporating design and/or operational features into new plant designs that would be beneficial to decommissioning or that take benefit from experience gained from decommissioning work undertaken in recent years. Chapter 5 provides recommendations on further advances might be envisaged. Appendix 1 provides a summary compilation of responses received to the survey undertaken at the outset of the WPDD study.

2. REQUIREMENTS OF THE REGULATORY BODIES FOR DECOMMISSIONING

The idea of looking ahead to the decommissioning aspects of existing and new plant is not new. Various national laws, decrees and regulations have required consideration of this since at least 1963 (e.g. in France). In Finland, the requirement that decommissioning plans must be in place and be updated periodically dates back to 1982. But in general, it is only relatively recently that the requirements of decommissioning plans have made specific reference to the management of waste arising from decommissioning operations, about site end-states and environmental issues, and about proof of financial provision for decommissioning. This is leading to a greater focus on associated issues such as the materials for construction, provisions for ease of maintenance and dismantling, provisions for limitation of contamination and the definition of national clearance levels.

The requirements of the Finnish regulator, STUK, and of the French regulator, *Autorité de Sureté Nucléaire* (ASN), are typical of those safety bodies that are facing construction licence applications for third generation reactors.

In accordance with the Finnish Nuclear Energy Decree:

1. The application for a construction licence must describe the applicant's plans and available methods for arranging nuclear waste management and decommissioning, including providing information on:
   i) How decommissioning is taken into account in the plant design.
   ii) Radiation protection optimisation during decommissioning.
   iii) Minimisation of the decommissioning waste.
2. The subsequent application for an operating licence must include a decommissioning plan that is detailed enough to serve as a basis for assessing the financial liability and should include the preliminary radiation protection plan for decommissioning.

Detailed guidance for designers is provided by STUK in Safety Guide YVL 7.18, *Radiation Safety Aspects in the Design of a Nuclear Power Plant* (2003). This emphasises that many design provisions that are useful for decommissioning are equally important for the purposes of radiation protection and waste management during plant operation. The guide requires that construction materials be selected in such a way that:

- The activation is low.
- The spreading of activated corrosion products is limited.
- The surfaces can be decontaminated easily.

In addition, from the point of view of major repairs and decommissioning, designers are required to consider specific plant layout aspects:

- Facilitating the removal of large components.
- Facilitating the handling of activated components.
- Enabling the decontamination of systems.

Finnish Regulations also address the collection of data, required for decommissioning, during the operating phase. Safety Guide YVL 5.4 *Management of Low and Intermediate Level Nuclear Waste and Decommissioning of Nuclear Facilities* requires, *inter alia*, that:

- During facility design, construction, operation and final shutdown facility specific information useful for decommissioning must be gathered and saved.
- During construction stage, properties of the construction materials likely to be activated must be collected.

Similar requirements are applied by the French regulator, ASN, reflecting changes to French regulations introduced in 2007. Decree 2007-1557 concerning *Nuclear Facilities and Control of the Transport of Radioactive Materials* outlines provisions that have to be taken into account for dismantling operations at the various stages of the lifetime of a nuclear facility. ASN decommissioning guides are subject to regular updates which take account of inputs from implementers and other stakeholders.

An example of how the French utility *Électricité de France* (EdF) has responded to the new requirements is shown in the box below. In certain respects the Flamanville-3 design goes beyond the recommendations of the European Utility Requirements group (EUR), e.g. the use of double walls for all pipes enclosed in concrete walls or in floors – see Chapter 3.

Responding to the new French regulations (2007), the Preliminary Safety Analysis Report (PSAR) presented by EdF for the EPR reactor being constructed at Flamanville (France) outlines two main objectives for dismantling operations:

- The reduction of the radiation doses of the workers.
- The reduction of the quantity of radioactive waste and dangerous materials.

Design rules established for those objectives include:

- Selection of materials (alloys with low levels of cobalt) to limit the activation and contamination process during operations.
- Use of barriers and radiological protection to reduce the activation of materials and equipment.
- Design of the access areas and handling devices to minimise exposure.
- Use of equipment that is easy to change and to maintain.

Additional main provisions proposed in the PSAR include:

- Dismantling of the main equipment of the reactor coolant system is taken into account in the design, e.g. core instrumentation, steam generators, reactor coolant pumps and pressuriser.
- The option of removing this equipment, without segmentation, is also considered in the design of the handling systems, in terms of providing specific openings and pathways (if necessary, this equipment will be dismantled in an appropriate onsite area).
- The design of the reactor pit will include a metallic liner in order to enable the dismantling of the reactor vessel and internals under water.
- The reactor construction sequence will be used to plan the dismantling sequence.

Special provisions are being made to limit the spread of contamination, including the use of double barriers for all pipes enclosed in concrete walls or in floors.

In the United Kingdom, the safety regulator (HSE) and the environmental regulator for England and Wales (the Environment Agency) are currently undertaking pre-licensing/pre-authorisation reviews (termed "generic design assessments") of a number of new reactor designs. The reviews take account of existing criteria for licensing and decommissioning that have recently been revised and published.[1-2] Applicants for such reviews are required to identify the management arrangements for spent fuel and radioactive waste arising from operation of the reactors for their projected life, including:

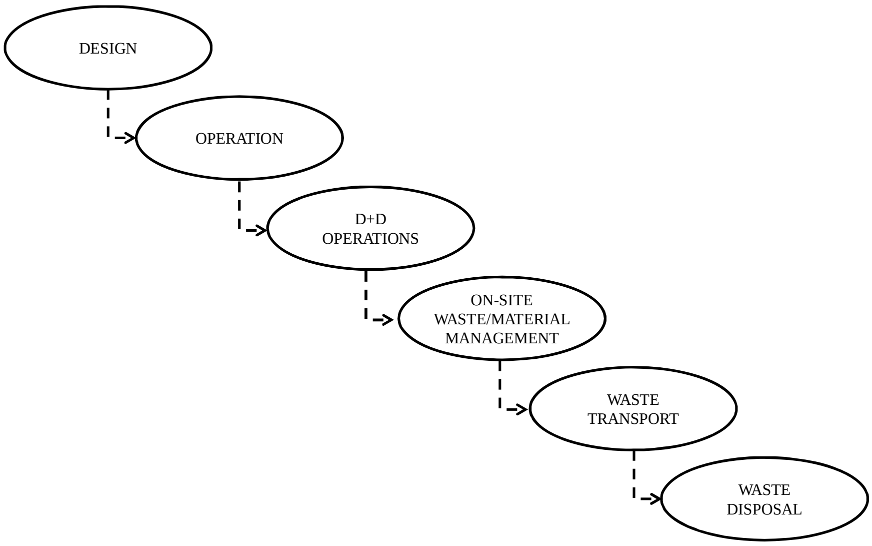
- The strategies for decommissioning, and for management of spent fuel, all radioactive wastes and substances that might become wastes.
- A demonstration of how the design and its proposed operation will avoid or minimise the generation of radioactive waste.
- The safe storage of radioactive wastes pending disposal.
- The disposability of wastes.

The assessment approach followed by the UK regulators recognises the important interaction between dismantling operations and "downstream"

1. http://www.hse.gov.uk/nuclear/notesforapplicants.pdf
2. http://www.hse.gov.uk/nuclear/decomm1.pdf

provisions for management of materials and waste from decommissioning, especially provisions for treatment of waste on site – see Figure 1. An implication of this approach is that optimisation of decommissioning requires that early consideration be given to design provisions for material management. This issue applies especially for those designs that envisage construction using modules.

Figure 1. **Interaction between decommissioning and waste management** [Source ENRESA]



As an input to the subsequent consent process to construct a new power plant in the United Kingdom, applicants will be required to submit a funded decommissioning and waste management programme to the relevant Secretary of State for approval. This programme has two main parts – one dealing with technical matters relating to decommissioning and waste management and the other dealing with financial matters. The regulatory bodies are statutory consultees of the Secretary of State for approval of the programme and for any subsequent modifications.

Taking note of the above requirements, the design of the Canadian ACR-1000 reactor provides the following features intended to facilitate the decommissioning and dismantling of the plant:

- Choice of materials, such that eventual quantities of radioactive waste are minimised and decontamination is facilitated.
- Access capabilities to facilitate easier dismantling and removal of components.
- Facilities necessary for storing radioactive waste generated in both operation and decommissioning of the plant.

Guidance on requirements for decommissioning of new plant designs in Canada, developed by Canadian Nuclear Safety Commission (CNSC), gives particular emphasis to decommissioning cost evaluation and funds accumulation. Section 7.21 of the CNSC regulation RD 337 requires that applicants seeking permission to construct new plants demonstrate that decommissioning has been taken into consideration in the design – see box above.

The USNRC Regulatory Guide (4.21) *Minimization of Contamination and Radioactive Waste Generation: Life Cycle Planning* emphasises the need to give consideration to contamination control at the plant design stage. The design features should minimise contamination of the facility and the environment, e.g. by design and operational procedures that enable the early detection of leaks. The guide also gives emphasis to maintaining records needed to facilitate the safe and effective decommissioning of the facility. Such records are required, *inter alia*, to contain details on contaminating events and residual levels of contamination in the environment during the life of the facility.

The USNRC has developed a process for the systematic collection and documentation of lessons learned from decommissioning and this information is published on the NRC website.[3] The Commission's approach recognises that allowing partial release of sites can enhance the decommissioning process, e.g. it may be very beneficial to allow the licensee to reuse released facilities and, in certain cases, to rent or sell a portion of the facility or site under decommissioning to offset decommissioning costs.

In Slovakia, it is a requirement of Act No. 541/2004 on *Peaceful Use of Nuclear Energy (Atomic Act)* that the licence holder must prepare, at different licensing stages, a decommissioning plan consistent with IAEA WS-R-2 *Predisposal Management of Radioactive Waste, including Decommissioning,* WS-G-2.1 *Decommissioning of Nuclear Power Plants and Research Reactors* and SRS No. 45 *Standard Format and Content for Safety Related Decommissioning Documents.* In addition, the licensee is required to record and maintain data on the operation of the nuclear installation important for decommissioning, which data are introduced into the decommissioning plan.

In Germany, construction of new nuclear power plants (NPPs) for commercial electricity production and of facilities for nuclear fuel reprocessing has been prohibited by law (Atomic Energy Act) since 2001. For the existing German NPPs, the issue of decommissioning has been considered well in advance of the end of operation. Regarding the preparation of decommissioning,

3. www.nrc.gov/about-nrc/regulatory/decommissioning/lessons-learned.html

Criterion 2.10 of the BMI safety criteria for nuclear power plants[4] includes the following requirement:

> *Nuclear power plants must be designed in such a way that they can be decommissioned in compliance with radiation protection provisions. There must be a concept for disposal after final decommissioning in compliance with the radiation protection provisions.*

As a rule, the operating licences for nuclear power plants stipulate a periodic review of the conceptual decommissioning strategy. Important aspects are the technical documentation of the facility, its systems, components, buildings and materials and data relevant to radiation protection (dose rate chart and contamination chart) and the consequences of incidents and/or accidents which are relevant for decommissioning. In addition, all maintenance precautions, as also mentioned under Criterion 2.4 of the BMI safety criteria, can be used for planning the decommissioning work.

Japan is currently in the process of revising its legal requirements for decommissioning. It is expected that the new legislation will emphasise the need for systematic collection of experience from ongoing decommissioning projects.

As part of an overall aim to achieve greater standardisation of regulatory practice in Europe, the Western European Nuclear Regulators' Association (WENRA) is developing standardised safety reference levels (SRLs) for decommissioning and waste management. An overarching requirement will be that a decommissioning plan is developed prior to the issue of an operating licence and that this plan is updated throughout the lifetime of the nuclear facility. The plan should be take account of a safety assessment for decommissioning that is also updated during the lifecycle of the facility.

In January 2008 WENRA published the final version of Reactor Safety Reference Levels,[5] which require that Safety Analysis Reports produced in support of the application for a construction licence should describe how relevant decommissioning and end-of-life aspects are taken into account. The SRLs refer for guidance to the IAEA Safety Guide GS-G-4.1 *Format and Content of the Safety Analysis Report for Nuclear Power Plants* (Chapter 15) which, for example, recommends that operators should investigate the availability of services, space and systems for waste management.

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4. BMI (Bundesministerium des Inneren/ Federal Ministry of the Interior): "Sicherheitskriterien für Kernkraftwerke" of 21.10.1977 (Bundesanzeiger/Official Federal Gazette 1977, Nr. 206)
5. WENRA, Reactor Harmonization Working Group, WENRA Reactor Safety Reference Levels, January 2008 (www.wenra.org)

Provisional SRL for waste management and decommissioning have also been developed by WENRA, which are currently undergoing review – see box.

Safety issue 2.1: Facilitating decommissioning during design, construction and operational phase

- D-12: Account shall be taken of the need to decommission a facility at the time it is being planned, designed, constructed and operated. Measures, including design features, contamination and activation control, shall be described and justified in the safety documentation of the facility.

Safety issue 2.2: Site decommissioning strategy

- D-16: The strategy shall be consistent with existing related national strategies, e.g. on decommissioning or radioactive waste management and disposal.
- D-18: The licensee shall propose an end-state in its decommissioning strategy, which is consistent with the national policy.

Safety issue 2.3: Facility decommissioning plan during design, construction and operational phases

- D-20: In accordance with the decommissioning strategy, the licensee shall establish and maintain facility decommissioning plans, the details of which are commensurate with the type and status of the facility (graded approach).
- D-21: The initial decommissioning plan shall be established in the design phase of the facility.
- D-24: The decommissioning plan shall be supported by an appropriate safety assessment for the decommissioning activities the details of which are commensurate with the type and status of the facility (graded approach).

It is clear from the foregoing that an important demand of regulators is that requirements for decommissioning be taken into account from an early stage of the design process for new reactors. Associated guidance is mainly focused on funding, waste minimisation and the protection of the workers and the environment during decommissioning. Less attention is currently being given to the need for design measures that anticipate waste management needs in decommissioning (i.e. segregation, characterisation, treatment, storage and disposal) – though it may be that regulators believe this is already sufficiently covered by general radioactive waste management regulations.

Regulators have provided little guidance on aspects such as plant configuration management, record keeping and maintenance in order to optimise the decommissioning process. It may be that safety authorities regard the existing requirements as adequate, especially if spent fuel has left the site. Nonetheless, these issues will also have an impact on decommissioning safety, and therefore may be also potentially of interest to the safety and environmental protection authorities. Similar issues are likely to apply in the case of other large nuclear facilities, in particular for large research reactors.

3. REQUIREMENTS OF ELECTRICITY PRODUCERS FOR DECOMMISSIONING

Electricity producers, as well as being the owners of commercial nuclear power plants, usually have the specific role of client, during the design and construction phase, and the role of plant operator in later phases. The initial responsibility includes establishing procurement specifications for the vendor organisation. In due course, during operation, the utility takes direct responsibility for the collection and conservation of information needed for future decommissioning.

Plant owners typically to take as their starting point the requirements of the national regulatory authorities, in particular the requirement to prepare a preliminary decommissioning plan during the design process – see box. The decommissioning plan is typically seen as a core document for ensuring that decommissioning requirements are reflected in the design and are borne in mind during future changes to the original design and during plant operation.

> In line with the requirements of French legislation, the utility EdF is developing a preliminary decommissioning plan during the design process for the Flamanville-3 reactor. Decommissioning is also addressed in the preliminary safety analysis report, which describes arrangements to facilitate decommissioning such as appropriate instrumentation, comprehensive and well organised documentation and measures to minimise waste generation by reducing contamination and activation through appropriate choice of materials and lay out solutions. In addition, (as described in the previous section) EdF is putting in place additional provisions that facilitate dismantling and prevent the potential for spreading of contamination at Flamanville-3.

In the United Kingdom, decommissioning plans are maintained and updated to ensure that cost estimates remain current. It is common practice that records from the siting, design, construction, operation and shutdown are essential to updates of the decommissioning plans. Modifications to plant made during the operation of a facility are subject to a strict change control procedure that includes identification of any modifications that have an impact on decommissioning liabilities. These need to be evaluated and incorporated into the decommissioning plan, which therefore will always reflect the ‘as built’ status of the power plant.

Decommissioning plans in Finland are also subject to periodic updates, reflecting modifications to the plant during operation and also contamination development within the facility. The decommissioning plan again provides the basis for definition of records to be retained during the lifetime of the plant. It is expected that requirements for decommissioning will be included in future procurement specifications, e.g. reflecting the requirements set out in Chapter 2.16 of the European Utility Requirements (EUR) document for design of new plant.[6]

Given that most European utilities are part of the EUR grouping, it may be assumed that the requirements in Chapter 2.16 of the EUR document will be widely reflected in future procurement specifications in Europe and, therefore, in the design of new plant. Indeed, it is evident that the standard reactor designs for the European market are already responding to these requirements. The EUR document notes that a complete decommissioning plan cannot be produced at the design stage, e.g. important elements of such a plan are anyway within the responsibility of plant owners/operators, rather than reactor designers. Instead, in addition to making provision for waste minimisation, designers are being encouraged to develop a sequence of dismantling operations – see box.

The EUR document requires that a dismantling sequence be developed that:

- Demonstrates that decommissioning, based on the layout of the plant and on the provisions for maintenance and repair, is feasible using the engineering techniques available at the time of commissioning (e.g. robotics, decontamination facilities and other mechanical aids), and considering the ALARA principle.
- Provides suitable information for cost estimation, to evaluate the adequacy of the financial provisions which have to be made by the facility owner.
- Demonstrates that the decommissioning programme can be carried out safely.
- Presents details of how much and what kind of active waste is to be disposed of during the decommissioning of the plant, including an activity inventory.
- Shows the expected personnel doses during the decommissioning stage.

It is understood that the EPRI utility requirements document (URD), which plays a similar role in the United States as the EUR document in Europe, will also in due course include a section on decommissioning requirements.

Several of the plant features developed for design objectives other than decommissioning will, nonetheless, also benefit the decommissioning process. These include features related to longer design life, replacement of components,

6. http://www.europeanutilityrequirements.org/eur.htm

higher plant availability, choice of materials, provisions for decontamination and reduction of operator dose. For example, it is a common requirement that all plant operational components and equipment, except the reactor pressure vessel, should be replaceable. This requirement should ensure the availability of handling facilities that in due course will be beneficial for decommissioning.

Third generation reactors are typically designed to operate for 60 years, and their design life may even be extended in future in the event of the replacement of major components. From the licensee viewpoint, an overriding priority is generally the smooth and optimal O&M of the plant. Therefore, the design priority is necessarily focussed on the best available and feasible O&M solutions. These solutions invariably support later decommissioning tasks. For example, good design practice for both O&M and decommissioning includes the provision of ample space for the activities being undertaken, minimisation of the doses during these activities, minimisation of waste quantities, and making provision for replacement of components. The availability of detailed 3-D models for new plants will also be extremely useful both for O&M and decommissioning.

Minimising waste arisings also has important cost implications, as the cost of managing waste may typically be of the same order as the dismantling costs, i.e. perhaps one-third or more of the total decommissioning cost[7].

The European utilities' organisation FORATOM has established a special working group, under the ENISS[8] initiative, to interact with WENRA on the planned development of SRLs for decommissioning. A key feature of the ENISS standpoint is the promotion of the IAEA Safety Requirements document WS-R-5 *Decommissioning of Facilities using Radioactive Material* as a basis for harmonised safety standards.

ENISS notes that there is a progressive reduction of nuclear and radiological risk in moving from operation to defueling and through to dismantling. Decommissioning involves processes – such as the cutting and dismantling of structures, plant and equipment – which involve both conventional and radiological hazards. After removal of the spent fuel some radiological hazards remain because of the possibly of coming into contact with radioactively contaminated or activated material and, in addition, new conventional hazards will arise, e.g. due to the lifting of heavy loads. In this environment, the balance of regulatory emphasis needs to change from nuclear safety (as in operating plant) towards the environmental and conventional safety aspects of what is effectively

7. See, for example, *Nuclear Energy Outlook*, OECD, 2008.
8. European Nuclear Installations Safety Standards

a waste management operation. There is growing evidence that this change of emphasis is indeed being recognised in regulatory practice.[9]

The development during construction of a baseline radiological characterisation of materials and the site will normally be of great value when decommissioning is undertaken or the site is to be released. Site characterisation is generally performed in the framework of the environmental impact assessment but requirements concerning the characterisation of construction materials are less common.

Experience from recent decommissioning projects suggests that plant records may sometimes be incomplete or inaccurate, e.g. they may not reflect the final plant configuration. The information provided suggests that utilities currently use plant configuration management systems that ensure that records are modified in line with plant changes. It is important that such systems include, in addition to those records that are directly relevant to operation, other records that might be important for decommissioning, e.g. information on temporary openings made during construction may facilitate the reuse of these accesses during decommissioning.

Past experience suggests that plant operators need to give special attention to the collection and preservation of information on contamination events. A related issue is the need to record information on periodic leak tests of embedded piping, which tests are important in limiting the potential for contamination of concrete; such contamination may otherwise only be identified during demolition of the concrete structure.

9. Nuclear Energy Agency (NEA) (2008), *Regulating the Decommissioning of Nuclear Facilities: Relevant Issues and Emerging Practices*, OECD, Paris.

4. PROVISIONS BY THE PLANT DESIGNERS FOR DECOMMISSIONING

This study found that designers of new generation power plants are giving increased consideration to facilitating the dismantling and removal of equipment, reflecting the requirement by utilities (mentioned above) that all components, apart from the reactor pressure vessel, should be removable using permanently installed lifting equipment. AECL design strategy for the Advanced CANDU Reactor (ACR-1000) takes explicit account of decommissioning requirements – see box. AREVA-NP also confirmed that making such provisions was part of the design process for the EPR[10] and Westinghouse intends to provide similar provisions.

The Design Guide Document for the ACR-1000 provides specific requirements addressing the impact of system/equipment and structure design on decommissioning:

- Reduce radiation source (e.g. material selection).
- Reduce time for dismantling radioactive equipment (e.g. open top construction and silos, modular design).
- Accommodate deferred decommissioning if chosen as the decommissioning strategy (e.g. structural integrity).
- Simplify waste management (e.g. plant layout and zoning, waste segregation).
- Manage design and operational information (e.g. this information will be useful should decommissioning be deferred).

Designers are required to complete specific decommissioning checklists:

- Civil design features.
- Material selection.
- Process design.
- Maintenance.
- Construction.

There are few data available publicly on the quantities of radioactive materials that may be expected during decommissioning. Clearly, reduction of

10. Evolutionary Power Reactor (AREVA).

decommissioning waste is an important objective in the design of third generation plant but there is little information available currently to show the extent to which this objective is being achieved.

It is common practice for designers to make provision for the minimisation of spills and leakages by, for example, detecting leakages at an early stage by means of humidity sensors (e.g. in the EPR) and to facilitate their early clean up. The design organisations also minimise the use of embedded piping and the drainage systems are designed to keep liquids separated according to their potential radioactivity. It should be noted, however, that complete avoidance of embedded piping may result in increased worker doses unless special shielding arrangements are incorporated in the design.

Several design approaches are being implemented to minimise the possibility of contamination being distributed around the plant. For instance, where concrete might become contaminated by leaks and spills, concrete structures are protected from contamination (lower sections of walls and floors are sealed and the sealing medium is reinforced where wear and tear is expected) and sumps and trenches constructed in concrete floors are lined with sheet steel to protect the concrete from contamination so to facilitate clean up.

Measures are also being introduced to reduce dose levels during decontamination, such as special surface finishes or polishing treatments to prevent contamination from adhering to or penetrating the surface of materials. In line with the requirements of utilities and regulatory organisations, current designs give special attention to material selection issues, in particular to limit the cobalt content of materials exposed to neutron radiation. Nonetheless, there is a wide variation in the specified cobalt contents of steels depending (for example) on the type of steel and the required duty. This issue would benefit from further consideration by the utility organisations such as EUR and EPRI, e.g. the formulation of more restrictive (quantitative) criteria on cobalt content and similar criteria.

Third generation power plant designs aim also to reduce contamination levels, and therefore waste arisings, by reducing the numbers of components in the design and in some cases by the use of modular concepts. In order to take into account the different sizes and power outputs of plants, this objective is best understood if presented in terms of the numbers of contaminable components per MWe. Such an approach may also be helpful in undertaking decommissioning cost calculations, given that the dismantling of non radioactive part of the facilities is essentially a conventional business.

For the AP-1000, Westinghouse proposes to use the spent fuel building and spent fuel pit for storage and decontamination during decommissioning but, for the most part, the provision of space seems to be related more to repair and maintenance than decommissioning.

For the EPR, AREVA-NP provides set-down spaces for dismantled radioactive parts within the buildings and includes a hot workshop and a decontamination facility in the design. Additional facilities for decommissioning are seen as a site specific (as opposed to a generic) issue that needs be addressed in collaboration with the utility.

For the ACR-100, AECL provides a radioactive waste management facility and a hazardous chemical storage building and aims to include space for characterisation and storage of radioactive materials.

Some design decisions may involve a conflict between, for example, structural requirements and requirements for decommissioning. The design of the biological shield, for instance, requires a balance to be made between materials with sufficient strength to withstand a severe accident and materials that minimise the extent of activation, e.g. concrete additives that reduce neutron activation may have negative effects on the structural properties of the concrete. Aggregates for concrete, including those used in the biological shield, are usually sourced locally. This could result in a non-optimal choice in terms of reducing neutron activation.

There appear to be differences in current design practices concerning the extent to which space should be allocated for onsite temporary storage, characterisation and treatment of equipment and materials deriving from decommissioning – see box. This site space allocation may be more important for those designs that foresee the use of piping/valve modules that are pre-assembled on skids. This should simplify dismantling and removal by reversing the construction sequence. By the same taken, an aim to follow this dismantling strategy results in a need to give greater attention to providing properly furbished space on site for decontamination and disassembly.

Although many new provisions have been introduced, it is difficult to draw quantitative conclusions about the likely effectiveness of the design measures being taken to facilitate decommissioning on the basis of the available information, e.g.:

- Although measures are being taken to minimise waste arisings, no detailed information is available on the expected quantities of waste from decommissioning. At this stage is not possible to compare the waste arising from the decommissioning of present and new generation plants. There is a similar lack of detailed information regarding the expected reduction in worker doses during both operation and decommissioning. An interesting point worth considering is: what level of cobalt in "low-cobalt" steels would bring this about?

- Some uncertainty is associated with the effectiveness of design provisions in specific situations. For instance, if the design provisions are mainly targeted at repair and maintenance, it is difficult to judge whether an accelerated dismantling programme could be implemented if so desired by the plant owner. It may be, for example, that facilities designed for easier maintenance are overwhelmed by a larger throughput of material during decommissioning.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 General conclusions

Experience from decommissioning projects suggests that the decommissioning of earlier generations of nuclear plants could have been made easier if this aspect had received greater consideration at the design stage and during operation of these plants. Better forward planning for decommissioning may have resulted in lower worker doses and reduced costs. This has led electricity producers and national authorities to demand that decommissioning needs be addressed from the design stage and that preliminary decommissioning plans be provided as an input to the licensing process.

Regulations in many countries have long required that consideration be given to decommissioning prior to granting of an operating licence for a particular nuclear facility. In recent years, it has become common practice that decommissioning plans should be developed at an early stage, and that these plans should make specific reference to the management of waste arising from decommissioning operations, to site end-states and related environmental issues, and should be used as a basis for showing that adequate financial provision for decommissioning is being made. This is leading to a greater focus on associated issues such as the materials for construction, provisions for ease of maintenance and dismantling, provisions for limitation of contamination and the definition of national clearance levels.

Regulators have begun developing standardised requirements, for example through the SRLs for decommissioning and waste management being developed by WENRA, for use in Europe. Central to these requirements is the insistence that a preliminary decommissioning plan is developed prior to the issue of a construction licence and that this plan is developed and updated throughout the lifetime of the nuclear facility. The plan should take account of a safety assessment for decommissioning that is also updated during the lifecycle of the facility. The association of European utility organisations has also been developing standardised requirements intended to ensure that all reactor designs for the European market incorporate certain basic design features, including making provision at the design stage for waste minimisation and component removal.

An important priority for utility organisations is that the design provides for optimal O&M of the facility. Design features to support O&M work will invariably also be beneficial for later decommissioning tasks, e.g. good design practices for both O&M and decommissioning include: providing ample space for the activities being undertaken, minimisation of the doses during these activities, minimisation of waste quantities, and making provision for replacement of components. A related issue concerns the minimisation of waste arisings, e.g. through careful selection of materials and by incorporating features to limit the spread of potential contamination. Careful optimisation of design provisions for decommissioning with those of "downstream" waste management may be expected to yield benefits in terms of reducing radiation exposure of the workforce and decommissioning costs.

Although many design requirements aimed at improved operation and maintenance will also be beneficial for decommissioning there are nonetheless design considerations that need to focus directly on plant decommissioning and dismantling, such as designing structures to maximise stability of components, incorporation of modular concepts, providing improved access through careful system layout, and by reducing the numbers of plant components and piping per MWe of installed capacity.

Experience from recent decommissioning projects suggests that plant records may sometimes be incomplete or inaccurate, e.g. they may not reflect the final plant configuration. It is important that such systems include, in addition to those records that are directly relevant to operation, other records that might be important for decommissioning, e.g. information on temporary openings made during construction may facilitate the reuse of these accesses during decommissioning. Past experience suggests that plant operators need to give special attention to the collection and preservation of information on contamination events, as such contamination may otherwise only be identified during demolition of the concrete structure.

5.2 Specific best practice recommendations from a decommissioning perspective

1. Decommissioning plan

The decommissioning plan reflects the planned end state for the facility; it should evolve, in tandem with the safety assessment for decommissioning, throughout the lifetime of the facility and during the decommissioning phase. In line with current practice in many countries, it is suggested that the plan be formally updated on approximately 5-year cycles, with a key update taking place prior to the granting of permission to proceed with decommissioning.

Development of the plan requires close collaboration with other interested parties, including those responsible for waste management activities.

2. Overlap between requirements for operation and maintenance (O&M) and for decommissioning

As well as the consideration being given to the nuclear island plant, it is recommended that attention is also given to the balance of the reactor plant, on the basis that areas which are difficult to access could give rise to later problems during decommissioning. In general, it is good practice to submit the entire plant to a structured review from the perspective of decommissioning.

3. Plant configuration management

Records of the physical configuration of the facility need to be maintained on an ongoing basis, as well as maintaining records of leaks and other contamination incidents. A risk to be borne in mind is that contamination may become fixed, painted over and eventually forgotten. It is noted that design tools can be used to show how configuration control can be maintained during sequential dismantlement. Additional guidance from the safety authorities on this general topic may be helpful in ensuring a more systematic approach.

4. Plant monitoring systems

Current good practice is to have in place monitoring systems for early detection of leaks and contamination, including leaks from underground piping (environmental monitoring). Providing means for monitoring of plant chemistry parameters, against an objective of minimising corrosion of metallic components, is also desirable.

5. Estimating the inventory of contaminated materials

It is suggested that records of the original composition of steel and concrete materials used in the plant (including technical specifications) be retained, as knowledge of any impurities may be important for future decommissioning and can reduce the extent of material characterisation that is ultimately needed. Materials used for the construction of neutron shields are of special importance. In particular:

- It is beneficial at the design stage to specify the allowable range of cobalt levels in steel, i.e. as well as to seek reduced cobalt levels in absolute terms as estimated quantities of certain other radionuclides are often linked to the cobalt level.

- The development of 3-D models as part of the design process may provide a useful management tool throughout plant operation, including for recording the locations of sources of activity to help assess where samples should be taken for radiation monitoring.

6. Embedded piping

Current best practice is to implement technical provisions that circumvent the use of embedded piping. This is to be commended and should be implemented as widely as possible. Leaks in embedded piping are difficult to locate and may lead to larger amounts of waste and longer outages during plant operation. At the same time, potential radiation doses from unshielded piping need to be addressed in designing the provisions for radiation protection.

7. Managing feedback from operators/decommissioners to designers

The design guidelines established by the electricity producers (as clients) provide an essential link between past experience and the design process; these need to be developed taking account of discussions with designers about what features can reasonably be delivered.

Appendix 1.

SUMMARY OF RESPONSES TO QUESTIONNAIRE ON APPLYING DECOMMISSIONING EXPERIENCE TO THE DESIGN AND OPERATION OF NEW PLANTS

1. Background information on questionnaire survey

A survey on current practice in applying lessons from decommissioning to the design and operation of new reactor systems was undertaken between May and September 2008 by the WPDD, as part of a study aiming to assess the added value that may be provided to the life cycle management of new plants by taking into account lessons from decommissioning experience. The questionnaire was sent to regulatory authorities, electrical utilities and reactor design organisations concerned with the development and implementation of new reactor systems. A synthesis of the survey results provided a basis for the discussions at a topical session held at the annual meeting of the WPDD on 12-13 November in Senec in the Slovak Republic.

Responses to the survey were received from five utilities (EdF, Fortum, British Energy, Vattenfall, KKG), as well as the Foratom/ENISS utility working group and from the European Utilities' Requirements (EUR) grouping; from the decommissioning and waste management organisation SOGIN and the Slovak nuclear engineering organisations Decom and VUJE; from four vendors of reactors or associated systems (AREVA-NP, Westinghouse jointly with Ansaldo, AECL), and from five regulatory authorities[(CNSC, STUK, HSE (UK) jointly with the Environment Agency for England and Wales and UJD-SR, the Nuclear Regulatory Authority of the Slovak Republic).

A summary version of the survey responses is provided in the Section 2.

2. Summary of questionnaire responses

2.1 Design considerations

The following design organisations responded to the questionnaire: AREVA-NP, AECL, Westinghouse/Ansaldo (abbreviated to Westinghouse), VUJE/DECOM (in the Joint Slovak Response – abbreviated to JSR).

2.1.1 Dismantling programme

Question D1: Did you identify at the design stage a dismantling plan, i.e. the sequence of actions needed to remove all radioactive material and dismantle equipment, systems and structures?

Westinghouse believes the decommissioning experience accumulated thus far all indicates that the most appropriate philosophy for decommissioning is the same as that embodied in the AP-1000 construction plan which is to remove components/modules as complete units.

AREVA-NP states that due to the long service life of the EPR it is anticipated that large components may have to be replaced. That is, dismantling/replacement is already considered in the design. In response to Q7 AREVA-NP says that the Decommissioning Plan is largely a matter for the utility.

AECL has developed a decommissioning strategy for the ACR-1000. This decommissioning strategy is not site specific, and will be developed into a preliminary (or interim) decommissioning plan by the utility. The ACR-1000 decommissioning strategy includes a provisional sequence for the dismantling of radioactive portions of the ACR-1000 (e.g., the nuclear steam plant), and sections of the plant which are not expected to contain any significant contamination at decommissioning (e.g. the balance of plant).

AECL has prepared guidance to Advanced CANDU Reactor (ACR) designers on design features that will facilitate decommissioning of the reactor and its ancillary buildings and structures at the end of their operational life.

The JSR states that Slovak law requires that preliminary decommissioning documentation, a dismantling plan and preliminary RAW (and spent fuel, where appropriate) management documentation must be prepared at the design stage.

Question D2: Are auxiliary systems that may be used in decommissioning being designed to ensure that their routing and layout is such as to minimise the need for modifications?

Westinghouse states that air and water services can remain functional for a major part of the removal of the main components but, once the systematic removal of the buildings begins, alternative means for providing these services will need to be provided. The provision of such services through the existing penetrations is envisaged for the latter stages of decommissioning.

AREVA-NP states that no special attention is paid to non-radioactive service systems. The nuclear ventilation system has been designed into sub-systems such that few or no modifications will be required in step with dismantling.

AECL states that auxiliary systems that will be needed during decommissioning (e.g. during storage to allow for radioactive decay) are designed such that during decommissioning they are available and will only require isolation from structures, systems and components that will have to be taken out of service and dismantled early in the decommissioning project.

The JSR states that the need for modifications to auxiliary systems is generally minimised but cannot be altogether excluded.

Question D3: Did you estimate the amount of radioactive wastes that may be produced in decommissioning?

Westinghouse states that an initial estimate of quantities and nuclides has been developed. It is anticipated that a further more accurate estimate will be generated as the final detail design is completed and final component manufacturers are selected.

AREVA-NP confirms that the amount of waste is estimated as part of the design process.

AECL states that the quantities of high-, intermediate- and low-level radioactive wastes generated during decommissioning of a two-unit ACR-1000 were estimated from design information. Also, the amount of concrete/structural steel wastes as well as non-radiological wastes (i.e., wastes suitable for free-release or management in conventional waste management facilities) were also estimated.

The JSR states that the amount of radioactive waste that may be produced in decommissioning is estimated in the conceptual decommissioning plans. The first such plan is elaborated before obtaining the operational license. The plan is updated during nuclear power operation regularly, either on 10 years basis or when a significant change in technologic or safety system is made. A part of the plan update is also the radioactive waste amount and management update.

Question D4: Did you identify and reserve sufficient space on the site for on-site temporary storage, characterisation and treatment of equipment and radioactive materials?

Westinghouse states that the current decommissioning plan envisages a facility, custom designed to handle the volume reduction of the large components within the site boundary fence. This will be custom built according to individual site or national circumstances and will be designed to minimise worker exposure and capture contaminated dust.

AREVA-NP states that this subject has not been considered since it depends on the utility and site. The design does provide set-down spaces for dismantled radioactive parts within the buildings. A hot workshop and a decontamination facility are also included in the design.

AECL states that sufficient space has been identified and reserved in the ACR-1000 design for on-site characterisation, treatment and temporary storage of radioactive materials and equipment. More specifically, the ACR-1000 design includes areas for radioactive material characterisation and storage. There is a radioactive waste management facility and a hazardous chemical storage building in the ACR-1000 plant design.

The JSR states that this space is identified.

Question D5: Have you access to systematic decommissioning lessons learned? Do you believe that such an activity to be carried out by NEA could be useful for your designs?

Westinghouse states that access to detail lessons learned on a correlated basis does not appear to be available. Information has been provided by personnel involved in such efforts and the various reports issued by the plant owners. Westinghouse has experience in the decommissioning of Fort St-Vrain. It would very helpful if the NEA could develop such a list. Westinghouse is very open to ensuring the use of the best available information.

AREVA-NP feels it would be difficult for the NEA to help in the design because other design aspects may be in conflict with decommissioning. Were the NEA to take up this suggestion, then all disciplines should be involved to address such issues.

AECL has access to systematic decommissioning and mid-life refurbishment projects (or life extension) lessons learned in Canada and decommissioning projects globally. It also keeps abreast of decommissioning lessons learned or information made available by operators of nuclear power plants currently being decommissioned around the world. AECL would welcome an NEA initiative.

The JSR states that information comes through the IAEA, professional activities of individual companies, regional and national technical cooperation programmes in the fields of decommissioning and RAW management. The NEA could do useful work in this area.

2.1.2 Operational maintenance related features

Questions D6-12: Did you consider the following design areas for improved maintenance that could be useful as well for plant maintenance and life extension? Have you considered additional areas in your designs?

The JSR gave a general response to questions D6-12 stating that all the named areas were, or will be, considered when designing decommissioning and RAW management activities.

None of the respondents indicated that there were any other areas, i.e. in addition to those listed below, where improvements could be made.

Question D6: Easier access to components equipment in normal and accident conditions

The Westinghouse AP-1000 design incorporates requirements for constructability and ease of maintenance. The focus is on the removal of components and associated egress and access routes. The removal and replacement for major components was considered due to the design life of the plant. This included the replacement of steam generators.

AREVA-NP states that sufficient clearance around the components is ensured. Facilities for accident management are installed. Safety-related components can be drained and flushed remotely after an accident to enable access for their repair. In addition, as for question D1, AREVA-NP states that due to the long service life of the EPR it is anticipated that large components may have to be replaced. That is, dismantling/replacement is already considered in the design.

The ACR-1000 plant design, layout and access routes are optimised to facilitate easy access and removal of large components, and easy detachment and remote removal/replacement of significantly activated components. This also facilitates future installation of decontamination and waste handling equipment.

Question D7: Development of specific tools and robots for component disassembly

Westinghouse states that the development of such tools is part of the detailed plant design. Examples range from lifting equipment for large composite modules to tools for the disassembly of small components.

AREVA-NP states that all rooms with large pumps etc. are provided with a means of lifting. Components are designed to enable easier removal for radiation protection reasons. Robots are not required if decontamination is planned (see below). This question is very much directed to a decommissioning plan which is a matter for the utility.

AECL has developed remote-controlled equipment and control systems for retube projects at Bruce and Point Lepreau Nuclear Generating Stations (both in Canada) to minimise dose to workers. Lessons learned from these projects will be used in carrying out component disassembly remotely during the decommissioning of the ACR-1000.

Question D8: Handling means and paths for removal of all components, including large and heavy ones (reactor vessel, steam generators etc.)

Westinghouse states that the polar crane main beams have been sized such that, with the installation of a temporary heavy lift trolley, a steam generator can be lifted and will pass between the beams. Routes for removal have been established and conceptual designs established to maintain containment integrity.

AREVA-NP states that due to the necessity to install and maybe replace large components handling means and paths have been considered in the design. Openings sealed after installation can be re-opened, if necessary.

Provisions are made in the design of the ACR-1000 to allow sufficient space and dedicated path for easy and quick transport of large components during maintenance and decommissioning. See response to question D6. In addition adequate provisions are made for material handling, and replacement or removal of components throughout all buildings by providing cranes, hoists and monorail as required (see Question D11).

The EUR document requires that all components, except the vessel, should be removable using permanently installed means of handling.

Question D9: Separation of radioactive and non radioactive equipment and minimisation of radioactive systems

For Westinghouse there are a range of criteria which influence the separation and segregation of equipment over and above the separation required for safety train requirements. Equipment which is carrying radioactive fluid is generally installed in separate areas and rooms for maintenance and ALARA considerations. This includes separation of redundant equipment in the same system.

AREVA-NP states that separation is a sound radiation protection principle and is implemented in the design. Separation is by means of shielding. (If a system is required, it cannot be minimised: it must function.)

The ACR-1000 design has taken into consideration and benefitted from lessons learned and operational feedback from existing CANDU® plants. For example, in order to minimise cross-contamination, atmospheric separation is used between high and low activity areas, with adequate leak tight barrier, pressure differential and negative pressure control in high activity areas. Waterborne contamination is minimised through extensive use of sealants.

EUR states that separation of radioactive and non-radioactive equipment is required by dose reduction obligations.

Question D10: Proper layout and shielding to minimise activation and contamination of structures and equipment

Radioactive areas of the AP-1000 plant are designed to ensure that radioactive equipment and components are shielded. Of particular significance is the extensive use of composite steel plate and concrete modules. Such modules present a steel plate face in much of the areas susceptible to contamination. In addition many of the surfaces which will be subject to neutron bombardment will also be faced with steel plate reducing activation of the concrete behind the plate. Avoiding activation in neutron fields is a primary design requirement.

AREVA-NP states that the controlled area is divided into shielded areas, staggered by dose rate. This means that the potential in contamination scope is also strictly limited to the local area of occurrence. But here the ventilation system is designed to remove air-borne contamination if it occurs. With regard to liquid contamination the rooms of potential contamination are provided with a drain system. The reactor shielding is sufficient to limit the main activation to the immediate vicinity of the RPV at core level.

The material of construction for ACR-1000 systems and components in high-neutron flux regions are carefully selected to minimise formation of activation products. Internal walls of ACR-1000 containment structures in highly radioactive regions of the reactor are steel-lined to minimise contamination of the concrete structure to a minimum. Tools and equipment used in radioactive areas of the plant are stored in dedicated facilities to prevent cross-contamination. In addition whenever possible the ACR-1000 design segregates the routing of contaminated process systems from non-contaminated systems to minimise possibility of cross contamination during operation and decommissioning.

Question D11: Potential for on-site decontamination, cutting and conditioning of large components for off-site transportation

Westinghouse considers the most effective way to decommission the plant is to provide a decontamination and volume reduction facility. The design and engineering of such a facility should be undertaken when the site has been selected and the final layout defined. Decisions at national level regarding the provision of final long term storage facilities will also affect the provision of this facility. In addition to this facility the proposed decommissioning plan envisages the use of the Spent Fuel building and the Spent Fuel Pit as areas where smaller components may be decontaminated and cut up to suit the local regulations regarding size for the transport of active waste.

AREVA-NP states that decontamination facilities and a hot workshop are provided in the buildings.

ACR-1000 lay down areas are provided within the containment, in low radiation field regions of the plant, for radiological inspection, decontamination and dismantling.

Question D12: Considerations for plant recovery after serious accidents and subsequent plant decommissioning

Westinghouse considers this is covered in the design to meet the ALARA considerations.

Since the EPR is designed to take account of core meltdown and RPV failure, the high radioactivity is constrained by design and wash-out effects to a very limited area beneath the RPV in the reactor building. Safety related components can be drained and flushed after an accident to allow access for their repair. Thus at a later time access to the containment can be regained to enable surveying and decommissioning decisions. The remaining structures can be decommissioned according to plan since, by design, they are not impacted by the accident.

In the event of a serious accident, which results in core degradation, the ACR-1000 plant has multiple systems, which can remove decay heat from core debris. In addition ACR containment system is designed to limit the release of radioactive materials to the environment in case of severe core damage. It includes the containment structure, provisions for containment atmosphere control and post-accident containment cooling, fluid and electrical systems and components that form part of the extended containment boundary, and isolation provisions to ensure an acceptably leak-tight containment envelope during and following an accident. Hence, a decommissioning strategy similar to the one used for normal plant shutdown will be used in the event of a forced shutdown, e.g. due to a severe accident).

2.1.3 Dose reduction – System and building design related features

Questions D13-20: Did you consider the following systems and building design areas for reduced operator doses and waste minimisation? Have you considered additional areas in your designs?

For questions D13, D14, D16-21, D24 and D25 the JSR states that, in general, issues relating to dose reduction are taken into account in the designs, e.g. low content of cobalt and silver, passivation of internal surfaces, smooth-faced surfaces suitable for easy decontamination, special coatings certified for decontaminability etc. Some questions (e.g. D15, D22, D23, D26, and D27) were not relevant to the respondent.

Question D13: Connections for decontamination of systems and components

For the AP-1000, the piping detailed design for many systems is being completed and provision for such connections will be made. Such provisions often create potential crud traps, thus the design has limited their inclusion. The primary circuit decontamination operations described in the Decommissioning Plan will be an operation which will be aimed at both Inconel and stainless steel decontamination. Since plant operations will no longer be a factor, decontamination can be a more aggressive process.

AREVA-NP states that large radioactive components are provided with shielded decontamination connections.

The ACR-1000 design includes a decontamination centre.

EUR requests permanent connections and space to install decontamination equipment.

Question D 14: Minimisation of potential traps for radioactive contamination

For the AP-1000 the piping routing and layout for systems containing radioactive fluids are designed to minimise contamination traps. Valves such as plug or ball type and butt welded connections are used wherever practicable. In addition the selection of diaphragm type sensor isolators, diaphragm air driven pumps, etc. are employed in the design

For the EPR radiation protection design ensures that no bucketing or dead zones are in the layout. Low flow rates are avoided.

For the ACR-1000 is considered, for example, piping layout is designed to eliminate crud traps wherever possible.

Question D15: Improved primary coolant and spent fuel pool contamination filtration

The AP-1000 CVS purification process provides for mixed-bed, cation demineralisers and filters. The nominal, continuous purification flow rate was increased compared to operating plants. This arrangement, in concert with the enhanced chemistry requirements, will provide a much cleaner reactor coolant medium. In addition the additional chemical control of the primary circuit utilising the zinc regime will significantly reduce active corrosion products. The SF Pit (pool) cooling system also incorporates filters and demineralisers appropriately sized to ensure reduced activity levels in the fluid.

AREVA-NP states that mesh sizes have been reduced on comparison with earlier designs. Filter changing is performed semi-remotely using a shielded machine and resin exchange is performed remotely by back-flushing.

For the ACR-1000, sub-micron filters are added to the coolant purification to improve efficiency in particulate removal. A vacuum cleaning circuit (a filter and a pump) is provided to reduce the concentration of solids debris in the spent fuel bay. This, along with the addition of a biocide to control of the growth of biological matter in the spent fuel bay, will prevent the accumulation of contaminants in the spent fuel bay. Removal of activated solid contamination prevents their transport around the system and the build-up of local high radiation fields in the accessible areas.

Question D16: Minimisation of the potential of spills and leakages and provisions for their early identification and clean-up

The design and layout of the AP-1000 is intended to minimise leakages and spills by the judicious placement of vents and drains. All slabs containing radioactive equipment is enclosed within rooms which have decontaminable surfaces and which are equipped with floor drains connected to the waste process systems. A record will be kept of radionuclide releases relevant to decommissioning.

EPR have the same provisions but in addition AREVA-NP states that leakages in the primary system are detected at an early stage by means of humidity sensors.

AECL states that where the potential exists for leakages that could result in release of radioactive material, welded construction is used. Collection systems are provided to collect, in a controlled manner, leakages from known paths (i.e. from pump seals, valve packing, etc.). In addition, various means are provided to detect leakages.

In addition all designers state provisions to ease clean-up.

Question D17: Limited use of embedded piping

For the AP-1000 the use of embedded pipes has been minimised to the extent possible, consistent with maintaining radiation doses ALARA. To the extent possible, pipes have been routed in accessible areas such as dedicated pipe routing tunnels or pipe trenches, which will provide good conditions for decommissioning.

AREVA-NP is basically on the same position no embedded radioactive piping is installed where possible. Exceptions to this can be drain lines, depending on utility requirements.

Also ACR-1000 design minimises the use of buried or embedded piping. In addition, AECL states that where pipes are embedded, materials used are designed to last the lifetime of the plant.

Question D18: Improved design of sumps and drains

Westinghouse states that the design and location of the active drains system and associated sumps reflects the requirements of the utilities requirements document (URD) and the Westinghouse experience in this area. All sumps are plate lined, welding is minimised and surfaces treated to limit crud retention.

AREVA-NP states that the drainage system is designed to keep the liquids separated from potential radioactivity. For example, drains for process components are kept separate from building drains. The component drain system is enclosed. Likewise a separate enclosed system accommodates primary system drainage.

For the ACR-1000 sumps and drainages in concrete floors are designed with sheet steel lining to protect the concrete from contamination and to facilitate final clean-up. This is particularly important for systems containing radioactive fluids. Floor drains in the ACR-1000 are equipped with sealed covers to prevent any spills of oils or chemicals from escaping to the environment.

Question D19: Smooth, non-porous, and free of cracks and crevices

Westinghouse has made a particular improvement on this issue because the modular construction. Actually a large part of the structural design incorporates composite structural modules. These are steel plate structures which are installed and then filled with concrete. These replace much of the traditionally placed concrete with the outer steel plates doubling as formwork in addition to their structural function.

Without providing any detail AREVA-NP states that surfaces are designed to be decontaminable.

Where radioactive fluids are expected, ACR-1000 process systems and concrete surfaces are kept impenetrable to minimise fixed-contamination from penetrating the surface. This is achieved by surface pre-treatment, painting or lining the surface with suitable materials.

Question D20: Smoother surfaces for floor and walls with no sharp corners

The responses were much the same as for Question D19: provisions are taken to facilitate decontamination. Only Westinghouse appears to make provision to avoid sharp corners by adopting a modular design that eliminates many of the sharp corners associated with traditional construction, e.g. fillet welds at plate junctions.

2.1.4 Dose reduction – Materials selection related features

Question D21: Selection of materials for systems that will minimise activation products (for example lower cobalt content)

It is noted that improvements made to improve operation will be beneficial also for decommissioning. Actually the major source of personnel exposure is from cobalt-60 thus every effort to minimise its production is employed in the design. This includes all materials in contact with the reactor coolant and or which may be subject to neutron bombardment. In the latter case this includes such items as hard facing materials for valves. For in-core components the use of stainless steel and Inconel are avoided wherever possible, zircaloy being the most favoured replacement. In addition the incorporation of zinc in the reactor coolant chemistry will result in a more stable corrosion layer on primary surfaces, minimising transport and subsequent activation of corrosion products.

Also AREVA-NP points out that the use of cobalt is restricted by design. This has been analysed to achieve the optimal reduction. Use of antimony and silver in gaskets has been minimised.

Material used in ACR-1000 systems, components and structures in high neutron flux regions are carefully chosen to minimise activation products. For example, stainless steel with as low as possible cobalt content is used in the highly radioactive reactor core. This also applies to other regions of the plant where neutron activation is expected.

The EUR document states that limits will be imposed on cobalt levels but the limiting values are still being discussed. The Westinghouse response indicates that the URD will have similar requirements.

Question D22: Finishing processes for internal surfaces of components in contact with primary coolant to minimise crud production

Electropolishing of surfaces exposed to reactor coolant will be required for the AP1000. Similar treatment of the reactor cavity and the spent fuel pit surfaces will also be required. The benefits of passivation and a selection of the most effective process are still being evaluated for the AP1000.

For EPR electro-polishing can be utilised as well as polishing by other means, especially at weld junctions.

As part of an effort to reduce worker dose and emission, the ACR-1000 project is currently assessing various surface treatments to minimise corrosion and crud production.

Question D23: Improved leak tightness of fuel

Westinghouse fuel is under continuous and aggressive development toward a "zero leakage" goal.

AREVA-NP fuel is already improved and leaks are few.

AECL points to low CANDU fuel defect rates and advantages of CANDU reactors with respect to detection and on-power removal of defective fuel.

Question D24: External surface finishing of equipment and piping

The AP-1000 design has incorporated many innovative features which support the ALARA principles for ease of maintenance and decontaminability. Piping surfaces in areas where piping could become contaminated will be specified to facilitate decontamination.

AREVA-NP states that equipment and piping within the controlled area are designed to avoid cracks and nooks and ensure their surfaces are smooth to enable cleaning.

For ACR-1000 standard industrial instruments and materials of suitable types are used in general. Special materials, treatments, finishes, and dust-tight and air-conditioned enclosures are employed where necessary.

Question D25: Selection of insulation materials to minimise the production of radioactive and even mixed wastes

For AP-1000 the insulation within the containment and the auxiliary buildings is generally of the stainless steel reflective type which can be decontaminated.

AREVA-NP plan to use mineral wool protected by stainless steel covers so to reduce the potential for radioactive waste production from activation or contamination.

For ACR-1000 the focus is on separation of active and non-active systems. Also, thermal insulation materials enclosed in metallic jackets minimise surface contamination and the quantity of radioactive waste that will be disposed during decommissioning.

The JSR states that insulating materials should be selected from those that are commercially available.

Question D26: Selection of materials for structures that minimise activation products

As said previously Material used in ACR-1000 systems, components and structures in high neutron flux regions are carefully chosen to minimise activation products.

For the AP-1000 the design of the concrete mix is not yet finalised but will reflect the need to minimise activation products.

For AREVA-NP see question D27.

Question D27: Improved biological shield design to minimise activation

For AP-1000 the biological shield is designed such that all sections facing the reactor vessel are part of a structural module and thus present a steel decontaminable face. The material used will meet the cobalt free/low criteria.

For the EPR, the concrete surrounding the RPV is designed to withstand a severe accident and therefore this design has precedence. However, the concrete is analysed to ensure that long-lived nuclides are present only as traces. The concrete composition is, however, dependant on site aggregates. Furthermore, any additives in the concrete to reduce the neutron activation also have negative affects in other disciplines.

As part of the ACR design process, the expected dose from the different systems and components are used as input in the layout in various rooms. Proper shielding is provided to minimise worker dose and activation of surrounding equipment.

2.2 Requirements of electricity producers

The following electrical utilities responded to the questionnaire: British Energy, EdF, Fortum, KKG, and Vattenfall. Other responses included in this section are from SOGIN and the Joint Slovakia Response (JSR)

Question U1: Did you include specific requirements for decommissioning in your recent procurement specifications or do you intend to do it?

EdF states that certain specific requirements are included.

FORTUM states that they intend to include specific requirements. The draft regulatory guide STUK-YVL5.5 already requires that the plant design has to provide for decommissioning. FORTUM considers that EUR Chapter 2.16 may be used as a basis for requirements.

Vattenfall states that environmental aspects are included in the specifications. They have requirements for chemicals with a focus on reactor safety but there will also be benefits in relation to waste treatment.

KKG responds in the context of decommissioning of existing plant.

The JSR responds mostly in the context of an ongoing decommissioning project but suggests that VUJE will include specific requirements for decommissioning when ordering new waste treatment plant.

SOGIN states that specific requirements for decommissioning, such as easy decommissioning of the NPP in terms of feasibility, cost and occupational doses for workers, are requested at the time of NPP or other nuclear facility procurement.

Question U2: Have you performed or do you intend to perform an initial baseline characterisation of the site and buildings?

EdF states that an initial baseline characterisation of the site is performed.

Vattenfall responds in the context of characterisation of shutdown or still-operating plant.

Fortum states that there is no current plan to do so. However, they feel that this may be beneficial and, if so, they will elaborate on it in due course.

For KKG this matter is to be decided later. All data available today are based on the *Stilllegunsstudie* and on Nagra's *Modellhaftes Abfallinventar*.

SOGIN states that no baseline characterisation of site end materials was performed. Later facilities underwent Environmental Impact Evaluation which provides an exposition of hydrogeology. SOGIN believes that collected data should be sufficient to identify migration paths.

The JSR response is written solely in the context of ongoing decommissioning or planned decommissioning of already operating plant. It should be noted that, for the Bohunice A-1 plant, an initial characterisation of the site was performed after the accident that caused its closure.

Question U3: Do you develop initial decommission plans on which you assess the funds to be accumulated? Do you periodically update these on the basis of operating experience or do you intend to do so?

British Energy develops the plans and these are maintained and updated to ensure that the cost estimates are current and that the funds available to manage and discharge the decommissioning liabilities are adequate.

EdF states that the 2007 French regulations now require a decommissioning plan to be produced at the start of the licensing process.

Vattenfall states that the decommissioning fund for all NPPs in Sweden is managed by an independent entity, SKB.

FORTUM states that the funding is based on the decommissioning plans. According to the Nuclear Energy Act the decommissioning plan shall be presented every sixth year.

KKG develops the decommissioning plan. The update period is 10 years according to *Kernenergieverordnung, Art. 42.*

SOGIN states that, when the nuclear plants were built, there was no decommissioning plan and costs were based on international practice. Future cost estimates will require regulatory approval and will be based on a detailed decommissioning plan.

The JSR states that the decommissioning plan (including a funding estimate) for A-1 NPP has five stages and is updated every 5 years or less (a legal requirement). Initial decommissioning plans for VUJE waste management facilities have been developed and funding is likely to come from the Slovak National Nuclear Fund.

Question U4: Did you identify design and operational information relevant to decommissioning and do you assure proper record keeping of them?

Decommissioning plans of British Energy now specifically address the issue of knowledge management for decommissioning.

EdF states that Information relevant for decommissioning will be properly recorded.

Vattenfall indicates that there was no gathering of information-relevant-to-decommissioning prior to shutdown (at Barsebäck). The task of information gathering started after shutdown and was aided by a good records management system.

Fortum states that the relevant design documentation was identified when preparing the decommissioning plans. The periodical revisions of the decommissioning plans as well as the contamination development follow-up provide assurance that the operational experience will be taken into account.

KKG refers to Stilllegungsstudie.

SOGIN states that, for the plant currently being decommissioned, there were no requirements to keep records specifically for this purpose. Before starting any dismantling activity it has been found necessary to verify that the design and other information tallies with the actual configuration of the plant.

The JSR states that operational records have been used for A-1 NPP decommissioning but more essential is the information on post-accident conditions and the design of the plant. Record keeping is ensured by the operator of the facilities.

Question U5: Have you a configuration management program to assure proper record keeping of modifications to the plant?

For British Energy, the modifications to plant are subject to a strict change control procedure which includes identification of any which have an impact upon decommissioning liabilities. If significant, these can be immediately evaluated, otherwise they are incorporated into the subsequent update of the decommissioning plan for the power station concerned.

EdF states that the proper record keeping of the modifications of the plant will be ensured by the management system.

Vattenfall and FORTUM state similar provisions.

For KKG plant modifications are part of the management programme.

According to SOGIN experience in Italy, proper procedures were in place to record f modifications but, in practice, not all the modifications were recorded in the archive copy. Consequently, the information must be checked as described in response to question U4.

The JSR responds in the context of modifications in the course of A-1 NPP decommissioning where two accidents occurred prior to shutdown. The configuration management programme has been extended also to the decommissioning phase. The documentation showing the layout and configuration of the A-1 NPP buildings and facilities is continually updated.

Question U6: Do you perform (or intend to perform) periodic integrity verification of embedded piping potentially contaminated?

For British Energy, extensive NDT of vessel penetrations is undertaken to support the operational safety case.

FORTUM performs periodic integrity verification, the scope of which depends on the safety class of the piping. Thus all piping is not covered.

Vattenfall and KKG provide the same response: “yes” and “no”: “yes” because verification is included in the control programme; “no” because they do not perform it for all of the embedded pipes – it depends on the classification.

According to SOGIN (referring to decommissioned plant), such verifications were not envisaged during operation and there is no need for such inspections once the pipes have been drained after shutdown.

The JSR states that during operation of the experimental bituminisation facility (from 1985 to 1999) periodic verifications of integrity of embedded piping were done. With respect to decommissioning of A-1 NPP, the response does not say whether such inspections were performed during the operational period, which ended in 1977 (decommissioning started 1999).

Question U7: Have you access to systematic decommissioning lessons learned? Do you believe that such an activity to be carried out by the NEA could be useful for your plants?

According to British Energy, access to decommissioning lessons learned tends to be opportunistic, coming from personal contacts, conferences and publications. Invariably the information is incomplete and requires follow-up. They suggest that the national Decommissioning Authority (NDA) could help to spread best practice by systematising and circulating the information.

EdF has access to specific decommissioning lessons learned by bilateral agreements with other organisations involved in decommissioning. Nevertheless, an activity carried out by NEA could be useful.

Vattenfall says that Barsebäck has access to the EPRI decommissioning programme. NEA could develop a broader programme, which would definitely be useful.

Fortum believes it could benefit from better access to such experience.

KKG has access via the World Nuclear Association to lessons learned. At the time being no further access is needed.

SOGIN has little access to such information and encourages exchange of experience along the lines of WANO or IDN (IAEA international decommissioning network).

The JSR states that the A-1 nuclear power plant was built as an experimental plant; is non-standard and operated for a short period only and, accordingly, the opportunity for learning lessons applicable to other plant or for applying lessons from other plant is limited. Activities carried out by the NEA could be useful, but should not duplicate those provided by the IAEA (e.g. VUJE already participates in regional and national technical cooperation programmes in the fields of radioactive waste management and decommissioning).

Question U8: Do your safety authorities provide sufficient guidance on what is expected in terms of the use of experience gained from decommissioning projects?

British Energy believes that safety authorities provide sufficient guidance.

EdF believes they do not need more guidance from the safety authority for this topic. It also notes that, at the request of the French safety authority, one chapter of the preliminary safety analysis report is devoted to decommissioning and describes different arrangements taken to make further decommissioning easier.

Vattenfall states that the regulatory authorities do not provide sufficient guidance.

According to FORTUM, they have some guidance from the safety authorities.

KKG say this is difficult to answer because it is not yet involved in a decommissioning programme.

SOGIN states that in Italy non-specific guidance has been developed to address decommissioning activities. The authorisation process is currently the same as for construction of an NPP so that decommissioning activities are proceeding through case-by-case agreements with the regulatory body, which is time consuming.

JSR indicates that the regulatory authorities provide sufficient guidance.

2.3 Requirements of the regulatory authorities

The following regulatory bodies responded to the questionnaire: the CNSC (Canada), the HSE/EA (United Kingdom/England and Wales), STUK (Finland) and UJD-SR (Slovak Republic)

Question R1: Do you consider it necessary to develop decommissioning requirements and review criteria for the licensing of new nuclear power plants? How detailed is the information you require?

The CSNC responded in the affirmative but did not provide details.

The HSE/EA issued guidance[1-2] to the reactor vendors on "generic design assessment" (GDA), which relates to pre-licensing and pre-authorisation assessments of candidate reactor designs. The GDA requires estimates of annual waste and spent fuel arisings (both character and volume) plus details of spent fuel and radioactive waste management, and decommissioning. The depth of the information required may vary according to the significance of each issue to the design acceptance. Requesting parties should demonstrate that:

- The design and the proposed operation will avoid or minimise the generation of radioactive waste.
- Radioactive wastes will be safely stored pending disposal.
- Wastes are disposable.

HSE will also use existing criteria for licensing and decommissioning, which have recently been revised and published.[3-4]

1. See "Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs", Environment Agency, version 1 January 2007, available at publications.environment-agency.gov.uk/pdf/GEHO0107BLTN-e-e.pdf
2. See "Nuclear Power Station Generic Design Assessment – Guidance to Requesting Parties", Health & Safety Executive, Version 2, 16 July 2007, available at http://www.hse.gov.uk/nuclear/reactors/design.pdf
3. http://www.hse.gov.uk/nuclear/notesforapplicants.pdf
4. http://www.hse.gov.uk/nuclear/decomm1.pdf

STUK states that the application for a construction licence shall be supplemented with the description of the applicant's plans and available methods for arranging nuclear waste management, including the decommissioning of the nuclear facility and the disposal of nuclear waste, and a description of the timetable of nuclear waste management and its estimated costs. The description shall particularly include information on:

- How the decommissioning is taken into account in the plant design.
- Radiation protection optimisation during decommissioning.
- Minimisation of the decommissioning waste.

The application for an operating licence shall include all the above plus the decommissioning plan, which shall be detailed enough to serve as a basis for the estimation of the assessed liability.

UJD SR requires decommissioning to be addressed in increasing detail through the licensing process:

- A Reference Report on the Decommissioning Method attached to the written application for permission for siting of a nuclear installation.
- A Preliminary Conceptual Decommissioning Plan attached to the written application for building permission for the construction of nuclear installation.
- A (detailed) Conceptual Decommissioning Plan attached to the written application for authorisation for the commissioning and operation of nuclear installation; this is to be updated every 10 years.

These reports cover all aspects of decommissioning including methodology, waste generation (both radioactive and conventional), cost estimation, securing of funds, re-use of cleared materials.

<u>Question R2</u>: Do you require that decommissioning plans for new plants take any account of possible future developments in terms of clearance and release criteria?

The CSNC responded in the affirmative but did not provide details.

The HSE/EA states that this requirement would be reflected in the periodic reviews that operators of nuclear facilities would be required to carry out of their decommissioning and waste management plans (see response to question R3).

STUK states that regulatory guidance for clearance exists (Guide YVL 8.2) and it is upgraded regularly. It is generally required in the legislation that the amount of the decommissioning waste is minimised, and also waste management schemes must be updated regularly taking into account technological and other developments.

UJD-SR requires clearance and release criteria to be included in the Conceptual Decommissioning Plan which is updated every ten years. The update reflects, inter alia, amendments of generally binding legal regulations including conditions for release and clearance of radioactive materials.

Question R3: What is your role in defining decommissioning costs and controlling that fund accumulation is constantly updated, as necessary?

The CNSC states that Class I and Class nuclear facilities in Canada require a decommissioning plan and a financial guarantee. The licensee (applicant) defines the decommissioning costs in support of the financial guarantee. The CNSC provides guidance on financial guarantees. The decommissioning plan forms the strategic basis for establishing a financial guarantee and provides the outline for the subsequent detailed planning; it is reviewed and updated periodically, as necessary and this may change the amount of the guarantee.

Almost all existing UK nuclear facilities are owned either directly or indirectly by the state, which has responsibility for ensuring adequate funding for decommissioning. Operators of new nuclear power stations are required to have secure financing arrangements in place to meet the costs of decommissioning and waste management. A Funded Decommissioning and Waste Management Programme must be approved by the relevant Secretary of State before construction of a new nuclear power station can begin. Operators must comply with this programme thereafter and review it regularly. Funded Decommissioning and Waste Management Programmes have two main parts: technical and financial. The regulators are statutory consultees of the Secretary of State for approval of the programme and for any subsequent modifications. Further guidance on the content of such programmes is being prepared.

STUK gives its opinion to the Ministry of Employment and Economy on the safety of the decommissioning, dismantling and disposal techniques in the waste management scheme presented and upgraded regularly by the licensees. The Ministry confirms the assessed liabilities and sets the annual amounts to be paid to the National Nuclear Waste Management Fund based on the waste management schemes. Key points are:

- The licensee is responsible for all nuclear waste management measures and costs. The financial obligation is met through annual payments into the National Nuclear Waste Management Fund. Securities must be provided as a precaution against insolvency.
- The National Nuclear Waste Management Fund is controlled and administered by the Ministry of Employment and Economy and independent of the State budget.

- Estimation of the liability is made by the licensee based on the proposed waste management scheme and current prices and costs with allowance for reasonable uncertainty.
- The waste management scheme must be sufficiently detailed for the calculation of the assessed liability. The scheme must be approved by the Ministry before beginning the operations that produce nuclear waste.
- The licensee must regularly update the scheme, waste estimates, prices, costs and calculations and submit them to the Ministry.
- Before approving the waste management scheme and confirming the assessed liability the Ministry must obtain a statement from the Radiation and Nuclear Safety Authority (STUK).

The Slovak Atomic Act requires the authorisation holder to ensure that the earmarked funds can cover the decommissioning costs. The rules for creation and use of the resources of the decommissioning fund are established by law. The same law requires a "back-end strategy" to be prepared by the Ministry of Economy and approved by the Government. The strategy is updated every five years and aims to ensure that the needed "back-end" activities do actually take place and that the appropriate financial arrangements are in place. UJD-SR reviews the strategy and issues a public statement of its findings. UJD SR is also represented on the nuclear decommissioning fund board of governors and its advisory committee. Finally, the decommissioning licence holder requires a statement of support from UJD-SR when applying for funding from the nuclear decommissioning fund.

<u>Question R4</u>: Have you access to systematic decommissioning lessons learned? Do you believe that such an activity to be carried out by NEA could be useful for your responsibilities?

CNSC responds to both questions in the affirmative.

The UK regulators do not have direct access to such a system. However, the nuclear industry operates various LFE systems which we are able to access. They welcome developments of systems that share experience and enable learning.

STUK responds "no" to the first question and "yes" to the second.

UJD SR has access to systematic decommissioning lessons learned through interactions with the IAEA (WASSC, SADRWMS, DeSa/ FaSa), the OECD/NEA and WENRA.

Question R5: Please give references to regulations and/or guidance documents that address the above issues.

Canada

- Canadian Nuclear Safety Commission (CNSC)
  - Nuclear Safety and Control Act (NSCA)
  - Class I Nuclear Facilities Regulations
  - G-219: Decommissioning Planning for Licensed Activities
  - G-206: Financial Guarantees for the Decommissioning of Licensed Activities
- Canadian Standards Association (CSA)
  - Standard N294 (currently in development)

International standards on this topic, to which the Canadian documents are aligned.

United Kingdom

- "Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs", Environment Agency, version 01/01/2007, http://publications.environment-agency.gov.uk/pdf/GEHO0107BLTN-e-e.pdf
- "Nuclear Power Station Generic Design Assessment – Guidance to Requesting Parties", Health & Safety Executive, Version 2, 16 July 2007, available at http://www.hse.gov.uk/nuclear/reactors/design.pdf
- CM 7296 "Meeting the Energy Challenge: A White Paper on Nuclear Power", January 2008 Department for Business, Enterprise & Regulatory Reform. January 2008. See: http://www.berr.gov.uk/energy/nuclear-whitepaper/page42765.html
- Energy Bill 2008
- Health and Safety Executive, Nuclear Safety Directorate, The Licensing of Nuclear Installations, http://www.hse.gov.uk/nuclear/notesforapplicants.pdf
- Health and Safety Executive, Guidance for Inspectors: Decommissioning on Nuclear Licensed Sites, http://www.hse.gov.uk/nuclear/decomm1.pdf

Finland

Regulatory guides:

- YVL 7.18 Radiation safety aspects in the design of a nuclear power plant, 26 September 2003
- YVL 8.2 Premises for removal of regulatory control from nuclear waste and decommissioned nuclear facilities, 18 February 2008.
- STUK YVL 5.5 Management of low and intermediate level nuclear waste and decommissioning of nuclear facilities (draft).

Slovak Republic

- Act no. 541/2004 Coll. on Peaceful use of nuclear energy ("Atomic Act").
- Regulation No. 58/2006 Coll. on details concerning the scope, content and method of preparation of nuclear installation documentation needed for certain decisions.
- Regulation No. 53/2006 Coll. on details concerning requirements for management of nuclear material, radioactive waste and spent fuel.
- Act No. 238/2006 Coll. on National decommissioning fund for decommissioning of nuclear facilities and spent fuel and radioactive waste management ("national decommissioning fund").
- Act No. 355/2007 Coll. on The protection, promotion and development of public health.
- Government Regulation No. 345/2006 Coll. on basic safety requirements for health protection of workers and population against ionising radiation.

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