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ON DECOMMISSIONING

Analysis of the Factors Influencing the Selection of Strategies for Decommissioning of Nuclear Installations

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1 Introduction

Decommissioning is the final phase in the lifecycle of a nuclear installation, covering all activities from shutdown and removal of fissile material to environmental restoration of the site.

As many nuclear installations will reach the end of their lifetime during the next 20 years or so, decommissioning is an increasingly important topic for European governments, regulators and industries.

The decommissioning of nuclear facilities and the management of the materials and waste arising during decommissioning involve environmental, technical, social and financial responsibilities and choices. In the past, it was not always clearly defined who will bear these responsibilities. Until recently, decommissioning strategies and policies have often been decided on a case-by-case basis and there are marked differences within individual European countries.

The operator of a nuclear installation is usually responsible for the strategy and for providing the necessary resources for the decommissioning work and the management of the resulting radioactive wastes. Nevertheless, the decisions will be strongly influenced by national nuclear policies.

At national level, legal provisions may exist that include strategies for the decommissioning of nuclear installations. These provisions may define the responsibilities for the different activities involved and create mechanisms for the provision of sufficient financial resources to deal with the expenses arising from the various activities at each phase of the decommissioning process, including the long term management of radioactive wastes and spent fuel.

Understanding the key elements leading to the selection of a given strategy is necessary, inter alia, for a sound programming of the financial resources.

Significant variations between countries exist in the amounts of money involved in the decommissioning activities, not only as a function of the size of the industry but also because of variations in the methodology for estimating the costs of decommissioning. These costs depend largely on the chosen decommissioning strategies, on the methods for calculating future costs and on the assumptions made about the future evolution of financial variables.

Approaches to the regulation of financial resources for decommissioning also vary significantly between Member States of the European Union.

Improving the management of radioactive wastes and the development of common safety standards in Europe, covering the full nuclear sector, are major themes on the agenda of the European Commission. By the end of 2002 and early 2003, the European Commission adopted a set of five documents known as the "nuclear package" centred on maintaining a high level of nuclear safety in an enlarged European Union.

Some of these documents have special relevance to decommissioning and to the importance of creating appropriate decommissioning and waste management funds:

- A Communication from the Commission to the Council and to the European Parliament on "Nuclear Safety in the European Union" - COM(2002) 605 final.
- Two proposals for Council Directives (Euratom) on the management of spent nuclear fuel and radioactive waste and on the safety of nuclear installations, adopted by the Commission in January 2003 - COM(2003) 32 final.

Furthermore, in the context of the debate on the Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity, the European Parliament drew attention to the adverse effects that the misuse of decommissioning and waste funds for nuclear power plants could have on competition. Sufficient funds obviously have to be available to cover decommissioning costs, but it is also necessary to ensure that those funds are used only for those activities. During the debate on the international market two statements were issued that resulted in a political commitment of the Community institutions to favour the adoption of the above directive:

Inter-institutional statement

"The European Parliament, the Council and the Commission underline the need for Member States to ensure that adequate financial resources for decommissioning and waste management activities, which are audited in Member States, are actually available for the purpose for which they have been established and are managed in a transparent way, thus avoiding obstacles to fair competition in the energy market".

Commission statement

"The Commission notes the importance of ensuring that funds established for the purpose of decommissioning and waste management activities, which relate to the objectives of the Euratom Treaty, are managed in a transparent way, and used only for the said purpose. In this context, it intends, within the scope of its responsibilities of the Euratom Treaty to publish an annual report on the use of decommissioning and waste management funds. It shall pay particular attention to ensuring the full application of the relevant provisions of Community law".

The costs for the decommissioning of nuclear plants have been estimated by operators and by regulatory bodies considering the specific conditions in the different countries. The funds for the decommissioning of commercial nuclear facilities are in most cases collected by the operator who raises the money by means of a levy on the price of electricity during the operational lifetime of the plant. The decommissioning of research and defence facilities is paid by the taxpayer via respective governmental budgets. As payments for gradual decommissioning may be required over long periods of time, the amount of funds collected at the time of final shutdown may be discounted at a rate that takes account of the annual cost of safe storage. Such financing plans must rely on many decades of economic stability and wise long-term investment fund management, however.

The level of regulatory control over collection and management of the decommissioning funds varies considerably between Member States. In some countries the management of the accumulated reserves remains entirely in the hands of the plant operator, whereas in other countries these funds have been put under the control of a governmental agency. Reserves are also taxed in certain countries while exempted in others. This may be a reason for overestimations or underestimations.

2 Objectives of the study

The purpose of this study was to identify and analyse the factors influencing the selection of strategies for the decommissioning of nuclear installations in the 25 European Union (EU) Member States as well as in the Candidate Countries Bulgaria and Romania. In addition, Switzerland was included in the comparison as a non-European Union Country.

The study involved a thorough consultation of the affected stakeholders on the factors that have been taken into account in the process of selecting a decommissioning strategy for nuclear installations in the various countries.

The initial stage of the consultation was performed by means of detailed and appropriately pre-completed questionnaires that were sent to relevant sources of information among the affected stakeholders within the scope of the study. At the end of the initial stage the replies to the questionnaires were investigated in order to analyse a sufficiently large number of representative nuclear installations of different types (power plants, fuel cycle facilities, major research centres, etc.), different size and geographical coverage. Optimising the use of the available budget resources, the replies were subject of further consultations including, as appropriate, meetings with relevant stakeholders in order to draw objective conclusions and provide recommendations that would be representative, applicable and relevant to the overall objectives of the study.

The results of the consultation process were analysed separating items which are site specific from those which are common to most decommissioning projects.

The study also took into account relevant publicly available publications relating to the selection of strategies for the decommissioning of nuclear facilities, with the aim to avoid duplication of work and provide clear added value to the existing publications on the subject.

The aims and the tasks accomplished in the study are following:

- To identify the factors which have been taken into account in the process of selecting a decommissioning strategy.
- To highlight the actors which have been involved in the process as well as their role in a timely manner.
- To provide guidelines of general application for the selection of a decommissioning strategy that could be validated based on the experience collected within appropriate, representative and real decommissioning projects within the EU Member States.

As the financial aspects of decommissioning were a priority object of the study, the factors with greater impact on the cost of decommissioning were subjected to particular evaluations. The sensitivity of decommissioning costs to variations in the identified factors was analysed and described.

The study took into account the various current approaches followed in the EU Member States and in the Candidate Countries in order to constitute and manage funds for decommissioning. The study describes the different approaches and analyses specific advantages and disadvantages, and hazards in the long term to ensure that sufficient funds will be available when needed.

The study produces a detailed list of information that should be provided by the EU Member States in order to assist the European Commission (EC) in preparing an annual report to the European Parliament and the Council on the use of the decommissioning and waste management funds. The intention of this annual report is to verify that adequate financial resources for decommissioning and waste management activities are actually available for the purpose of which they have been established, and that these resources are managed in a transparent way, avoiding obstacles to fair competition in the energy market.

The study includes the most updated and reliable data concerning the decommissioning funds in the EU Member States. These data were obtained from publicly available sources and from experts of the relevant countries. They were assessed and used as input data for preparing a model for the related annual report on the status and use of the decommissioning and waste management funds to be submitted by the European Commission to the European Parliament and the Council.

3 Procedure

The work for the study was divided into the following phases:

1. Inception phase.
2. Data collection and assessment.
3. Presentation and comparison of findings.
4. Conclusions and recommendations.

3.1 Inception phase

The main objective of the inception phase was to get an agreement on a Detailed Work Programme that was subject of approval by the Commission services.

In practice, all major nuclear installations (i. e., nuclear power plants, nuclear fuel cycle facilities and major nuclear research centres) within the 25 Member States of the European Union were subject of the study. In addition, Candidate Countries Bulgaria and Romania were included in the scope of work and in a later phase, also Switzerland was included in the comparison as a non-European Union Country.

The objective of the inception phase was also to define the countries that had to be studied in detail as well as the major related facilities in these countries.

During the inception phase, also the planning for the implementation of the study, the identification of the affected stakeholders, the consultation procedure, the methodology for gathering data, the methodology for analysing the collected information and other working methods were established. This information was provided for the kick-off meeting that was held in Luxembourg shortly after the starting date of the contract.

As a result of the inception phase, a report with the Detailed Work Programme was delivered.

3.2 Data collection and assessment

3.2.1 Preparation of questionnaire

Data were collected by means of detailed and appropriately pre-completed questionnaires that were sent to relevant sources of information among the affected stakeholders in the different countries. The aim of the questionnaires was to collect information on the factors that influence the selection of strategies for the decommissioning of nuclear installations in the countries.

The questionnaire had a general part, including a request for information such as:

- The characteristics of the facility, such as the name, location, category, kind of facility, date of commissioning, date of final shutdown, date of start of the decommissioning activities, other information on the history of the plant relevant for decommissioning;
- The general decommissioning strategy in the country and the specific decommissioning strategy that was developed for the facility, including specific regulations or agreements with authorities or communities;
- The future use of the site;
- The general social considerations that have been addressed.

In addition, the questionnaires comprised a specific part, including a request for information relating to:

- Policies relating to decommissioning, such as:
  - Decisions on a nuclear phase-out and the consequences of such decisions on the decommissioning of facilities;
  - The distribution of responsibilities;
  - Funding mechanisms and the management of decommissioning funds;
  - The starting point of decommissioning activities;
  - The end point of decommissioning activities;
  - The licensing procedure;
  - Adopted time periods for deferred dismantling;
  - The involvement of stakeholders (Environmental Impact Assessment);
  - Waste management options and activities;
  - The availability of final disposal facilities;
  - The availability of release criteria, and the recycling of materials;
  - Possibilities for authorized re-use of materials;
  - The situation relating to trans-boundary material and waste movements;
  - The acceptance of foreign waste for processing, storage, disposal.
- Strategies relating to decommissioning, such as:
  - The role of the nuclear industry within the energy programme (e. g., liberalization of the electricity market);
  - The development and management of funds;
  - Elements of program management;
  - Considerations relating to project management activities;
  - Considerations relating to immediate or deferred dismantling;
  - Socio-economic considerations;
  - Possibilities for the re-use of sites;
  - Incentives relating to release and recycling of materials.
- Funding aspects, such as:
  - The accuracy of estimations of financial needs;
  - The availability of sufficient means to cover the programme;
  - The availability of funds at the moment they are needed;
  - Considerations about security and/or uniqueness of the destination of the funds;
  - The principle of unique collection of all financial means at start-up of plant operation;
  - The principle of continued raising of funds during the operational period of the plant;
  - The availability of insurances;
  - The principle of financing progress of a programme by means of current benefits from other plants;
  - The principle of annual or pluri-annual public endowments;

- The alternative for the internal management of funds (e. g., internal investments);
- The alternative for the external management of funds (e. g., bank, financial subsidiary, etc.);
- The possibility for transferring funds to authorities or an agency;
- Others.

When developing the questionnaires, adequate attention has been given to the two specific documents that have special relevance relating to decommissioning and the importance of creating appropriate decommissioning and waste management funds:

- A Communication from the Commission to the Council and to the European Parliament on "Nuclear Safety in the European Union" - COM(2002) 605 final.
- Two proposals for Council Directives (Euratom) on the management of spent nuclear fuel and radioactive waste and on the safety of nuclear installations, adopted by the Commission in January 2003 - COM(2003)32 final.

Furthermore, in the context of the debate on the Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the international market in electricity, the European Parliament drew attention to the adverse effects that the misuse of decommissioning and waste management funds for nuclear plants could have on competition. Sufficient funds obviously have to be available to cover decommissioning costs, but it is also necessary to ensure that those funds are used only for those activities.

Also other important documents of reference relating to the nuclear sector have been used, such as the European Commission's study reports on nuclear issues and in particular those related to the decommissioning of nuclear installations and those published on the same subject by relevant international organisations (e. g. NEA, IAEA, …).

All along the study, also the legal framework derived from the Atomic Energy Community (Euratom) Treaty has been considered.

The questionnaires were sent to the relevant organisations from the 25 Member States and the 2 Candidate Countries of the European Union as defined in Section 3.1, "Inception phase", as well as to the relevant organisation in Switzerland.

A reference copy of the questionnaire used for the collection of the necessary information and data is attached to this report as Annex 1.

3.2.2 Data collection

It was the aim to perform the initial stage of the consultation by sending a detailed questionnaire to all sources of information among the affected stakeholders, as mentioned in Section 3.2.1, "Preparation of a questionnaire".

It was recognised that all information required for the project could be collected and compiled through questionnaires to be sent to appropriate organisations. In the past, experience had demonstrated, however, that organisations do not respond expeditiously to requests for information that is readily available through sources of information such as annual reports and websites. As a result, it was proposed to provide appropriately pre-completed questionnaires for each decommissioning project using the readily available information.

Furthermore, to be effective and to respect the time schedule, it was important that the questionnaires were sent to individuals that were competent and prepared to provide the requested information.

In addition, during the initial phase of work, the European Commission requested the work to be co-ordinated with partially similar activities that had to be implemented in 2005 by the Directorate Transport and Energy of the European Commission. As a result, the questionnaires were reviewed and it was agreed that the adequately pre-completed versions were sent by the European Commission to the permanent representatives of the European countries and further to the assigned responsible persons in charge in each particular European Country. The respondents were asked to complete the answers not later than the end of e. g. July 2005.

3.2.3 Analysis of collected data

The information collected during this first phase was compiled into a database, the structure and the content of which was agreed during the kick-off meeting for the project. This database was considered to comprise the special information that was collected from all the affected stakeholders relating to the strategies, policies and funding principles for decommissioning adopted in the various countries/projects, paying adequate attention to the factors influencing the selection of strategies for decommissioning projects that should be further analysed.

At the end of the initial stage, the replies to the questionnaires were analysed in order to select a sufficiently large number of representative respondents that would be subject of an in-depth analysis, optimising the use of the available budget resources.

3.2.4 In-depth analysis

As indicated in Section 3.2.3, "Analysis of collected data", a selected number of representative respondents were subject of further studies and evaluations, including, as appropriate, meetings with these relevant stakeholders in order to draw objective conclusions and provide recommendations that would be representative, applicable and relevant to the overall subject of the study.

The results of the consultation process were analysed in order to collect them in a final report separating those which are site specific and those which are common to most of the decommissioning projects.

3.3 Presentation and comparison of findings

A detailed description is given of the results and the experiences collected during the consultation and analysis stages, including the conclusions that were drawn, the site specific issues and the generally applicable information relating to the adopted policies, strategies and funding for decommissioning in the various countries/projects.

The study took into account all relevant publicly available publications in relation to the adopted policies, strategies and funding for decommissioning, avoiding duplications and providing clear added value to any existing publications on the subject.

Based on the information obtained from the questionnaires, on more specific questions that were developed and on the information that was collected during visits to the most representative respondents, a data base was created as well as a report including the collected data and the important tasks reflected within the information. Detailed comparisons were carried out between the various countries/projects.

For the majority of the comparisons, tabulated summaries of the information were used. These were supplemented by summary statements relating to the main items in order to provide a broad overview. Where quantitative and semi-quantitative information have been obtained, tabulated comparisons were supplemented with graphical presentations that will aid comparisons between different decommissioning projects. In particular graphical presentations were used to show trends and commonalties.

In detail, the aim of the overview was to provide the relevant information relating to:

- The identification of the factors that have been taken into account in the process of selecting a decommissioning strategy.
- Highlighting the actors which have been involved in the process and their role in a timely manner.
- Analysing the financial aspects of decommissioning, analysing and explaining especially the factors with greater impact on the cost of decommissioning, including the sensitivity of the decommissioning costs to variations in the identified factors.
- Developing a guideline of general application for the selection of a decommissioning strategy that could be validated based on the experience collected within appropriate, representative and real decommissioning projects within the EU Member States.

3.4 Conclusions and recommendations

An overview of the analyses and conclusions as well as recommendations were drawn from the study which were taken from the most updated and reliable data, collected from public sources and experts from relevant countries, in order to use it as an input for preparing a proposed model of annual report from the European Commission to be submitted to the European Parliament and the Council on the status and use of the decommissioning and waste management funds.

4 Current developments relating to decommissioning policies, strategies and funding

A large number of nuclear power plants will require decommissioning in the coming years peaking around 2025 and extending to 2050.

Many other nuclear installations will also require, sooner or later, safe removal from regulatory control, like fuel reprocessing, isotope production facilities and other radiotherapy installations.

Each of these installations will require a study and the implementation of the optimum strategy for decommissioning, taking into account the large number of factors that may influence the way how these facilities should be dismantled. Reasons for choosing a particular strategy may be radiological and/or financial, but may also include factors like public acceptance and political considerations.

In the following sections, an overview is given of the current situation relating to the choice of a strategy for the decommissioning of nuclear facilities (not only for nuclear power plants) and describes various factors affecting this choice.

4.1 Decommissioning policy and decommissioning strategy

Some confusion may exist between the concepts of decommissioning policy and decommissioning strategy. A recent publication on *Decommissioning Policies, Strategies and Cost*, Ref. [1], of the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD), clarifies the issue:

- **Decommissioning Policy:** refers to government policy, and includes all governmental (national and regional) choices, as described in laws, regulations, standards and mandatory requirements that will influence the framework in which decommissioning takes place. For example, requirements regarding the use of decommissioned sites, waste management policies, policies for re-use and recycling of materials, public and worker health and safety policies, environmental safety policies, regional development aspects are to be seen as elements of the decommissioning policy.

  The review and analysis comprised in the current report is mainly based on answers to a questionnaire received from twenty-seven countries including twenty five EU Member States and two Candidate Countries (Bulgaria and Romania). In addition, Switzerland was included in the comparison as a non-European Country. A number of questions related to the decommissioning policy was included in the questionnaire (see Annex 1, questions QP1 - QP21). The answers to the questions on the policy related to funding mechanisms and schemes (QF1 - QF23) are analysed in Chapter 6.

- **Decommissioning Strategy:** refers to industrial approaches, and includes all aspects of decommissioning projects that are proposed to national competent authorities in the context of an application for permission to decommission.

  For the purpose of this report, a decommissioning strategy relates to how reactor site owners and operators apply the decommissioning policy. It covers specific plans and assumptions made in the context of decommissioning projects, particularly where this might have an impact and would influence the selection of a decommissioning strategy.

  In order to gather relevant information, a number of questions related to strategy and reactor site details were included in the questionnaire (Annex 1, questions QS I-1 to QS V-4). Information was requested for individual reactor sites, including:

  - Outline descriptions and data of the sites (nuclear power plants and other nuclear facilities;
  - What is included in the assumed scope for decommissioning;

- Which decommissioning strategies have been considered;
- The methodology for determining the preferred strategy and the main factors considered; and
- Dismantling and waste disposal plans.

All information that was provided in response to the questionnaire was collated and compared in order to assemble the summary presented in Chapter 6. In considering this summary, it should be noted that full answers were not always provided to every question for every reactor site or for every reactor and that there was some variability in how some of the answers were presented. Some countries provided data for reference or generic reactor types rather than for specific or named reactor sites. Consequently, the trends reported below should be considered to be indicative while individual data illustrate the variability of the information provided.

4.2 Decommissioning alternatives

A distinction should be made between the three **decommissioning stages**, that were earlier proposed by the International Atomic Energy Agency (IAEA), and the currently used **decommissioning strategies**: immediate dismantling, deferred dismantling and, in special cases, in-situ entombment.

The stages represent the intermediate or the end state of the decommissioning process, while the decommissioning strategy defines the different ways and operations to reach the stages formerly defined by the IAEA.

4.2.1 Decommissioning stages

Late in the 1980s and early in the 1990s, the IAEA identified three decommissioning stages. The definition of these stages (identified as Stages 1, 2 and 3) was not completely clear. The end point of each stage was even less clear. There was some confusion as to what each stage meant and some did not result in a final solution, Ref. [2].

In the mid of the 1990s, the IAEA adopted three decommissioning strategies: immediate dismantling, safe enclosure and entombment. These strategies have been well defined and are currently used in all IAEA safety standards.

Therefore, the "stages" are described here for completeness and for comprehension of existing literature, Ref. [3].

Each of the three decommissioning stages of a nuclear power plant can be defined by two parameters as follows:

- The physical state of the plant and its equipment.
- The surveillance, inspection and tests necessitated by that state.

4.2.1.1 Stage 1 decommissioning

The first contamination barrier is kept as it was during operation, but the mechanical opening systems are permanently blocked and sealed (valves, plugs, etc.). The containment building is kept in a state appropriate to the remaining hazard and the atmosphere inside the building is subject to appropriate control. Access to the inside of the building is subject to monitoring and surveillance procedures. The unit is under surveillance and the equipment necessary for monitoring radioactivity both inside and outside the plant is kept in good condition and used when necessary and in accordance with national legal requirements.

Inspections are carried out to check that the plant remains in good condition. If necessary, checks are carried out to see that there are no leaks in the first contamination barrier and the containment building.

4.2.1.2 Stage 2 decommissioning

The first contamination barrier is reduced to minimum size and all parts easily dismantled are removed. The sealing of that barrier is reinforced by physical means and the biological shield in a reactor is extended if necessary so that it completely surrounds the barrier. After decontamination to acceptable levels, the containment building and the nuclear ventilation system may be modified or removed if they are no longer required for radiological safety.

Depending on the extent to which other equipment is removed or decontaminated, access to the former containment building, if left standing, can be permitted. The non-radioactive buildings or equipment in the plant may be converted for new purposes. Surveillance around the barrier can be relaxed but it is desirable for periodic spot checks to be continued as appropriate, together with surveillance of the environment. External inspection of the sealed parts should also be performed.

4.2.1.3 Stage 3 decommissioning

All materials, equipment and parts of the plant in which activity remains significant despite decontamination are removed. In all remaining parts contamination has been reduced to acceptable levels. The plant and site are cleared for unrestricted use. From the point of view of radiological protection, no further surveillance, inspection or tests are necessary. In some cases the whole plant, including inactive components, may be dismantled to make room for a replacement facility or other usage.

These stages may be carried out by rapidly progressing from one stage to the next or be carried out over a prolonged period lasting as long as 100 years or more. Although most countries intend to complete all three stages, a facility could remain at stage 1 or stage 2 for a relatively long period of time, or decommissioning could proceed directly from stage 1 to stage 3.

4.2.2 Decommissioning strategies

As mentioned before, in the mid of the 1990s, the IAEA adopted three decommissioning strategies as described in the following paragraphs. These strategies have been well defined and are currently used in all IAEA safety standards, Ref. [2, 3, 4, 5].

The actual strategies used to decommission a nuclear facility are usually variants of the following.

4.2.2.1 Immediate dismantling

The implementation of the immediate dismantling strategy normally begins very soon after shutdown of the plant, usually within five years. All radioactive material above a specific level is removed and the end point of the project is that the site or facility can be cleared or used without any regulatory restrictions. This strategy allows current work force to be used to perform the decontamination and dismantling activities. This work force, although reduced from the operating phase, remains fairly constant during the period. This option does not allow for any significant decay of radio-nuclides. It also implies that waste and spent fuel management, as applicable, must be available. This does not mean that a disposal site must be in place, but some type of waste management system (i. e., interim storage) must be available. Of course, the funding must also be available to allow the resources to be committed. This is the option preferred by the IAEA.

4.2.2.2 Deferred dismantling (or safe enclosure)

There might be a case where the final disposition of the facility may be delayed for a period of time. This decommissioning strategy is called safe enclosure (or sometimes Safestore). The facility is placed into a long term storage condition for up to 50 years, followed by the final decontamination and dismantling of the facility to allow removal of all regulatory control. To allow this storage period to occur, all of the liquids are drained from the systems, any operational waste that has been collected during the operational period is removed and areas not normally in need of access during the storage period are secured. This option does not allow for the decay of radio-nuclides, but this is not normally the primary reason this strategy is chosen.

There are many advantages to this option. Some minor decontamination may occur and allow the boundary or "footprint" of the controlled area to be significantly reduced, which will save money and other resources over the period of 50 years. Portions of the facility or site may be used for other purposes.

Large exclusions or buffer zones are no longer needed. This option also allows for the collection of funds over the safe enclosure period.

There are also some disadvantages to this strategy. The work force will be drastically reduced during the storage period. This means that the operational workers will have to find other employment. When the final phase approaches, workers will have to be rehired, but after 50 years, most of the experienced personnel will not be available. Also, as the operational workers leave the plant, the facility and operational knowledge leaves with them. There must be some system in place to capture and retain this knowledge.

Spent fuel may also be an issue. It is preferred that all spent fuel is removed from the site before the long-term storage period begins. This reduces the safeguards and security concerns and allows for a large reduction in the overall risk of the facility. It also reduces the number of systems that must be maintained to ensure safety during the 50 year period.

The safe enclosure option is normally selected if a national waste management strategy is not in place. This option is also selected if sufficient funds are not available to support the dismantling activities. It may be the preferred option if there are multiple facilities on the site which will require decommissioning. This allows better allocation of resources when they are needed, because workers can go from one facility to the next performing decommissioning activities and the work force remains more stable.

4.2.2.3 Entombment

The third decommissioning strategy is entombment. In this situation, the overall controlled area is reduced and the remaining radioactive material is encased on-site, normally in concrete. The remaining structure must be monitored and maintained for a period of time. This site essentially becomes a near surface waste repository. All the requirements for such a waste repository will have to be met, including the siting and design requirements. It has been found that most sites for nuclear facilities will not meet these requirements.

However, this may be an acceptable option for countries with very small nuclear programmes, just including a research reactor.

4.2.2.4 Variations

Although the assumed strategies tend to be classified as either "immediate dismantling" or "deferred dismantling" there is quite a variability within these two categories. For example, some utilities are proposing what could be considered to be "rapid" immediate dismantling, with all work being completed in about 10 years, while others are considering a more prolonged dismantling period of 20 to 40 years, but still classifying this as immediate dismantling, Ref. [1].

Under the deferred dismantling option a variety of deferral or dormancy periods are being considered which result in dismantling being completed in periods ranging from about 40 to around 100 years. There is also a variability in the extent of the plant for which dismantling is to be deferred. On some sites, it is effectively the dismantling of significant radioactive parts of the plant and the structures such as the reactors that is to be deferred, with all other parts of the plant and buildings being dismantled on an "immediate" basis. Also, in a deferral strategy, the extent of work and on-site staffing assumed is that 24 hour on-site staffing is required while others assume that some measure of remote surveillance is allowable. Some utilities consider that, following a deferral period, radiation levels will have reduced sufficiently to allow simpler reactor dismantling technologies to be used, e. g. that fully remote operations will not be required. This is particularly the case for gas-cooled, graphite moderated reactors, Ref. [1].

4.2.3 The "No action" strategy ("Wait and see")

Ref. [6] describes the risk of the "No Action" strategy in the case of the decommissioning of smaller nuclear facilities. In all cases, this strategy should be avoided by careful planning and funding:

"Following the permanent shutdown of a nuclear facility a hazardous situation can eventually arise if no action is taken. The no-action strategy is unfortunately common practice for many shutdown small facilities, and often occurs because they can, by their nature, be easily shut down for periods of non-use or maintenance but thereafter never restarted for commercial, obsolescence or other reasons. No action being taken often results from the erroneous perception that the risks associated with the shutdown facility are trivial and therefore can be disregarded. In other cases no action being taken may be due to a lack of funds for the decommissioning of the facility. Eventually, no action being taken may end up with the abandonment of the plant".

4.3 Reasons for premature shutdown of a nuclear facility

The reasons for premature plant shutdown could have implications on the strategy for the planning of decommissioning activities. The reasons for premature plant shutdown can be technical, economic, safety related or political.

Ref. [7] indicates that among the technical reasons, obsolete technologies and out of date equipment play the major role. Uneconomic operation may represent another reason for facility closure and subsequent decommissioning (e. g., the operating costs are too high). The closure of a facility for safety reasons could occur if, for example, the regulatory body requires conformance with new standards and these improvements cannot be justified economically. In addition, the facility may have undergone a serious accident making refurbishment and restart too costly. Political decisions to stop nuclear power generation can also lead to the premature shutdown of nuclear installations (Italy, Sweden, Germany and Belgium).

Ref. [8] analyses the non technical factors influencing the closure of a facility:

- Changes in safety philosophy;
- Changes in regulation;
- Extension of facilities' useful life;
- Operational and decommissioning costs;
- Political and socio-economic aspects;
- Decommissioning strategies.

The study reviews the influence of these factors on the useful life of nuclear power reactors and research reactors and not only on the closure of the installations.

"Nuclear safety, costs, political aspects and increasing competitiveness in energy production may force the operators to a premature shutdown of their nuclear power plants. On the other hand, there is a trend to extend reactor life times as far as possible, also for economic reasons and for energy needs, as well as attempts to decrease greenhouse gases.

The situation of research reactors is somewhat different: the current retirement rate of research reactors is rather due to the completion of research and experimental programs or to safety considerations than to economical and political aspects".

4.4 Factors influencing the selection of a decommissioning strategy

A number of factors must be weighed and balanced when preparing the decommissioning plan for a nuclear power plant. The plan will vary with each facility and these factors must be evaluated on a case-by-case basis.

The factors to be considered when selecting the optimum strategy for the decommissioning of the nuclear facility include the national nuclear policy, the characteristics of the facility, health and safety, environmental protection, radioactive waste management, future use of the site, improvements of the decommissioning technology that may be achieved in the future, costs and availability of funds for the project and various social considerations.

The relative importance of these factors has to be judged on a case-by-case basis and will vary according to the facility considered. Besides nuclear reactors, there are in most countries large numbers of other industrial and research facilities which will require decommissioning in the next years and decades.

It can be observed from literature that an increasing awareness exists of the importance of the non-technical factors on the selection of a decommissioning strategy, in addition to the technical elements that were the major concerns so far.

The following list identifies the issues that seem to be particularly relevant to the selection of a strategy, other than the obvious issues of safety and the availability of practical decommissioning techniques:

- The basic decommissioning options; the scope of the decommissioning activities.
- The reactor type; the reactor size; the number of units on a site; the operational history.
- Project planning; analysis of material flow.
- Regulatory and policy requirements (timing; clearance criteria).
- Socio-economic issues.
- Waste management provisions.
- Funding arrangements.
- Staff availability and personnel issues.
- Knowledge retention.
- Site reuse.
- Strategy selection process (e. g., multi-attribute analysis, …).
- Stakeholders; decision makers, regulators and the public.

4.4.1 Decommissioning policy and regulatory requirements

Decommissioning policy, as explained before, refers to the government policy, and includes all governmental (national or regional) choices, as described in laws, regulations, standards and mandatory requirements that will influence the framework in which decommissioning takes place. For example, requirements regarding:

- the disposal of shutdown nuclear facilities,
- the use of decommissioned sites,
- the responsibility of the decommissioning: industry or government,

- the national radioactive waste management policy,
- the national policies for re-use and recycling of materials,
- the national policies for public and worker health protection,
- the environmental, safety, and regional development aspects,

are to be seen as factors influencing the decommissioning policy.

Member States legislative and regulatory requirements may to some extent dictate the strategy to be followed and may take into account any or some of the factors mentioned. These requirements may prohibit certain strategies from being considered. They may also impose certain conditions such as time limits on safe enclosure phases.

For example, in Japan, the national policy prescribes immediate dismantling after shutdown and the completion of the decommissioning activities 30 years after they have been started. This position reflects the scarcity and the limited size of sites suitable for the construction of new nuclear power plants, and the willingness to solve the decommissioning issues by the generation which took advantage of the nuclear electricity generation plants.

Another example on how national policies and regulations have affected decommissioning and dismantling technologies is in Germany where the Atomic Energy Act favoured the recycling of dismantled radioactive components unless this was opposed for major technical, economical or safety reasons. This situation resulted in the development of a set of regulations for the restricted/unrestricted release of radioactive materials and in the establishment of industrial infrastructures, e. g., melting facilities, which in turn influence the strategy chosen for decommissioning and dismantling, its costs and its timing.

The type of legislation which is developed to implement the decommissioning requirements depends very much on the legal system in each country. In some systems, legislation is goal setting. In other cases, legislation is very detailed and prescriptive. In addition, there may be regional requirements. For example, within the European Union, relevant Directives on radiation protection and environmental impact assessment must be incorporated into the legislation of the Member States. The way this is done will depend on the individual legal system of a State.

Therefore, it is clear that the regulatory regimes in different countries vary markedly; however, they share the overall objective of safe decommissioning.

It must be noted that the proposed EC Safety Directive included in the Nuclear Package makes no proposals concerning the choice of the strategy for decommissioning to be followed, neither for the time decommissioning starts or the speed at which it is activated, nor for the status of the site at the end of the process.

Nevertheless, the EC considers that there is a need for a Community Strategy on decommissioning aiming at the development of a common approach in Member States and encouraging them to work towards the harmonization of decommissioning strategies and practices wherever possible, Ref. [9].

Through the survey performed in the 28 countries there is an indication that in more than half of the responding countries, the utilities/operators are explicitly requested to perform a broad strategy optimization before selecting a decommissioning plan. In some of these countries, guidance is given on how to perform this optimization. It should be observed that some of the responding countries remark that even if no formal request exists for a strategy selection, such optimization is assumed to be performed.

Further, the survey reviewed who is responsible for selecting the decommissioning strategy. Most utilities/countries identified that it is the responsibility of the utility/operator, but a few indicated that the decision is made by the Government.

In a global evaluation of the factors influencing the selection of a strategy it could be seen that the operators have taken their decision based on the factors linked to the regulatory requirements, which are:

- Public and worker protection;
- Protection of the environment;
- Material management and clearance practices;
- Waste minimization;
- Existence of waste management facilities, including disposal;
- Availability of funding.

An additional regulatory factor that could influence the strategy chosen by the operator of a nuclear installation is the uncertainty on the stability in the long term of the given legislation. An operator can never be sure of the stability of the existing legislation, although he can be sure that if there is a change, it will lead to more strict constraints and higher costs.

Ref. [10] gives the outcome of an international seminar held in Tarragona, Spain, in connection with the entering of the Vandellós-I nuclear power station into the safe enclosure period. The seminar focussed on strategy selection for the decommissioning of nuclear facilities.

During the seminar the question about the role of regulators in selecting a decommissioning strategy was raised. It was stated:

"The answer is not simple and varies from country to country. In Spain, the responsibility finally rests with the Governmental Authority. It was noted, however, that in general the regulators must deal with various aspects and must have a broad understanding of the whole process".

Other valuable information on the subject of strategy alternatives and the impact of regulations can be found in the proceedings of the international conference held at Berlin in October 2002 on the *Safe Decommissioning for Nuclear Activities*, Ref. [2], and in IAEA Ref. [11] whose section 4.1 gives a number of reference works and studies related to the subject.

It can be concluded that the selection of a decommissioning strategy depends on many factors that are often specific to the country, to local policy, to Governmental guidelines or policies, etc. There is no "universal" good strategy and the selection has to take account of various parameters while ensuring that decommissioning operations are undertaken safely.

4.4.2 Public and worker protection

The requirements imposed by the legislation on Radiation Protection and Industrial Safety on the decommissioning process will also influence the selection of a decommissioning strategy.

4.4.2.1 Influence of radiological protection on the selection of a decommissioning strategy

A primary concern in any decommissioning programme is to ensure health and safety of the workers and to protect the general public and the environment.

Public exposure and environmental impacts are expected to be minimal and well within the regulatory limits for operating facilities. Therefore they are not likely to be significant factors in selecting a decommissioning alternative, Ref. [12].

However, protection of the decommissioning workers is an important consideration and significant effort is made in all nuclear operations to keep the exposure as low as reasonably achievable. A cost-benefit analysis should be carried out to determine to what extent delayed dismantlement will have a positive effect. Although this depends on the physical state of the nuclear facility, as well as on the available resources and equipment, the property of radioactive substances to decay has led to the suggestion that there is some advantage in leaving the plant or buildings in care and maintenance for periods of time on the grounds that this will make eventual decommissioning safer and easier. This argument may be valid for short-life radio-nuclides in situations where the material can be contained and physical deterioration will not make the decommissioning task more hazardous. Examples may be structures that have been contaminated with nuclides such as ^{60}Co (half life of 5.3 years). On the other hand, reprocessing plants are contaminated with long-life nuclides such as plutonium, and may therefore not benefit from decay but clear "disbenefits" may result from the in-growth of daughter radio-nuclides such as ^{241}Am, Ref. [2].

The role radiological factors play in the selection of a decommissioning strategy is described in Ref. [13] for Pressurised Water Reactors (PWR), Boiling Water Reactors (BWR) and Magnox reactors and also for non-reactor nuclear facilities. In Ref. [13] it is shown that in a PWR reactor vessel, the radioactivity level decreases by a factor of 17 after 30 years of decay. The same reference indicates that a total dose rate experiences a decrease of 50 after 30 years and of 1,000 after 50 years.

On the other hand, the reference shows that the occupational exposure from the decommissioning of a PWR does not follow the same reduction rates (theoretical studies, values given in man-sievert). Indeed:

"In areas of high radiation fields, manned access may be precluded. In such instances, application of remotely operated techniques including robotics can minimize occupational doses. Alternatively, manned access would be possible in areas with reduced radiation fields, potentially resulting in higher occupational exposures. Therefore, correlating occupational doses with the length of a safe enclosure period is not a straightforward exercise".

Nevertheless, a deferred strategy could lead to a reduced cost if expensive remote control tools can be avoided. This is to be compared with the future labour cost and the time spent on the dismantling activities.

On the other hand, deferred decommissioning will significantly raise the maintenance and surveillance cost.

Delaying decommissioning beyond 100 years would not achieve additional benefits, as the decay rate of the radioactive substances is significantly slowed by then. Furthermore, surveillance beyond 100 years cannot be relied upon.

On the whole, when choosing a decommissioning strategy, a radiological impact should be made to determine:

- The individual and collective doses (i. e., the total dose over a population group exposed to a given source) to workers during the dismantling activities, including waste handling.
- The individual and collective doses to the public throughout the operations including those produced by waste disposal and activity remaining on site.
- A risk assessment of the possibility of a fire or explosion, of a possible deterioration of the installation or of the possible loss of integrity of the containment barriers, leading to the release of radio-nuclides to the environment.

4.4.2.2 Influence of non-radiological risks on the selection of a decommissioning strategy

Here again, the conventional safety of the public and the workers will not be a factor that has a high impact on the selection of a decommissioning strategy as it is assumed that the operations will be implemented within the context of national legislation protecting the public and the workers like in any other industrial operation.

Nevertheless, if periods of care and maintenance to allow for radioactive decay are included in the strategy, the containment of radioactive material and the integrity of the structures may become key safety issues to protect both the workforce and the public. The deferred dismantling activities can be affected by the ageing of materials and buildings and may require additional protection of the workers; the period of care and maintenance may impose specific monitoring programmes and a contingency plan to remediate specific hazards like flooding or water intrusion.

4.4.3 Protection of the environment

This factor is linked to other factors impacting the selection of a decommissioning and dismantling strategy which are analysed in following parts of this section (4.4.4, 4.4.9, 4.4.10, 4.4.12).

In order to keep consistency, the following paragraphs will only deal with the specific issue of the Environmental Impact Assessment (EIA) and its impact on the selection of a decommissioning strategy, while the environmental protection effects related to each of the other related factors can be found in the following relevant parts.

In the European Union it has been mandatory since 1988 (Council Directive 97/11/EC of 3 March 1997) that an EIA is undertaken prior to consent being given to begin construction of a commercial nuclear power plant, although it is recognized that some Member States carried out EIAs for nuclear power plants much earlier, e. g., in France in 1977. That specific assessment should address impacts during the complete life cycle of the plant including the decommissioning phase. Alongside the EIA process, Member States have separate licensing procedures under the nuclear safety legislation, requiring the development of a Safety Case for the plant. The Safety Case comprises the arguments provided by the developer to demonstrate to the relevant authorities that the plant can be operated and decommissioned in accordance with the requirements of the Member State. This should be a "living" document, i. e., it needs to be kept up-to-date throughout the lifetime of the facility, in order to reflect the actual state of the plant. Associated with the Safety Case there is normally a "decommissioning plan" which inevitably becomes more detailed as the decommissioning phase is approached.

Key considerations relating to an EIA for the decommissioning of a nuclear facility can be found in proceedings of a workshop organized by the European Commission on the "Current Regulatory Status of the EU Member States and Applicant Countries" concerning "Environmental Impact Assessment (EIA) for Decommissioning of Nuclear Installations", Ref. [14]. Among others, the following subjects, most applicable to the selection of a decommissioning strategy, are treated in this very extensive report:

- EIA information on the decommissioning alternatives;
- Role of EIA in decommissioning;
- EIA process: screening, scoping and selection of preferred alternatives, impact minimization and mitigation, monitoring;
- Cost and resources implications.

In particular, for the selection of a decommissioning strategy, Ref. [14] recommends that a preliminary qualitative assessment of feasible alternatives be undertaken against selection criteria developed through a stakeholder dialogue process. Those not meeting the selection criteria should be discarded and the others scoped for potential environmental impacts. This process, undertaken in conjunction with ongoing dialogue should be used to reduce the number of options to one or a few preferred alternatives, as well as establishing the impact factors for assessment.

The history, current status and anticipated future evolution of the nuclear facility and the associated buildings should be investigated. This should include investigation and assessment of the operating history, waste management practices and consequences of normal operations and any non-routine events leading to environmental consequences.

The proposed development and the alternative options should be presented in terms of the project plan, key activities, description of principal engineering works, waste arising and the environmental situation at key stages such as completion of dismantling of plant systems in buildings peripheral to the reactor building.

The key features of the alternatives must be defined, concentrating on those issues identified as being significant in terms of the selection of alternatives for further assessment. A record of design decisions, and the reasoning behind them should be maintained. The justification for key decisions should be recorded in the EIA.

4.4.4 Public acceptance

In Ref. [9], one of the greatest challenges in nuclear decommissioning is described:

"The final dismantling of a nuclear installation as part of a global environmental restoration strategy is of great concern to the public. They are worried about what will happen to the waste and about any lengthening of decommissioning time-scales. In addition, there is concern about leaving our waste to future generations. Even if the existing decommissioning regulations and procedures protect workers and the general public, they still need to be informed of the preventive measures taken. Decommissioning operations and the related strategy decisions should be undertaken with transparency, the involvement of the public and openness to their concerns".

Through a survey organized at an international seminar on "Strategy selection for the decommissioning of nuclear facilities" in Tarragona, Ref. [10], the seminar attendees identified the issues of "early discussion with plant stakeholders" and "continued dialogue with local communities" as of significance and requesting further attention from the international community.

Ref. [15] indicates that the process of deciding between the different decommissioning strategies may take into consideration the possible effects of "the public's perception of the hazards, whether the installation is maintained in a safe shutdown condition or is dismantled".

It also analyses the public opinion about the proposed choice in the final strategy to be adopted, the influence of stakeholders such as community members, the media, activists, political and business leaders, and the employees themselves. Challenges that are to be confronted in this area are firstly, that the employees are well aware that the plant staffing will be dramatically reduced shortly after or within months of shutdown and secondly, that the decommissioning process involves "working oneself out of job". Pre-planning can blunt the negative impact of both. This should be factored into the nuclear power plant life cycle human resources strategy discussed earlier.

Other references raise the issue of the social and economic situation around sites of nuclear facilities where it is not uncommon to have the nuclear facility support up to 50'000 local inhabitants who are linked directly or indirectly to the operation of the site. Concerning the on-site employment, immediate dismantling requires a larger staff and work force than other strategies, resulting in a slower and smoother reduction of the operations staff.

4.4.5 Technology, feasibility

Few references indicate the availability of technology as a major factor influencing the selection of a decommissioning strategy. On the contrary, the strategy chosen may have an impact on the development of new technologies necessary for the dismantling of facilities, their characterization or their decontamination.

Immediate decommissioning will lead to the development of remote control equipment or robotic systems that can access difficult to reach areas of the plants with the objective to reduce the radiation exposure to the personnel.

A deferred strategy will initiate the development of programmes aiming at a better understanding of the degradation of buildings and structures with time and of the ageing process taking place in a known (and controlled) environment.

4.4.5.1 Technology as a factor relating to the selection of a decommissioning strategy

While the stages of decommissioning and the end state of the facility are mostly governed by regulatory, economic or environmental issues, the strategy to reach these conditions depends on factors like the existence of decommissioning funds or the availability of the requested and financially sound technology.

The existence of adequate technology in a given country faced with a specific decommissioning plan, early elaborated and well substantiated, will lead to an immediate dismantling of the facility if in addition, the necessary repositories exist and will be able to handle the type and the level of wastes generated by the decommissioning and dismantling operations.

The lack of technological means may influence the strategy by deferring the dismantling to later times, hoping that the technological development will tackle the issues in the future. This could result in a deferred dismantling scenario, as illustrated by the decision to select the safe enclosure option for the French gas-graphite reactors G1, G2 and G3, Ref. [13], or to the extension of the life time of the facility if the safety assessment of the plant has confirmed the viability of this alternative, Ref. [15].

Long term safe enclosure does not usually require sophisticated decommissioning and dismantling methods and techniques. But the dismantling operations performed in the extended future could prove to be more difficult than expected due to the degradation of equipment, if proper studies have not been developed to predict these mechanisms, Ref. [11].

This situation can also evolve in countries where the technological development has not followed the ageing of the production facilities and/or were not disseminated through the nuclear industry.

A mixed approach could prevail in several countries which consist of using one or two shutdown facilities for the purpose of developing the technology while leaving the other facilities under safe enclosure for a stipulated period of time.

4.4.5.2 Issues considering decommissioning and dismantling related to the choice of a strategy

It is widely accepted in the decommissioning and dismantling industry that the current technology is adequate for today's decommissioning needs. Many decommissioning projects have been achieved throughout the world demonstrating this fact as clear evidence in the industrialized countries.

Technological issues exist not only for the dismantling of nuclear facilities, but also for the treatment of the wastes generated during the decommissioning and dismantling activities. Examples of areas where technological development are needed can be found in Ref. [16]:

- The measurement to clearance levels of activity contamination in inaccessible areas of contaminated equipment.
- The measurement of clearance levels for alpha contamination.
- The treatment and disposal of specific decommissioning wastes, particularly medium and high activity materials.
- The treatment of special materials, e. g., beryllium, graphite.

- The treatment of wastes that could require special disposition provisions.
- The decontamination factor of melting facilities.
- The radionuclide inventory in reactor areas/components.

The selection of a decommissioning strategy could be influenced by the decision to pursue or not the necessary research and development efforts that would decide on one option or the other: a large national decommissioning or environmental restoration programme is more likely to embark on research and development works aiming at verifying general cost reduction, improved safety or waste reduction effects of one strategy or the other. A country with a small number of facilities may prefer to use or adapt technologies available in the commercial sector. This choice will also depend on the timing of decommissioning, i. e., if it is envisaged that decommissioning will take place in the near future or in the longer term, Ref. [11].

In general, the choice of the prevailing decommissioning options depends on a large variety of factors but it appears that the type of reactors is not a major factor influencing the decision, despite the technological differences between them. Ref. [10] shows a clear example of the observation that "one size does not fit all in decommissioning": in the United States of America, with the same regulatory framework and similar plant types, 8 nuclear power plants have selected a safe enclosure strategy while 11 have selected prompt decommissioning as the preferred strategy.

The list of retired reactors and their status of decommissioning or the intended strategy (Ref. [10]), shows that water cooled reactors (PWR, BWR, WWER, CANDU) can be either decommissioned immediately (before 10 years after final shutdown) or after a period of safe enclosure (25 to 40 years) depending on other factors than the "type of facility".

An example of the impact of the design of a nuclear power plant on the strategy relating to decommissioning and dismantling can be found in the special case of the WWER 230/213 (Greifswald) where the structural conditions - simple roof over the reactor, no containment - leaves little choice but early dismantling. The costs and efforts necessary to upgrade the facility for the isolation and containment of radioactivity during a long deferred period would be prohibitive.

Gas cooled reactors are generally dismantled after a period of safe enclosure due to the higher complexity of their design, the presence of quantities of graphite, the limited possibilities to decontaminate the systems and to work under water. In these cases, there is interest in delaying the decommissioning activities to benefit from the dose reduction in a complex environment.

Ref. [13] gives a summary of selected decommissioning strategies for various types of reactors and comprehensive descriptions of selected cases of safe enclosure.

The strategy chosen for the decommissioning of the Nuclear Power Plant Stade in Germany, a privately owned PWR that was shut down by the end of 2003 because of a Government commitment to phase out nuclear power was immediate dismantling. This option was preferred because there was little difference between immediate and deferred dismantling in terms of final waste volumes or dose commitment, and it enabled the activities to be implemented by the existing staff.

The decommissioning of the Jaslovske Bohunice V1 Nuclear Power Plant in the Slovak Republic was analysed through three options. One option involved immediate dismantling (Option 1). Two options involved deferred dismantling for 30 years, one with safe enclosure of the reactor (Option 2) and the other with safe enclosure of the whole nuclear island (Option 3).

The analyses showed that, if emphasis is placed on costs, Option 1 would be selected and, if placed on collective dose and radioactive waste generation, Option 3 would be selected. In the event, and on the basis also of other subjective criteria, Option 3 has been preferred.

As mentioned before, the strategy selected for the decommissioning of the Nuclear Power Plant Greifswald in Germany, comprising 8 reactors of the Russian WWER 440 type, was immediate dismantling, with construction of an interim storage facility for all spent fuel and waste in the absence of disposal facilities. Early dismantling of these reactors involves the least cost, least dose commitment and produces the least waste. It was also decided to perform as much as possible of the work with the existing personnel, and to reuse the site for industrial use or energy.

The United Kingdom governmental policy for the dismantling of the Magnox reactors has led to the selection of a strategy based on a deferral period close to 100 years. The main considerations for this choice are radioactive decay, the reduction of the quantities of intermediate level waste (ILW) for disposal, and the fact that the disposal facility at Drigg would probably not accommodate the large amount of low level waste (LLW) if it was produced sooner.

The techniques for dismantling fuel cycle facilities are essentially similar to those for dismantling nuclear power plants except that a safe enclosure period would not be helpful in reducing the radioactivity of those facilities contaminated with long-life radio-nuclides. For these facilities, early dismantling is therefore the preferred strategic choice. Ref. [10] discusses the strategy selection process for fuel cycle facilities and summarizes the numerous similarities and differences between these facilities and nuclear power plants.

4.4.5.3 Impact of the design of a facility on the selection of a decommissioning strategy

Decommissioning experiences to date indicate the importance of taking into account decommissioning issues at the design and construction phases of a nuclear facility. The objectives of design features to facilitate decommissioning should be to reduce occupational exposures, minimize waste generation and other environmental impacts, simplify dismantling procedures and reduce costs. It is highly desirable that designers of new plants are aware of the issues, the strategies, the techniques and the needs involved in decommissioning.

4.4.6 Status of the facility

When considering the status of a facility, a distinction should be made between plants that are still in use or plants that are no longer operated, i. e., either in power conditions for a commercial reactor or in operations for a fuel facility/research reactor, or in shutdown conditions.

While this distinction is fairly easy to do for commercial power reactors, it is not as trivial for research reactors and for other small nuclear facilities.

There is no consistency or clear definition of what constitutes a "shutdown" reactor. It can range from being shut down for refuelling or for maintenance purposes, to being permanently shut down and remaining in a state of safe enclosure. The general consensus is that at least half of the identified "shutdown" research reactors are no longer operational, but planning and implementation of decommissioning has not yet been started. Once the decision is taken that a facility will not be operated anymore in future, the classification can change to decommissioning. The implementation of the decommissioning strategy should begin at this point.

If the plant or the reactor is still in operation, the strategy can be chosen based on the selected factors and the established general decision-making process. A planned shutdown may enable the development of specific tools or decontamination processes that are better adapted to the facility and that would influence the development of a strategy, as well as the timing and the duration of the decommissioning period.

If a facility has already been shut down, the selection of a strategy is more limited and the decision will be taken based on analyses of factors such as: the time since shutdown, the current physical conditions of the plant, the existence of physical degradation of buildings or structures, the existence of decommissioning funds, the existence of knowledge of the history and past operations of the facility, incidents, contamination, etc.

Although spent fuel management is not considered to be part of the decommissioning process, experience shows that spent fuel management may strongly affect the selection of a decommissioning strategy. The facilities to store, dispose or reprocess spent fuel may not be readily available. This may force a licensee into a safe enclosure strategy with spent fuel on site. Some dismantling activities may be carried out with fuel on site, however.

Another status factor that could influence the choice of a strategy is the number of units in operation on the same nuclear site as the unit to be decommissioned. If other operating facilities continue to be in service in the vicinity, Stage 1 decommissioning or variants thereof may be the preferred strategy in order to benefit from the availability of resources, and from the necessary security, monitoring, surveillance and maintenance provided by the remaining operating facilities.

Another impact on the selection of a strategy is the type of facility to be decommissioned, i. e., is the facility a commercial nuclear power reactor (PWR, BWR, GCR, CANDU, WWER, RBMK,…) or a research reactor, or a fuel nuclear facility, or a particle accelerator?

The physical integrity of buildings and structures, or the expected evolution based on proper modelling, will also be a factor that influences the decision whether to undertake immediate dismantling or not. During safe enclosure, there is a potential for a gradual deterioration of the barriers between the available radio-nuclides and the environment. This degradation may also apply to systems (cranes, ventilation systems) that could be necessary during plant dismantling operations.

One of the main influences that the actual condition of a plant may have on the selection of a decommissioning strategy is due to the residual radioactive inventory within the facility. The nature and the quantity of radio-nuclides present in a shutdown nuclear facility will orient the strategy to immediate dismantling for low activity levels or long-life nuclides, while highly activated or contaminated materials may need a long period of safe enclosure to render the dismantling activities easier, safer and less demanding in dose-uptake.

The operational history of a facility can also have an impact on the selection of a decommissioning strategy. This will certainly be the case if there has, for example, been an accident or an incident on the site that resulted in damage or spread of contamination requiring different or more extensive decommissioning efforts.

Other history related issues that may affect the selection of a decommissioning strategy include fuel leakage and water chemistry events as well as the reactor operating load factor during its lifetime. Fuel leakage events can result in the dispersion of alpha-emitting radio-nuclides within the primary circuit that will complicate the decommissioning and dismantling process.

Some reactors have experienced relatively low load factors over their lifetime whereas others higher ones. This can have an effect on the residual radioactivity levels at shutdown. Some plants may have undergone refurbishment or replacement programmes during their lifetime. This may have resulted in additional radioactive plant equipment or materials being stored on site, e. g., redundant heat exchangers, the removal of which have to be included in the decommissioning plans, which will increase the overall costs.

Historic liabilities can exist in some countries where the State has to take over the management of wastes or facilities either as a result of new regulations or by the cease of activities of the "responsible producer". In such cases, the "responsible producer" was not able to finance the liabilities he incurred and the Sate has to intervene and take the responsibility for both the management and the financing. Such facilities will be decommissioned according to a strategy that will depend on the history of the liabilities and the political decision of the State.

4.4.7 Risk factors

A major reason given for the selection of a decommissioning strategy is often the radiological risk. In a scenario of deferred dismantling, radioactive decay over time will directly lead to a reduction in the level of radiological risk from the dismantling activities to the workers and the public.

Deferred dismantling may lead to other risks, however, as for example the risk of intrusion or the loss of integrity of buildings and equipment.

Therefore, the selection of a decommissioning and dismantling scenario must also take into account these additional risk factors and their evaluation and impact on the possible strategies.

Following are some of the major risks identified that need to be taken in consideration:

- Radiological risks: the radiological risks can be higher during early dismantling because of the higher radiation levels, but lower if remote equipment is used and the risks of intrusion or leakage of a safe enclosure have to be considered as an alternative.
- Technological risks: the technological differences between facilities can lead to different decommissioning and dismantling strategies (e. g., PWR - WWER).
- Loss of safety culture and morale within the dismantling staff which may lead to accidents, sabotage, extensive delays in decommissioning and dismantling activities.
- Work implemented by contractors that have no knowledge of the plant may lead to wrong hypotheses or accidents.
- Risks of neglecting the unit under decommissioning on a multiple unit site may lead to loss of safety culture, delays.
- Lack of funding.
- Loss of building/structure/equipment integrity which may lead to more complex decommissioning and dismantling activities at a deferred time, and to higher costs for plant modifications at the start of a safe enclosure period.
- Uncertainty of funding at the end of a safe enclosure period.
- Loss of competence as no plant knowledge nor historical data may be available at the end of a safe enclosure period.
- Loss of documentation, such as descriptions, drawings, etc.
- Intrusion, vandalism which may lead to radiological risks outside the safe enclosure buildings.
- Increasing costs of waste disposal due to scarcity or to largely filled repositories in the future.
- Loss of waste disposal routes due to completely filled repositories in the future.
- No actions of the next generation on the current liabilities.
- Environmental changes (climatic, flooding, earthquake) that may lead to environmental issues in an undetermined future.
- Increasing public opposition, requesting an unplanned change of the selected strategy.
- Change in regulations which may be a potential risk in a far future.
- Licensee has ceased to exist, leading to unforeseen takeover by the State.
- Regulator does not exist any longer which could happen in a society without any further nuclear energy production.

- Discrepancy between the position of the Government and the Regulator as in the timeframe of a safe enclosure period the official positions may change.
- Risks unknown after a certain time, such as unknown conditions of the equipment in the plant after a certain time, ageing, corrosion.
- Delayed decommissioning and dismantling may result to be more complex and expensive due to future degradation, unknown conditions, unexpected situations.

4.4.8 Risk assessment and cost/benefit optimisation

The risks factors mentioned in the foregoing section, or some of them depending on the particular situation of the facility, can be used in a risk assessment study analysing the residual overall risk of each alternative considered for the dismantling of the facility.

Such risk assessments can be combined with the cost of each alternative in order to produce a systematic cost/benefit or multi-attribute analysis helping the decision-making process in selecting the best decommissioning strategy for the plant considered.

It can be seen from various studies that the different decommissioning scenarios, i. e., immediate dismantling or deferred dismantling, do not result in significant differences in decommissioning costs, specifically if undiscounted costs are considered (overnight costs). This fact should also be taken with prudence, given the difficulties to assess the costs in such multifactor analyses, and given the variability of the decommissioning costs as a result of the profound effect of such country and site-specific factors as the model and design of the plant, the selected decommissioning option and its initial and final conditions, the amount of radioactive wastes resulting from the decommissioning and dismantling activities, the regulatory environment in the country, etc.

Several reference documents confirm further that the cost alone is not a determining factor in the selection of a decommissioning strategy.

For the selection of a strategy, it is more meaningful to combine the costs of decommissioning with a risk assessment and generate a comprehensive cost-benefit evaluation which can provide a more complete overview of the benefits of each alternative.

4.4.9 Waste and material management

All known studies, surveys and publications emphasize the importance of the availability of a final repository in order to enable a fast, economic and final clearance of a site. This is an obvious factor when one needs to decide the start of the dismantling of a facility which will generate large volumes of waste materials.

If no disposal facility is available, it may be judged appropriate to defer the decommissioning until a disposal route has been established.

However, the absence of a final repository should not be considered to be an obstacle to early dismantling, if other factors than waste disposal and costs intervene in the decision-making process.

The regulator should provide guidance to operators on the appropriate conditioning of waste materials and on the removal to a temporary storage facility. Of course, this facility will also have to be dismantled some time in the future, thereby requiring the availability of more resources. Moreover, existing temporary facilities are in most cases designed for the storage of radioactive wastes generated during the normal operation of a plant, and cannot accommodate the amounts of waste materials produced during the decommissioning activities. This means that new facilities will have to be constructed, increasing again the cost of the decommissioning operations.

The same reasoning can be held, although to a lesser extent, for the existence or the absence of waste treatment facilities that will be used to minimize the amounts of waste materials and decrease the volumes by compaction, incineration, melting, decontamination, recycling, free release when authorized by the Authorities. The lack of such facilities can lead to higher decommissioning and dismantling costs.

Similar to the waste management factor and although the spent fuel issue is not generally associated with the actual dismantling of a facility, the availability or not of spent fuel storage and/or disposal capacity is a major factor in deciding on a national approach to decommissioning. The absence of a repository for this kind of waste can result in the temporary storage of spent fuel on site and in the decision to postpone the dismantling of the facility until a final solution has been found.

4.4.9.1 Material management and clearance

The impact of material management on the selection of a decommissioning strategy results from the amounts of waste materials generated during the dismantling process, from its influence on the decommissioning and dismantling costs and on the risks involved in manipulating large amounts of radioactive materials which may be more radioactive if an early decommissioning scenario is implemented.

The selected strategy will have a direct impact on the type and costs of the waste materials that have to be disposed of. Deferred dismantling may reduce the amounts of intermediate level waste materials and increase the amounts of low level waste materials. In addition, the radioactivity of some waste materials may be reduced to below clearance levels.

National differences in clearance levels for radioactive waste materials, however, may rise various supra-national issues. They are likely to create difficulties with the trans-boundary movement of material that may have been cleared in one country but still require regulatory control as radioactive wastes in a neighbouring country. It may also have implications on fairness of international business, as there would be an impact on the decommissioning costs, its funding and the price of the kWh. It was suggested at the Tarragona conference in September 2003 that *"what is required is a set of clearance levels that operate in the same way as the internationally accepted standards for transport of radioactive materials"*.

4.4.9.2 Waste minimization

The concept of waste minimization cannot be separated from the concept of clearance levels. The quantities of waste materials that will be produced depend directly on the level of the clearance criteria used for clearing materials from regulatory control. An early dismantling will benefit from a known situation in terms of clearance principles, even if not consistent everywhere. Uncertainty on clearance values will affect delayed dismantling.

The concept of waste minimization during decommissioning activities, which is not only advocated by economical reasons but also by IAEA and EC Standards, will benefit from a period of safe enclosure due to the decay of the isotopes, but can also benefit from the existence of waste treatment facilities where waste minimization and volume reduction can be performed through decontamination, melting, incineration, compaction, clearance, recycle, reuse.

The actual existence of such facilities will depend on political decisions relating to the waste issue in the country, and on the regulation in place.

Waste minimization efforts could lead to an early decommissioning strategy becoming competitive with a period of safe enclosure.

4.4.10 Site reuse

The following alternatives are possible for ending the nuclear supervision of a facility:

1. Clearance of the site for unrestricted reuse without radiological supervision after total removal of the facility.
2. Clearance of the site and the remaining structures (buildings, systems) for another commercial use without radiological supervision.
3. Conversion of the site and the remaining structures into another facility which is licensed under the nuclear legislation (as a new facility or by joining it into an existing neighbouring facility) without radiological clearance.

One factor influencing the decommissioning strategy is the decision/possibility to reuse the site after dismantling.

Early decommissioning will be chosen if scarcity of nuclear sites imposes the reuse of existing nuclear sites for new projects. This may also be dictated by the difficulty to find adequate sites, either because of physical constraints or because of opposition from the public to the opening of new sites for new nuclear developments.

The reuse of nuclear sites after decommissioning will dictate the target of the end state of the decommissioning effort. This may be "green field" if the complete removal of the site from regulatory control is decided, or "brown field" if some of the previous installations can be reused. In the latter circumstances, the green field concept might be overly expensive and unnecessary for the specific industrial reuse of the site.

The land could also be reused in "green field" conditions for recreational purposes, or for other public use.

4.4.11 Political and socio-economic impact

Scheduled or non scheduled closure of a nuclear facility has a considerable impact on the local political and socio-economical situation of the plant and the community living nearby. Alternatively, the local situation can influence some aspects of the strategy selected by the owner of the facility. Regardless of the nature of the plans for post-closure, there are ways to involve the public in the planning, which will improve the acceptance of changes that cannot be avoided.

4.4.11.1 Early closure

In addition to technical factors or to the effect of accidents, early closure of a facility can find its origin in various political and/or socio-economic aspects: the country's political climate governed by the overall economic situation, the public attitude towards the nuclear programme, the activities of anti-nuclear groups and movements, the perception of the country's nuclear programme by neighbouring states.

Cost of electricity and deregulation may force utilities to decide the shutdown of a plant, e. g. when customers shift to lower-cost electricity suppliers as competition between electric utilities may push down the market price of electricity.

Early closure of a facility may exacerbate the impacts of a final shutdown by the fact that no proper communications with the local authorities and the local communities may have been established in preparation of the closure.

4.4.11.2 Local communities

During construction and operation large nuclear facilities contribute to the social and economic development of the region around the sites and shutdown of these facilities will have negative consequences on the life and the economy of these local communities.

The socio-economic impacts will be different during the various phases of the dismantling project, i. e., during the transition period, the preparation for safe enclosure, the safe enclosure period or during final dismantling.

Among the issues of concern are:

- The negative impact on the local demography, resulting in a decrease in the population.
- The decrease of economic activities in the area.
- The loss of jobs (unemployment, anticipated retirement).
- The reduction in local incomes.

The importance of creating and keeping open the channels of communication with the local communities is crucial.

4.4.11.3 Staffing

Another important issue to be decided at the time of decommissioning is staffing: should decommissioning be a self-managed project or a turnkey operation managed by contractors? Staffing does not seem to be a factor that will influence the selection of a decommissioning strategy, however. The same is true for the change of culture that is leading to a potential loss of motivation from the facility operators.

4.4.12 Cultural, aesthetic and archeological impacts

Only limited information is available on the impact of cultural, aesthetic and archaeological factors on the selection of a decommissioning strategy. These factors are part of the Environmental Impact Assessment developed for a plant being decommissioned, and will be taken in consideration during the overall evaluation of the assessment.

Aesthetic and visual aspects were key factors in the considerations that lead to the selection of the decommissioning strategy for:

- Trawsfynydd: the visual impact of the site within the national park in the long term.
- Vandellós-I: the reduction of the visual impact of the plant on the coastline.

Examples of a decommissioning end-state dictated by the technical knowledge that could be drawn from the decommissioning and dismantling operations are plants, the decommissioning of which was not completed for political reasons, but were transformed into training centres and/or nuclear simulators.

4.4.13 Availability of funding

The availability of funding for the decommissioning of nuclear facilities is a key factor for the selection of a strategy.

4.4.13.1 No funding available

No funding at the time of closure means that the required amount of money must be collected from sources like the State or donors if immediate dismantling is decided. If those sources of financing are not available, deferred dismantling must be envisaged through a newly instituted fund collecting the necessary means to implement the dismantling activities.

If the facility has no funding but is still in operation, funds can be collected during the remaining period of its operating life by a levy on the kWe sold in case of a nuclear power plant, or through a percentage on the contracts passed with customers of the facility. Combination with State support or other donors can also be considered.

If the facility can safely operate beyond its design life time, life extension programmes can be developed to give the licensee time to collect enough money for the end-activities of the plant.

A risk of shortfall in funds for nuclear power plant decommissioning and waste disposal may exist in a competitive environment and a deregulated electricity market due to early plant closure, or due to the absence of a guaranteed volume of electricity for sale.

Most often, historic liabilities do not have decommissioning funds. In that case, funding is usually provided directly from the State budget. The selection of a strategy is dictated by cost/benefit evaluations and by other factors considered to be important for the country at the time of decision. Early decommissioning remains an option.

4.4.13.2 Funding available

Even in the case of an operating plant which has well anticipated its future liabilities, uncertainties will affect the fund that has been established. Cost estimates can be modified by unforeseeable factors like changes in:

- Staff or equipment costs;
- Regulatory requirements;
- Governmental priorities or policies;
- Disposal costs for radioactive wastes;
- Criteria for release of materials, buildings and sites from regulatory control.

Similarly, there may be uncertainty about the funding arrangements to be sufficient to meet the costs when they arise, by changes in:

- Assumptions about inflation;
- Discount rates;
- Value of the assets held by the fund.

One way of minimizing these uncertainties is to complete decommissioning as early as possible, after final plant shutdown. However, this benefit of early dismantling must be balanced against the many other factors that influence the selection of a decommissioning strategy.

4.4.14 Availability of expertise, staff from operations

As mentioned before, the existence of records, archives, documents, drawings, descriptions of the facility are important factors to consider at the stage of selecting a decommissioning strategy. They will orient the decision to immediate dismantling in order to ensure that this information is available when the work is performed. It is also a matter of radiological and industrial safety.

Important as well is historical information that is not recorded in documents, but in the know-how of the operators and the workers who managed the facility for many years. This information will not be lost and will be most helpful during immediate dismantling.

The skills of the workers and their knowledge of the plant will be useful during immediate dismantling and will lead to timely and safe dismantling works, if the precautions have been taken to prepare them to the change of the objectives, i. e., from a production to a deconstruction philosophy. Malicious actions cannot be ignored, however, if the new undertaking has not been fully prepared well in advance.

4.5 Funding for decommissioning

Protection from ionizing radiation is a concern after the end of the active life of a nuclear installation. The final shutdown of a nuclear facility marks the start of a new phase with the objective to lift the radiological protection restrictions imposed while the facility as it was in operation. These restrictions are due to the presence of large quantities of radioactive materials in the form of structural materials, equipment, operational waste and spent fuel.

It is necessary to remove these materials and to subject them to appropriate treatment, considering the physical characteristics and the level of radioactivity and in accordance with the safety standards in force. All activities involved in decommissioning produce major quantities of waste materials. It is the ultimate management and disposal of these waste materials which accounts for the majority of the costs of decommissioning.

As a consequence, decommissioning activities involve major financial resources. In order to avoid risks to human health and to the environment, it is necessary to guarantee that financial resources will be available for the completion of the required decommissioning work in conformity with the safety standards. To this end, specific regulations should be adopted for the creation of decommissioning funds, to which the operators of nuclear installations should contribute throughout the active lifetime of the installation. These regulations should guarantee the availability and the adequacy of funds at the time of the decommissioning operations and the restoration of sites.

4.5.1 Responsibilities for the funding for decommissioning

The responsibility for the funding of decommissioning and dismantling of nuclear facilities lies firstly with the owner of the facility. In the case of most of the commercial facilities, it is a requirement established either directly in legislation or in the related operating licenses, that operators should create and maintain funds or financial guarantees for this purpose.

In the case of other facilities, such as the early research and development facilities and demonstration plants for which no specific provisions was made, the cost of decommissioning and dismantling generally fall to the State and funds have to be raised by other means, such as general taxation. Cases exist, like in Spain, where the responsibility for the decommissioning and waste management is transferred to a third organization financed by fees paid by the waste generator.

4.5.2 Requirements for the decommissioning funds

The level of regulatory control over the collection and management of decommissioning funds varies considerably between Member States. In some countries the management of the accumulated reserves remains entirely in the hands of the plant operator, while in other countries these funds have to be put under the control of a governmental agency. In certain countries, reserves are also taxed while exempted in others. This may be a reason for over- or underestimations.

The following principles benchmark the requirements for a safe management of radioactive wastes and hence for decommissioning funds:

- The "Polluter Pays" principle

  It is clear that the fundamental environmental principle of the "Polluter Pays" should be applied to waste management, giving a waste generator a clear economic incentive to reduce the quantities of produced waste materials.

- The legal requirements for funds.

  Acts, decrees, and directives should provide the authority for the funds to be established and preserved. This is important as it demonstrates, at the highest possible level, that there will be funds available to deal with the issues of decommissioning, waste management, and spent fuel management.

  The role of the State in establishing the legislative context for decommissioning funds and in securing the financial arrangements is described in detail in the OECD/NEA document *Future financial liabilities of nuclear activities*, Ref. [17].

- The IAEA requirements.

  The *Waste Standards Safety Guide for Nuclear Power Plants and Research and Development Reactors*, Ref. [3], requests that "… *the regulatory framework of a country should include provisions for the decommissioning of nuclear installations …",* and the other guides of the Series (Ref. [4, 5, 18]) make similar recommendations for the fuel cycle facilities, medical, industrial and research and development facilities, and mining/milling industries.

  In addition, the IAEA requirements are laid down in the Joint Convention of September *1997*, concerning the safety of managing irradiated nuclear fuel and radioactive waste.

- The requirements of the European Commission.

  Except for the Directive 96/29 Euratom, laying down basic safety standards for protection of the workers and the public against the danger of ionizing radiation, and Directive 85/337/EEC amended by Directive 97/11/EC on the assessment of the effect of certain public and private projects on the environment, there is no specific European Commission legislation relating to the decommissioning of nuclear facilities.

  In 1999, the European Commission prepared a Communication on decommissioning of nuclear installations in the European Union, Ref. [19]. In this Communication guidelines for decommissioning policies and strategies were proposed and, among others, for the financial aspects relating decommissioning. The Communication also described a number of actions to be undertaken at Community level.

  Following this Communication, the European Commission adopted the "Nuclear Package" (Ref. [20]) on nuclear safety in an enlarged European Union and made two proposals for new nuclear legislation. Decommissioning and radioactive waste management are key issues in these proposals, and with this package, the Commission shows her determination that a clear European framework is required within which the nuclear option could play whatever role the Member States decide.

  In January 2004, the European Parliament voted in favour of this package including some amendments. In particular, a stronger wording on decommissioning was added, including an amendment dealing with the issue of decommissioning funds.

  The minimum criteria for the funds can be found in the annex to the "Nuclear Package", Ref. [20]. They are indicated in the following paragraphs:

  - *The funds shall be created from contributions by operators of nuclear installations during their operation, in order to reach a level of resources, at the time of the final shutdown, sufficient to cover all expenses related to decommissioning.*
  - *Contributions shall be made to the fund in line with the estimated service life of the installation and with the decommissioning strategy chosen, in such a manner as to cover, in particular, decommissioning of the installation; safe, long-term management of the conventional and radioactive wastes from decommissioning of the installation; and safe, long-term management of the spent fuel from nuclear power stations and of the wastes from reprocessing operations not already fully covered as an operational cost.*
  - *The assets of the funds shall be managed in a manner ensuring liquidity compatible with the timetable for the decommissioning obligations and the costs foreseen for these obligations.*
  - *The assets of the funds are to be used only to cover the costs associated with the decommissioning strategy and may not be used for other purposes. To this end the decommissioning funds shall be duly established with their own legal*

personality, separate from the operator of the installation. If exceptional and duly justified reasons make such legal separation impossible, the fund could continue to be managed by the operator, provided that the availability of assets is guaranteed.

- *In the case of a nuclear installation whose operation will cease before the entry into force of the legislative, regulatory and administrative provisions set out in article 17 of this Directive; or within … [period to be decided] of the entry into force of these provisions, approaches other than the creation of decommissioning funds as required by this Directive may be taken.*
- *Member States shall define the method by which the necessary resources for decommissioning, already accumulated by the operator before the entry into force of measures taken to implement this Directive, shall be transferred. These transfers must take place within at least 3 years from the date envisaged in Article 15.*

Considering the information mentioned above, well defined requirements have been formulated in country legislation, in recommendations from international organizations and in proposed Directives that govern the necessity of creating decommissioning funds.

Little information is available on the requirements for funding of the decommissioning liabilities of, e. g., WWER reactors and nuclear facilities in Central and Eastern Europe (CEE). No funds were created for covering these future costs until the economic and political changes occurred at the end of the 1980s. It was assumed that the state/government would be responsible for funding of the decommissioning activities at a large stage.

An overview of the situation of WWER reactors in Central and Eastern European countries is given in the IAEA TECDOC Series No. 1133, *The Decommissioning of WWER Type Nuclear Power Plants*, Ref. [21].

4.5.3 Basic elements for the collection of funds

It is very important for an operator/legislator to identify exactly the nuclear liabilities that he will have to deal with in the future. Such an evaluation will also prevent unforeseen "historic" liabilities to appear and enables the operator/government to take the necessary corrective measures in time in order to deal with any shortcomings.

An inventory of nuclear liabilities consists of locating and recording the installations and sites where radioactive materials are present, and evaluating the situation in order to develop a policy that offers the requested financial guarantees on safety in the long term.

Only when the liabilities are identified, the related total decommissioning and remediation costs may be determined and, for the government, a global view of the situation in the country obtained.

A special feature of decommissioning and radioactive waste management is the timescale during which it is required to ensure that adequate amounts of money are available for proper discharging all obligations or liabilities. In addition, the decommissioning of a nuclear facility is a major industrial undertaking that can last for many years, depending on the strategic approach.

The costs of the decommissioning operations may be important. Estimates for the complete decommissioning of a 1,000 MWe nuclear power plant range from some € 170 to 850 million. It is essential to avoid any possibility that decommissioning cannot be started as planned, cannot be carried out using appropriate procedures under safe conditions, or should be abandoned before completion due to a lack of resources.

Many factors may affect decommissioning costs such as excluding spent fuel management from the global decommissioning costs, and the two cost elements that may represent a significant part (i. e. up to one fourth or one third) of the total costs, i. e., the effective dismantling and the waste treatment/disposal costs.

The methods for calculating and reporting liabilities may differ from one country to another and sometimes also from one operator to another in a given country. In practice, two main methods, i. e., the "current value method" and the "net present value method" and sometimes variations of these methods, are generally used to calculate future financial liabilities associated with decommissioning. In both methods, the value of the liability is adjusted periodically as the cost estimates evolve due to technology progress, regulatory changes and inflation, as applicable.

The "current value method" evaluates the financial liability based upon what decommissioning would cost today if the expenses were incurred at present. In that case, the value of the liability is equal to the decommissioning cost estimate and does not depend on the timing of the decommissioning activities; it is independent of the time at which the expenses will occur.

The "net present value method" consists of estimating the current cost of liability and projecting it into the expected time frame. An estimate is then made of the net present value of the relevant cash flows. The estimate requires the assumption of a discount rate and depends on the timing of the decommissioning activities and the associated expenses. The net present value of a liability recognized in this manner is lower than if it were calculated using the current value method.

Like the "current value method", the "net present value method" requires periodic revisions in order to account for inflation and technological changes.

The main difference between both methods lies in that the net present value accumulates funds more slowly and is more sensitive to an assumed expense schedule and a return rate on capital set aside. The provisions being collected faster, the interest generated by the accumulated provisions will be higher in the current value method, and the charges to the owner/operator alleviated if the provisions are tax deductible.

In 8 countries, e. g., in Bulgaria, Czech Republic, Finland, France, Germany, Italy, Lithuania and Slovak Republic, the decommissioning funds are based on overnight/undiscounted costs. In other countries, e. g., in Belgium, Hungary, Spain, United Kingdom and Slovenia, the decommissioning funds are based on the net present value, the discount rate usually ranging between 1 and 4 %. In a few other countries, no specific policy has been detected.

Once the decommissioning costs have been determined by the operators and by the regulatory bodies for the specific conditions and decommissioning strategies defined in the different countries, and once the methods of accounting and presenting the liabilities have been fixed, the funds must be collected.

The way of accumulating the decommissioning funds varies from country to country. In some countries or cases, the calculated amount of money required for decommissioning is accumulated year by year over the entire planned lifetime of the facility. Other methods may be used in other countries or cases, such as requiring the funds to be collected over a shorter period than the expected lifetime of the plant, or requiring the operator to make a down payment for all future costs as a condition for obtaining the first operational licence. In this way, some of the risks associated with premature shutdown of the facility may be reduced.

4.5.3.1 Collection of funds for nuclear power plants

While, for simplicity, in most cases the funds are referred to as "decommissioning" funds, they must in principle cover all nuclear costs remaining at the end of the normal lifetime of a nuclear power plant. In other words, they must cover the entire decommissioning activities and the complete management of the resulting decommissioning waste materials. Within the scope of decommissioning this may also include the on-site storage of spent fuel and in some cases the management of spent fuel (reprocessing or final disposal).

Different approaches in the establishment of funds may be possible. One unique fund may cover the costs of decommissioning, including the resulting decommissioning waste materials and spent fuel management, or separate funds can be raised to cover each of these activities.

Nuclear power plants have a normal operating life cycle of at least 30 years, but even 60 years of operation are possible. Operators are expected to constitute provisions from the sale of the electricity during this life cycle in order to cover the future decommissioning costs. Two different approaches of collecting funds are being applied:

- Collection of funds over the expected life cycle of the nuclear power plant.
- Collection of funds over a shorter period (typically 25 to 30 years) than the expected life cycle of the nuclear power plant.

Both options have advantages and disadvantages. In general, collection over the entire expected life cycle will lead to less annual amounts to be transferred to the fund, while collection over a shorter period will reduce the risks associated with a premature shutdown. As spent fuel is produced continuously, the collection period for the management and disposal of spent fuel is typically distributed throughout the whole life cycle of the nuclear power plant.

In general, for privatised utilities it is the electricity consumer who pays for the nuclear liability and, depending on the electricity pool of the utilities, mostly no distinction is made between "nuclear" and "non-nuclear" electricity. In accordance with the applicable legal basis and the rules in the country, the contribution may be comprised in the consumer's total electricity bill, or clearly indicated in the form of a special levy on the sold nuclear kWh.

In addition to the possibilities for collecting funds as for privatised utilities, for state owned facilities the taxpayer may contribute indirectly to the funds when they are collected from public budgets. In some cases, for state owned utilities a special levy may be collected by the distribution companies via the electricity bill.

4.5.3.2 Collection of funds for other nuclear facilities

Other nuclear facilities could include research reactors, fuel fabrication facilities, reprocessing facilities, enrichment facilities, etc.

Similar as for commercial nuclear power plants, for privatised facilities the client is paying a share of the decommissioning costs in the price of the "products or services" purchased. Contractual relations may define specific conditions if, for example, the client has to pay his part of the decommissioning costs when the project starts. In this case, the client has to make a provision for the amount of money.

Typically for state owned facilities such as research reactors, decommissioning will be paid from public budgets, and as such indirectly by the taxpayer, when the costs arise. In other cases, the client is paying a share of the decommissioning costs in the price of the "product or services" purchased, such as radioisotopes or material tests.

4.5.4 Management of the decommissioning funds

Normally the necessary resources will have to be built up by the plant operator during the active life of the nuclear installation. It is not simply a matter of collecting money, however, but also of managing the funds in such a way that the money is available as required and when required over a longer period of time. Furthermore, in view of the size of the funds, there is some concern that they should be managed in a way not to disrupt the electricity market.

In order to meet these objectives and other concerns, legislation would require the creation of decommissioning funds that are independent of the regular accounts of the operators and specifically earmarked for the decommissioning of their nuclear installations. In other words, the funds would be "segregated" or "ring-fenced". Only in exceptional cases, where duly justified reasons make such a separation of funds impossible, the management of the funds could continue to be undertaken by the operator, provided that the availability of assets to cover the costs of decommissioning operations is guaranteed.

The ownership of the funds varies from one country to another. In some countries, the operators are allowed to accumulate and manage their own decommissioning funds, which remain in their own accounts, i. e., the so-called internal management of the funds, or accruals. In other countries, the funds are collected from the operators or the electricity system and managed by separate, independent bodies, i. e., the so-called external management of the funds, or trusts.

Both management approaches have the same goal, i. e., to cover the expected costs and to have the money available at the time the costs occur. The funds should be managed in such a way as to ensure them retaining their value, and the money not being spent on something else than the identified purpose. The liabilities remaining following closure of a nuclear power plant must be managed safely, even though this may last over a period ranging from a few years to possibly even more than 100 years. It is vitally important that the financial resources for the safe management of these costs can be guaranteed over the full period. Assuring this is essential for obtaining public confidence.

4.5.4.1 The internal management of decommissioning funds

One possibility that has been adopted is to keep the operators responsible for collecting and managing the funds. The operators are also appointed to be directly responsible for the implementation of the decommissioning activities. In this case, the contributions are held within the operator accounts in the form of reserves. In some countries, there are separate reserves for decommissioning (including decommissioning waste), and for the management and disposal of spent fuel. In the case of internal management of a decommissioning fund, it is important that formation of the reserves and spending of the funds are established in national regulations.

4.5.4.2 The external management of decommissioning funds

Alternatively, the creation of an external trust fund, independent of the regular accounts of the utilities has been put forward in the European Union, and is already applied in several European countries. Different options are possible in a system of external management of decommissioning funds, such as:

- The operators are required to contribute periodically to an external financial product. It can be a bank or a treasury account, subject to specific rules protecting the fund from misuse and financial risks.
- It can be mandatory to create a legally established external fund, managed by a body that is independent of the operator. In specific cases where the nuclear installation belongs to the state, the funds can be kept and managed by the national administration.

In the case of an external account or trust fund, the modalities for reimbursing may vary, mainly according to the assignment of the responsibilities for decommissioning. If the operator will carry out the decommissioning activities, he will use the funds as needs arise. In some situations, a specific company may be created for implementing the decommissioning activities, taking over ownership of the facility from the operator at plant closure. At that moment, the account/fund manager may distribute the funds in instalments as decommissioning work progresses.

In some countries, the operators of nuclear power plants contributing to the fund are entitled to borrow a certain percentage (up to 75 %) of the capital in the fund against full securities, and at a defined interest rate. In addition, the state has the right to borrow the remaining part of the capital in the fund.

In case of a unique external national fund for several nuclear operators, each operator can be said to have its own "account" in the fund, and the state authorities regularly establish the required balance of that account. In case an operator can no longer take care of his obligations to ensure the required financial provisions, the state can take over the account and the securities furnished by the operator to the fund in order to guarantee that the fund can return money to the state in a timely manner.

The OECD/NEA document *Future financial liabilities of nuclear activities*, Ref. [17], suggests a further distinction between "**centralised**" and "**decentralised**" funds, where the term "centralised" is used for an external fund, usually depending on the state. A "decentralised" fund may be either an internal or an external fund. This classification also applies to the body taking responsibility of the decommissioning operations.

4.5.4.3 Growth of the fund

The growth of the fund depends on the investment strategy, i. e., how aggressively or conservatively the funds are invested, thereby determining the amount of money to be collected. It is reasonable that the owners, depositing money in the fund, want to see the largest possible return on investment so that in the long term they will have to deposit less money. On the other hand, governments tend to have a more conservative approach and want to protect the capital in the fund. To achieve this, they are willing to accept a lower return rate. For optimum performance of the fund, a balance between the two perspectives is required.

Implications for the investment concept are a long-term saving process with a lengthy investment horizon, a sustainable nature of investment income, and sometimes individual goals for each nuclear power plant.

Specific guidelines may be defined, such as:

- Only low-risk investments are permitted.
- Investments in companies associated with legally obliged contributors to the funds are prohibited.
- Investments in companies having invested the majority of their assets in nuclear facilities are prohibited.
- Investments in domestic or international money markets are prohibited.

The management of the fund itself may be entrusted to a variety of custodian banks and asset managers with the task of investing the fund's assets. The investment policies and their compliance with specified guidelines can be monitored by a specific investment committee or by external experts, submitting reports on a regular basis.

Different asset management possibilities exist, such as:

- Investment in national currency bonds.
- Investment in international currency bonds.
- National equities and international equities (indexed and active).
- Investment in real estate.

5 National approaches to the decommissioning of nuclear facilities

The approaches to the decommissioning of nuclear installations vary within the different European countries with significant nuclear capabilities. In the following sections, a description is given of the decommissioning plans and decommissioning policies in the various countries, as well as information relating to the specific organizations that are responsible for overseeing such important aspects as safety and environmental impacts arising from decommissioning activities.

Some of the related information has been collected from other national and international reports. Other information directly results from the responses to the questionnaires that were sent to the permanent representatives of the European countries and further to the assigned responsible persons in charge in each particular European Country, as indicated in Section 3.2.2, Data collection.

5.1 Austria

In Austria there are no nuclear power plants, three (3) research reactors, two of which are currently under decommissioning, and one radioactive waste treatment and interim storage facility which is available in Seibersdorf.

The ASTRA Research Reactor in Seibersdorf belongs to the Austrian Research Centres Seibersdorf GmbH - ARCS which is by the majority federal property. 50.5 % of ARCS belongs to the Federal Bund that is represented by the Federal Ministry of Transport, Innovation and Technology - BMVIT.

In an extended agreement with the Federal Bund as the major shareholder, represented by BMVIT and the community of Seibersdorf, the Nuclear Engineering Seibersdorf (NES) has been charged with the decommissioning of all nuclear research facilities in Seibersdorf. In return the BMVIT pays the costs for the decommissioning and decontamination of the ASTRA research reactor as well as other related research facilities and equipment. This agreement is based upon the Austrian Radiation Protection Act (Strahlenschutzgesetz - StrlSchG. BGBI. Nr. 227/1969, last amended in 2004).

The Nuclear Engineering Seibersdorf is responsible for the decommissioning and decontamination of the ASTRA research reactor (scheduled 2000-2006, 160 t), a hot cell facility (46 t) and related research facilities and equipment (2001-2015, 875 t), and for the treatment, (re-)conditioning, interim storage of all radioactive wastes accumulated in Austria.

The BMVIT is the representative of the Federal Bund as the major shareholder and pays shareholder allowance for the actual decommissioning costs of all nuclear research facilities in Seibersdorf, incl. treatment, interim storage, preparatory work for disposal, etc. The total amount (until 2015) is estimated to be approximately € 100 Mio.

The decommissioning of the TRIGA Mark II research rector of the Vienna University of Technology, which became a public corporation in 2004, is a matter of current negotiations for financial liabilities. It is envisaged to send the spent fuel elements back to the US DOE at a rate of € 4,500.-/kg for disposal in a final repository. Based on an estimation, the overall decommissioning costs for this reactor will amount to € 6,720,000. As soon as the decommissioning plan will be realized and the reactor dismantled, the negotiations will ensure the availability of the necessary financial resources. Ultimately the research reactor lies within the responsibility of the Federal Bund. This is why the necessary funds for decommissioning will be ensured.

The decommissioning of the zero-Watt research reactor ARGONAUT in Graz, which is operated by a private research organization (The Graz Reactor Institute), is guaranteed by the owner of this facility, the Federal Bund and the province of Styria. Spent fuel will be returned to the United States.

5.2 Belgium

In Belgium, the regulation laid down by the Royal Decree of July 20, 2001 comprises the general framework for the protection of the workers, the public and the environment against the dangers of ionizing radiation.

Decommissioning is defined as the complete set of administrative and technical operations enabling a nuclear facility to be withdrawn from the list of classified installations as defined in terms of the dispositions of the Royal Decree of 20 July 2001.

The function of the Regulatory Body for radiological protection and nuclear safety, including safety of decommissioning and waste management, is assumed by the Federal Agency for Nuclear Control, FANC, established by the law of April 15, 1994. It is a government agency with its own board of directors.

The role of the agency can be summarised as follows:

- To prepare laws and regulations related to radiation protection and nuclear safety;
- To follow up the scientific and technical evolution and to propose new regulations or amendments to existing regulations to the minister who is politically responsible for radiation protection and nuclear safety, in order to keep those regulations up to date;
- To implement and enforce those regulations;
- To ensure compliance with those regulations.

The agency is also the scientific and technical support of the Ministry of Foreign Affairs in matters related to radiation protection and nuclear safety, and to the Ministry of the Interior for matters related to emergency preparedness. Furthermore, the agency has been given the duty of informing the general public on radiation protection and nuclear safety.

Compliance assurance is organised for each of the licensed facilities on three levels:

- The Health Physics department of the licensed facility;
- An Inspection Organisation, e. g., Association Vinçotte Nucléaire (AVN) or Controlatom, that is recognised by the competent authority to supervise the Health Physics department of the facility; this recognised body is also entrusted with specific duties, e. g., in case of clearance of materials;
- The Federal Agency for Nuclear Control (FANC).

The National Agency for Radioactive Waste and enriched Fissile Materials (NIRAS/ONDRAF) was established by law of August 8, 1980 which was amended by the laws of January 11, 1991 and December 12, 1997. The role of the agency is the safe management of all radioactive wastes and enriched fissile materials wherever it is produced in the country.

The legislator also assigned by law of January 11, 1991 certain responsibilities in the field of decommissioning to the agency NIRAS/ONDRAF. Among others, the agency has to collect information relating to the decommissioning programmes of nuclear installations within the country, to approve those programmes, and to execute programmes at request or in case of failure of an operator. In this case, the technical and financial modalities for the execution of those programmes have to be defined within a convention between the operator or the owner of the facility and the agency. Furthermore, initial, ongoing and final decommissioning planning, following the IAEA Safety Requirements and Guides in the field of decommissioning is now a common practice.

Finally, the legislator assigned in 1997 by law to NIRAS/ONDRAF the elaboration of an inventory of all nuclear installations and all sites containing radioactive substances within the country, including a cost assessment for decommissioning and remediation, and the verification of the existence of sufficient financial provisions for the future execution of the decommissioning and restoration programmes.

The regulation laid down by the Royal Decree of July 20, 2001 requires in the case of cessation of a licensed activity from the operator or the liquidator to inform the Federal Agency for Nuclear Control (FANC) and the Radioactive Waste Management Agency (NIRAS/ONDRAF) of the intention to stop the activity. The operator has to provide information relating to an appropriate destination for the radioactive substances, i. e., the disposition in the sense of final disposal, recycling or re-use under acceptable conditions. For the major nuclear facilities, a decommissioning licence is furthermore required which defines the ultimate objectives of the decommissioning programme. The request for a decommissioning license introduced by the operator has to include general information as well as the objectives considered relating to the appropriate destination of the radioactive substances and a preliminary safety report. For specific installations, an Environmental Impact Assessment (EIA) report has to be included. The application for decommissioning also has to include the advice of NIRAS/ONDRAF concerning the final decommissioning plan that was previously transmitted for approval to NIRAS/ONDRAF.

In cases where article 37 of the Euratom Treaty applies , which has the objective to forestall any possibility of radioactive contamination of another member state of the European Community, the FANC has to seek the advice of the European Commission before a decommissioning licence can be granted.

Clearance of decommissioning waste is an option that may be proposed by the operator or the decommissioner when he applies for a decommissioning licence. Generic clearance levels are appended to the general regulations, based on the guidance of the European Commission. The applicant may propose specific destinations for the decommissioning materials and wastes (reuse, recycling, incineration, landfill disposal) for which the generic clearance levels do not necessarily apply. The applicant will then have to demonstrate compliance with the radiological criteria for clearance which are the same as for exemption.

Safety requirements continue to apply during decommissioning as long as the corresponding safety functions must be ensured. Equipment, components or systems which are left from the operational phase and which continue to be necessary, are regulated as during the operational phase by "Technical specifications". After justification (safety analysis), those specifications may be adapted in accordance with the progress made in the decommissioning process.

The organisation of inspections is not changed and is the same during operation as during transition from operation to decommissioning or during decommissioning. The concerns for inspections remain the same: safety (availability of systems and components needed to ensure the remaining safety functions,…), radiation protection (ALARA, policy,…), waste production and treatment,… Periodicity or subjects of inspections may vary, in accordance with the progress made in the decommissioning progress, in order to ensure that necessary maintenance, care and surveillance are carried out and achieve their aim.

NORM (Naturally Occurring Radioactive Material) industries that were judged by the FANC to comply with all or part of the general regulations are also subject to a decommissioning licence. The related licences may include specific provisions.

The decommissioning strategies are project specific and may differ from one facility to another. The operator of the existing commercial nuclear power plants did not define up to now a strategy for the decommissioning of these plants. In fact, no final shutdown of the facilities is actually planned before the year 2015. Nevertheless, the cost evaluations and the financial provisions are based on a strategy of immediate dismantling of the plants as this approach is more conservative as far as cost aspects are concerned.

Immediate dismantling was the selected strategy for the ongoing decommissioning of the so-called "nuclear liability programmes", mainly owing to the fact that financial means were provided by the Belgian Government and the electricity producers on the basis of annual endowments. Nevertheless, technical and safety reasons also contributed to this choice:

- Deferring the dismantling of the former Eurochemic reprocessing plant presented no interest from the point of view of radioactive decay due to the presence of U and Pu contamination.
- The former waste treatment facilities of the Belgian Nuclear Research Centre (SCK•CEN) presented some α-contamination and required immediate measures for safety reasons.
- The pressurised water reactor BR3 was selected in 1989 by the European Commission as one of the pilot projects for decommissioning with financial contribution from the Commission. Decommissioning cost estimates were carried out for different strategies which indicated that immediate dismantling had to be preferred.

The selection of a decommissioning strategy for a facility belongs to the responsibility of the operator. An analysis of the appropriate strategy is part of the decommissioning plan that has to be prepared by the operator. The selection of a strategy is also part of the licence application for decommissioning that has to be submitted to the Regulatory Body.

As the final shutdown of the commercial nuclear power plants is not planned before the year 2015, no social or environmental issues have been identified or analysed up to now.

The ongoing decommissioning programmes are all located on historical nuclear sites with a broad acceptance by the local population of these kinds of activities. The transition from the operating to the decommissioning phase for the facilities was carried out smoothly taking account of the social situation of the employees. The existing workforce was integrated as much as possible in the preliminary programme as well as later on in the decommissioning programme itself.

Mid 2003, a law was published concerning the settlement and management of provisions for later decommissioning of the seven nuclear power plants and the management of the spent fuel from these power plants. The provisions are managed by Synatom based on the advice formulated by a specifically created "Surveillance Committee" with the participation of NIRAS/ONDRAF. The settlement of provisions aims at providing full financing of the decommissioning programme and spent fuel management, guaranteeing that the funds will be available 40 years after commissioning of the plant. The provisions for decommissioning and spent fuel management are charged to the selling price of electricity.

The financial provisions for the decommissioning of other nuclear facilities than commercial nuclear power plants is regulated by the law and the Royal Decree from 1991 and the law of 1997 relating to the missions of the national agency NIRAS/ONDRAF. The agency has to control the existence and the adequacy of the provisions to be created by the operator or the owner of nuclear facilities and sites contaminated by radioisotopes. The legal responsibility for building sufficient provisions and for the management of the funds remains with the operator or the owner, however. In case the agency considers that the provisions are insufficient, the minister in charge of energy may enforce the operator or the owner to take the necessary actions based on the recommendations of NIRAS/ONDRAF. The cost evaluations and the mechanisms for building provisions are analysed by the operator and presented to the agency within the framework of the decommissioning plans and summarised in the responses to a questionnaire to be completed in the framework of the national inventory. Decommissioning and remediation costs as well as the financial provisions that have to be provided annually are re-evaluated every five years.

The financing of the ongoing decommissioning programmes for which no provisions were made in the past, is provided by means of annual endowments from the Federal Government with contributions from the electricity users.

Until now, four "Nuclear liability funds" have been raised by the Federal Government. These funds concern the decommissioning and remediation programmes of the former Eurochemic reprocessing plant, the former waste processing site of the Belgian Nuclear Research Centre (SCK•CEN), the Belgian Nuclear Research Centre sites, and the Institute for Radio-elements.

5.3 Cyprus

Cyprus has no nuclear power generation and there are no future plans in this area. Neither are there decommissioning activities in Cyprus.

Nevertheless, the existing legislation is fully in line with the European recommendations and covers all matters relating to ionizing radiation, including decommissioning. It provides, among others, also the requirements for licensing of sources and relevant practices.

5.4 Czech Republic

In Czech Republic the legal framework for decommissioning is based particularly on Act No. 18/1977 Coll. of 24 January 1997, on the Peaceful Utilisation of Nuclear Energy and Ionising Radiation (the Atomic Act) and on Amendments and Additions to Related Acts, and on Regulation No. 196/1999 Coll. on the Decommissioning of Nuclear Installations or Workplaces with Significant and Very Significant Ionizing Radiation Sources

The State Office for Nuclear Safety (SUJB) is the regulatory body responsible for the administration and supervision in the fields of the use of nuclear energy and radiation, and radiation protection as stipulated by Act No. 2/1969 (full wording Act No. 122/1997, §2). The authority and the responsibilities of the SUJB are given in the Atomic Act.

Based on the Decision of the Minister of Industry and Trade No. 107/1997 issued in pursuance of Article 26 of the Atomic Act, the Radioactive Waste Repository Authority (RAWRA) was established in 1997 as a state organisation responsible for the management of activities related to the disposal of radioactive wastes. The main responsibilities of the RAWRA are also given in the Atomic Act.

The basic requirements relating to the decommissioning of nuclear facilities are indicated in the Atomic Act and can be summarised as follows:

- Technological aspects:
  - Nuclear facility decommissioning is defined as the sum of all activities intended to make the facilities of the decommissioned plant available for other purposes or to clear the facilities from the requirements stipulated in the Atomic Act.
  - Decommissioning is a planned process. An operator or an applicant for a licence to use a site and to construct, commission and operate a nuclear facility has to submit the relevant documentation to the SUJB. This documentation should also specify a procedure for the decommissioning of the nuclear facility. Taking into account the operational period of the plant, a concept for a safe termination of the operational phase and for the decommissioning phase is defined as well as a proposed decommissioning procedure. The documentation to be submitted for getting a licence for the individual stages relating to the plant decommissioning process represents an executive summary level of the global documentation that is developed in order to start the decommissioning activities, and its content is indicated in an Appendix (item G) to the Atomic Act.
  - The overall decommissioning procedure is proposed by the operator and submitted to the SUJB for approval.
- Economical aspects:
  - The operator must create a financial reserve to cover the costs relating to the decommissioning of the nuclear facility. This reserve must be created in compliance with the proposed decommissioning procedure as approved by the SUJB. As required in the Atomic Act, the reserve is based on the decommissioning costs that are estimated by means of a procedure that is approved by the SUJB and the RWRA.

The Regulation No. 196/1999 Coll. on the Decommissioning of Nuclear Installations or Workplaces with Significant and Very Significant Ionizing Radiation Sources is considered to be a key issue in the entire decommissioning process. It includes the scope and procedures for radiation protection during the decommissioning of nuclear power plants or other facilities comprising significant or very significant sources of ionising radiation. The principles of radiation protection are stipulated for the stages preparation for decommissioning, termination of operations and implementation of the decommissioning process.

The Regulation prescribes a procedure for decommissioning and the form of the documentation to be elaborated on the decommissioning process and to be submitted to the SUJB for approval, which is important for an operator, respectively for an applicant for an operating licence.

It is also a positive feature of this Regulation that it comprises a definition of the decommissioning activities and the requirement for a regular update of the decommissioning cost estimate.

For elaborating the concept for the decommissioning of its nuclear power plants, the Czech Energetic Company (CEZ) has taken the existing regulation as a basis, and the following principles were adopted:

- The locality will be used for future commercial activities of the company. Using the land for agriculture or residential purposes after termination of the decommissioning process is not considered.
- After termination of the decommissioning process, the nuclear facility will be cleared from the requirements stipulated in the Atomic Act, enabling that it is no longer required to consider any radiological supervision.
- Demolition is considered for the buildings that comprised the technological systems or that were in contact with radioactive substances.
- It is expected that the RAWRA will provide sufficient disposal capacity for the waste materials resulting from the decommissioning process. Within the framework of the requirements of the Atomic Act, the data relating to the future production of radioactive waste materials will be provided to the RAWRA, including the data relating to the waste materials expected to be produced during the decommissioning process.
- According to the definition in the Atomic Act, nuclear facilities are structural or operational systems that comprise a nuclear reactor. The systems that have to be included in the decommissioning process and for which financial provisions have to be provided in order to cover the costs for the implementation of the decommissioning activities are defined in accordance to this definition in the Atomic Act.
- A fund is created for the decommissioning of the "active" parts of a nuclear power plant, i. e., the buildings that comprised the technological systems or that were in contact with radioactive substances.
- When selecting a decommissioning, the aspects of minimising the dose uptake for the staff engaged in the decommissioning activities and minimising the volumes of radioactive waste materials to be disposed of are taken into account.

Considering these principles, a case-by-case evaluation is implemented to define the decommissioning strategy, including a decay period depending on the character of the installation. In the case of a nuclear power plant it is assumed to be a maximum of 60 years. The IAEA decommissioning stages are adopted without modification but achievement of stage 3 is not obligatory.

The clearance of material is regulated by SUJB No 184/1997 Coll. The radiometric monitoring effectuated by the licensee is controlled independently by both the regulator and by a third party. Waste disposal facilities are available at the near surface repository at Dukovany and at Richard.

In order to provide the financial resources for the decommissioning activities, the CEZ started to create a financial reserve based on a decommissioning procedure approved by the SUJB and on a verification of the cost estimates relating to the decommissioning procedure approved by the RAWRA. The reserves for the decommissioning of the nuclear power plants of Dukovany and Temelin were defined for a deferred decommissioning strategy with a period of safe enclosure and the related cost estimates were verified by the RAWRA in 1997, respectively 1999.

The total time period for creating the reserve fund corresponds to the period of commercial operation, i. e., a service life of 30 years.

5.5 Denmark

In 1985 the Danish Parliament decided that Denmark would not use nuclear energy for the production of electricity. The issues of decommissioning and spent fuel management are therefore limited to the activities of the three research reactors DR1 (2 kW), DR2 (5 MW) and DR3 (10 MW) at the Risø National Laboratory.

The overall policy and practice relating to the spent fuel management for the DR2 and DR3 reactors include temporary storage of the fuel elements in dedicated storage facilities after irradiation, waiting for being transferred under jurisdiction of the United States of America according to an agreement with the United States Department of Energy. The reactor DR2 was taken out of operation in 1975 and the reactor DR3 in 2000. The spent fuel from these two reactors was transferred to the United States in June 2002. The spent fuel from the reactor DR1, which was taken out of operation in 2001, is stored under safe and secured conditions waiting for a decision on the final management.

In March 2003, the Danish Parliament agreed on the costs and the general approach relating to the decommissioning of all the nuclear facilities at the Risø National Laboratory with the objective to decommissioning the facilities as soon as possible within a timeframe of 20 years. The nuclear facilities that are in decommissioning and the status of the decommissioning activities are given in Table 5.1.

Table 5.1 Nuclear facilities under decommissioning in Denmark

Nuclear facility	Type	Taken out of operation	Decommissioning status
DR1	Small homogeneous 2 kW reactor mainly used for educational purposes.	2001	Fuel removed; planning for decommissioning to "green field" ongoing.
DR2	5 MW research reactor of the swimming pool type.	1975	Fuel elements removed; water removed from reactor and cooling systems; planning for decommissioning to "green field" ongoing.
DR3	10 MW heavy water research reactor of the DIDO type.	2000	Fuel elements removed; planning for decommissioning to "green field" ongoing.
Hot cells	Facility for post irradiation investigations of nuclear fuel.	1990	Cells emptied, cleaned and sealed; planning for decommissioning to "green field" ongoing.
Fuel fabrication	Fuel fabrication facilities for DR2 and DR3.	2002	Planning for decommissioning to "green field" ongoing.

The Risø National Laboratory is owned by the Danish Government under the Danish Ministry of Science, Technology and Innovation. The financial situation of the Waste Management Plant is and will be secured in future in order to ensure adequate financial resources to meet the safety requirements for the storage facility imposed by the Nuclear Regulatory Authorities.

The decommissioning of all nuclear facilities at the Risø National Laboratory will be carried out by a new organization, Danish Decommissioning (DD). This organisation is independent of the Risø National Laboratory in order to avoid any competition relating to funding between the decommissioning activities and the continued research activities at the Risø National Laboratory.

5.6 Estonia

At present, Estonia does not have any power producing reactors or research reactors and there are no plans to build any nuclear power plants or other nuclear facilities in the future. Two nuclear reactors were located in the training centre of the Soviet Union navy at Paldiski. Both reactors were partially decommissioned by the Russian authorities and the spent fuel transferred to Russia in 1994. In 1995, the training centre was handed over to Estonia.

ALARA Ltd. was established as a governmental company in 1995 to manage the radioactive waste stored at Paldiski and elsewhere. ALARA holds the sole licence for radioactive waste management, issued by the Estonian Radiation Protection Centre in 1997.

The Paldiski International Expert Reference Group, PIERG, was established in 1994. The original objective of the PIERG was the decommissioning of the reactors at Paldiski. This was modified in 1995 to reflect the changed circumstances, the new objective being solid waste storage and the preparation of an interim storage facility for conditioned waste.

The regulatory authority for radiation protection, the Estonian Radiation Protection Centre (ERPC), was established in 1996 and the Radiation Act came into force in May 1997. Among other tasks, the ERPC is responsible for preparing regulations for the application of the Radiation Act. The regulation for licensing was implemented in August 1997 and the regulation for radioactive waste management by the end of 1998. There are no plans to prepare a regulation for decommissioning of nuclear installations.

5.7 Finland

The principal legislation regulating nuclear activities in Finland consists of the Nuclear Energy Act (1997) and a Decree (1988). They define the responsibilities and the principles for financing the decommissioning projects. The licensing procedures included in the legislation are also applicable to the decommissioning of nuclear facilities.

The licensees are responsible for the decommissioning activities. In the event that a licensee is incapable of doing so, the state has the secondary responsibility. In this case, the costs are covered by assets collected in a Nuclear Waste Management Fund and by the securities provided by the licensees.

The safety related regulations are issued by the Government (general rules) and the Radiation and Nuclear Safety Authority (STUK) (detailed rules). Currently, there are no specific regulations for decommissioning.

According to the governmental policy decision of 1983, the licensees are obliged to update their decommissioning plans every five years. These plans aim at ensuring that decommissioning can be appropriately performed when needed and that the estimates for the decommissioning are realistic. The latest updates of the decommissioning plans were published at the end of 2003.

The Finnish decommissioning plans cover the dismantling of only those structures and components the activity of which exceeds the clearance constraints; thus the "green field" option is not required on the basis of the regulations.

The decommissioning plan for the nuclear power plant Loviisa is based on immediate dismantling within less than 10 years from the shutdown of the reactors, excluding facilities needed for spent fuel storage. The plan for the nuclear power plant Olkiluoto envisages a 30 years safe enclosure period prior to the dismantling of the reactors.

The implementation of an Environmental Impact Assessment (EIA) procedure is required prior to the decommissioning of a nuclear power plant.

The nuclear energy legislation includes the requirement for the creation of financial provisions for nuclear waste management, including decommissioning. On an annual basis, the licensees collect money in the State Nuclear Waste Management Fund. The fund is operated under the supervision of the Ministry of Trade and Industry.

At each moment, sufficient funds will be available to take care of the remaining nuclear waste management measures. Payments to the fund are based on liabilities, which are yearly estimated by the operators, scrutinized by the regulator and confirmed by the ministry. The fund does not pay for the current waste management measures but ensures the availability of the money corresponding to the costs of the liabilities.

A special feature of the Loviisa decommissioning plan is that large components, i. e., the pressure vessels and steam generators, would be removed intact, i. e., without being cut in pieces. Before dismantling, the whole primary circuit would be decontaminated.

The Olkiluoto decommissioning will start with a thorough flushing of all contaminated systems. The dismantling will start with the intact removal of the reactor vessels and internals.

Both utilities envisage on-site disposal of the decommissioning waste materials. The existing repositories for operational low and intermediate level waste, located in the crystalline bedrock at the sites of the nuclear power plants, would be enlarged to accommodate the waste materials from decommissioning as well.

5.8 France

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

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

- Establishment and application of general safety rules.
- Issuing licences to each installation after in-depth technical appraisal of the safety case;
- Surveillance.

The Nuclear Installations Safety Directorate (l'Autorité de Sûreté Nucléaire**,** ASN) is a specialized department in the Ministry of Industry. Its services are also available to the Ministry of the Environment. It is responsible for licensing of the construction, the operation and the decommissioning of nuclear installations.

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

The ASN was created by a decree of the Council of State in May 1991 to take over the responsibilities of the SCSIN (Service Central de Sûreté des Installations Nucléaires) which had existed since 1973. The ASN uses the competences of the Institut de Protection et de Sûreté Nucléaire (IPSN), a major branch of the CEA, as a source of technical support.

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

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

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

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

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

- Dismantling of non-radioactive equipment and structures.
- Maintenance or strengthening of containment barriers.
- Performing site radiological characterization.

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

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

In some cases, when dismantling operations modify the installation beyond a point at which it becomes no longer recognizable as described in its previous licence, a new nuclear installation has been created. This must be subject of a new licence. The new licence may be issued simultaneously with the dismantling licence.

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

The CEA (which has the responsibility for most of the nuclear installations that have been decommissioned in the past or that are currently being decommissioned) has a stated policy to undertake prompt decommissioning whenever possible. Deferred dismantling is only considered if a significant reduction in radioactivity is expected over time and if there are no safety reservations regarding the condition of the shutdown facility. A recent review of CEA decommissioning experience noted the importance of taking advantage of the knowledge of the plant operating personnel, and in not underestimating the costs of monitoring facilities that are waiting for being dismantled.

The decommissioning status of specific French nuclear facilities is given in Table 5.2.

Each year, the owners of the French nuclear facilities calculate the liabilities, i. e., all clean-up responsibilities including decontamination, remedial actions, radioactive waste management, landlord requirements and surveillance and maintenance activities, and set aside the required provisions in the company's accounts. Each year, the actually accumulated provisions must be reviewed (the value must be recalculated) to cover inflation and the real return rate, and the provisions adjusted. The additional amount of money resulting from the review is taken from the company's profit and added to the account for the provisions.

For the CEA, a dedicated fund has been created based on AREVA capital assets, in order to enable the CEA to manage its decommissioning plans.

Table 5.2 Decommissioning status of specific French nuclear facilities

Plant/Installation	Name	Type*	Operating Period	IAEA Decommissioning Stage
Large power reactors	G1 Marcoule	GCR	1956 – 1968	2
	G2 Marcoule	GCR	1959 – 1980	2
	G3 Marcoule	GCR	1960 – 1984	2
	Chinon A1	GCR	1963 – 1973	1
	Chinon A2	GCR	1965 – 1985	1
	Chinon A3	GCR	1966 – 1990	1
	Chooz A	PWR	1967 – 1991	1
	Saint Laurent A1	GCR	1969 – 1990	1
	Saint Laurent A2	GCR	1971 – 1992	1
	EL4 Monts d'Arrée	HWR	1966 - 1985	2
Small reactor plants	EL2 Saclay	HWR	1952 – 1965	2
	EL3 Saclay	HWR	1957 – 1979	2
	PEGASE Cadarache	PWR	1963 – 1975	3
	RAPSODIE Cadarache	FBR	1967 – 1983	2
	TRITON Fontenay-aux-Roses	PR	1959 – 1982	3
	MELUSINE Grenoble	PR	1958 – 1988	1
	MINERVA Saclay Fontenay-aux-Roses	PR	1959 – 1976	3
	ZOE Fontenay-aux-Roses	HWR	1948 – 1975	2
	NEREIDE Fontenay-aux-Roses	PR	1960 – 1981	3
	PEGGY Cadarache	GCR	1961 – 1975	3
	CESAR Cadarache	CA	1964 – 1974	3
	MARIUS Cadarache	CA	1960 - 1983	3
Other installations	Elan II B La Hague, Source Fabrication Plant	-	1970 – 1973	3
	Elan II A La Hague, Pilot Plant for Elan II B	-	1968 – 1970	3
	AT1 La Hague, Fuel Reprocessing Plant	-	1969 – 1979	3
	PIVER Marcoule, Waste Vitrification Plant	-	1966 – 1980	3
	ATTILA, Dry Processing Pilot Cell	-	1966 – 1975	3
	RM2, Radiometallurgy Laboratory, 13 cells	-	1968 – 1985	3
	Building 19 Fontenay, Plutonium Metallurgy	-	1968 - 1982	3

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

5.9 Germany

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

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

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

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

Section 9, paragraph (1) of the AEA states:

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

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

- The Act on the Precautionary Protection of the Population against Radiation Exposure (Precautionary Radiological Protection Act) as promulgated in December 1986.
- The Ordinance on the Protection Against Damage and Injuries Caused by Ionizing Radiation (Radiological Protection Ordinance - RPO) as promulgated in June 1989 and amended in August 1994.

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

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

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

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

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

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

Separate licences are required for:

- The withdrawal of an installation from services, i. e., shutdown of a nuclear installation.
- The safe enclosure, following defuelling.
- The complete dismantling of an installation.

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

- Complete dismantling of all radioactive components is feasible in due time after final shutdown.
- Sufficient financial means are available to dismantle the plant even in the case of an unplanned early final shutdown.

A major review of the German nuclear power generation and waste management policy was made following election of the government in 1998. In June 2000, an agreement was obtained between the Federal Government and the nuclear industry to shut down all existing reactors at the end of their design lives and to proceed with their decommissioning.

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

The current decommissioning status of specific German nuclear installations is shown in Table 5.3. It may be seen that most redundant facilities have been, or are being, decommissioned to the equivalent of IAEA Stage 3. A small number of facilities (the Lingen BWR and the two HTRs) have been completely defuelled and the operators have been granted a safe enclosure licence. This allows the nuclear installations to be kept in a Care and Maintenance (C&M) state, but only for a specified limited timescale (20-30 years). The merits of this approach have been questioned, however, and it is recommended that immediate dismantling to a green field site would be cheaper and easier than deferred decommissioning.

Nuclear facilities are often located in small communities. They are often a major source of employment for the community, for the income of the community as well as for the local business. Closing down such a facility and decommissioning it to "green field conditions" is a major change for such communities. In order to avoid such major changes, immediate decommissioning will help to keep a good deal of the staff of the nuclear facility employed which is a major importance to the staff and the community.

In the long term, in particular in the case of a phase out of nuclear industry, a decision on the replacement of nuclear industry by another industry is a challenge. Such an approach is, for example, taken in the case of the Greifswald nuclear power plants which are located in an economically depressed area. It seems to be very likely that this initiative will be successful.

Table 5.3 Decommissioning status of specific German nuclear facilities

Plant/Installation	Name	Type*	Operating Period	IAEA Decommissioning Stage
Large power reactors	HDR Karlstein	BWR	1969 - 1971	3
	KKN Niederaichbach	HWR	1973 - 1974	3
	KRB A Gundremmingen	BWR	1966 - 1977	3
	KWL Lingen	BWR	1968 - 1977	1
	MZFR Karlsruhe	HWR	1966 - 1984	3
	VAK Kahl	BWR	1961 - 1985	3
	AVR Jülich	HTR	1967 - 1988	1
	THTR 300 Hamm-Uentrop	HTR	1985 - 1988	1
	KKR Rheinsberg	PWR	1966 - 1990	3
	KGR1 Greifswald	PWR	1973 - 1990	3
	KGR2 Greifswald	PWR	1974 - 1990	3
	KGR3 Greifswald	PWR	1977 - 1990	3
	KGR4 Greifswald	PWR	1979 - 1990	3
	KGR5 Greifswald	PWR	1989 - 1990	3
	KNK-II Karlsruhe	FBR	1978 - 1990	2
Small reactor plants	Otto-Hahn ship reactor	PWR	1968 - 1979	3
	FR-2 Karlsruhe	HWR	1962 - 1981	2
	FRJ-1 Merlin Jülich	PR	1962 - 1985	2
	RFR Rossendorf	PR	1957 - 1990	3
	FRG-2 Geesthacht	PR	1963 - 1995	3
Other installations	Nukem-Alt fabrication plant Hanau		1960 - 1988	3
	WAK reprocessing plant Karlsruhe		1971 - 1990	3
	Hobel fabrication plant Hanau		1962 - 1992	3

*Key: BWR = Boiling Water Reactor; PWR = Pressurised Water Reactor; HTR = High Temperature Reactor; PR = Pool Type Reactor; HWR = Heavy Water Moderated Reactor

In accordance with the legal requirements, the operators have to cover the costs for the decommissioning of the nuclear facilities and the disposal of the resulting radioactive wastes. Nuclear power plants have to accumulate the respective funds during their operational period. Nuclear research facilities (including research reactors, critical assemblies and reprocessing plants) are basically in public hands (Federal and State Government) and the costs for their decommissioning have to be borne by public funds.

5.10 Greece

In Greece, no decommissioning activities have to be considered as the country has no nuclear facilities.

5.11 Hungary

In Hungary, the legal background for the decommissioning of nuclear facilities is the Act No. 116/1996 on Atomic Energy and the Government Decree No. 108/1997. The Nuclear Safety Regulations (NSR) were promulgated as Appendices to this Government Decree. The NSR considers the complete clearance of a site for unlimited reuse as a free non-nuclear area.

The Atomic Act and the decrees relating to its implementation also assigned the responsibilities for the various ministries: the Ministry of Health, the Ministry of Environmental Protection, the Ministry of Interior, the Ministry of Transportation and Water

Management, the Ministry of Agriculture and Regional Development and the Ministry of Economy.

In the case of decommissioning, the licensing authorities are the Nuclear Safety Directorate (NSD) of the Hungarian Atomic Energy Authority (HAEA) and the State Public Health and Medical Officer Services (SPHAMOS) on behalf of the Ministry of Health.

Hungary has created a quite classical system for the preparation of the future decommissioning of nuclear facilities. The responsible organisation, the Public Agency for Radioactive Waste Management (PURAM) was created by the Government as a non-profit agency based on Act on Atomic Energy.

Decommissioning activities cannot be carried out under an operating licence. They have to be implemented under a specific decommissioning licence. Licences for decommissioning nuclear installations are issued by the NSD. Licences for radioactive waste facilities are issued by the SPHAMOS. According to the definitions of the Atomic Energy Act, in Hungary radioactive waste facilities are not included in the list of nuclear facilities. No specific decommissioning authority has been established. The acting Authorities provide both a prescriptive approach and general licence conditions for the decommissioning of nuclear facilities.

The design of a new plant is required to include information relating to the decommissioning of the facility, mainly in terms of estimated waste arising from decommissioning.

At present a case-by-case system is used rather than a published policy for selecting a decommissioning strategy. A specific period of decay has not been defined. The licensee determines when decommissioning should start. However, the Governmental Decree No. 108/1997 connected with the Atomic Energy Act specifies three phases for the decommissioning procedure: final shutdown, a period of preparation for decommissioning which may include a period of safe enclosure, and the period of decommissioning. The first two phases require a Final Shutdown License. The third phase requires a Decommissioning License issued by the HAEA NSD. The three phases roughly correspond to the IAEA Stages 1, 2 and 3. Achievement of Stage 3 or equivalent is not obligatory as it depends on the decommissioning licence procedure. For the nuclear power plant PAKS this has resulted in a 70 years' safe enclosure period.

Generally the clearance of materials is regulated by decrees on clearance levels for different radioisotopes (Governmental Decree No 124/1997 and Ministerial Decree No 23/1997 issued by the Ministry of Health).

The Act on Atomic Energy provided for the Government to take steps aimed at creating a financial system to implement a coherent and comprehensive solution for the following tasks:

- The back-end of the nuclear fuel cycle;
- The final disposal of radioactive wastes;
- The interim storage of spent fuel;
- The decommissioning of nuclear facilities.

According to the Act, financing the tasks mentioned above shall be provided from a fund, and all costs must be paid by the licensees (with exception of the budget institutions, in which case by the central State budget).

The member of the Government, who supervises the HAEA, is responsible for the operation of the fund and through the HAEA - as the manager of the fund - controls the implementation of the management tasks associated with the operation of the fund.

The fund is a separate State fund pursuant to the Act on Public Finance. Payments into the fund by licensees of nuclear facilities are determined in a way that the fund will fully cover all the costs arising as a result of the final disposal of radioactive waste, the interim storage and final disposal of spent fuel and the decommissioning operations.

In the case of the nuclear power plant Paks, payments made by the licensee are considered to be expenditures that are recovered as a levy on the electricity price.

In order to ensure the stability of the value of the fund, a certain amount of money is provided from the Government budget calculated on the basis of the average basic interest rate of the Central Bank.

Payments into the fund started in 1998.

PURAM has to submit a proposal for the long and intermediate term, as well as for the annual plans. These are evaluated by a special committee created by the Hungarian Atomic Energy Authority and chaired by the director general of the HAEA.

The plans negotiated in this way have to be approved by the Minister supervising the HAEA who submits the plan for inclusion and approval within the annual budgetary act. Following approval by the Parliament, the tasks may be implemented.

Besides the legal requirements mentioned above, it is mandatory to keep the public informed on a permanent basis of all actions and measures taken. This responsibility involves not just disseminating information but also creating a dialogue with the population and the local, regional bodies involved in the proposed choice of a disposal site or a site for interim storage of spent fuel.

The requirements for public involvement are dealt with through the licensing process relating to the environmental impact (according to the Act 53 of 1996 on the protection of the environment and the Governmental Decree No. 152/1996 on environmental impact evaluations).

It is of particular importance to obtain widely based social understanding and support for the efforts being directed towards realising decommissioning or any waste disposal activity.

The biggest challenge for experts and the scientific community to raise the level of social trust is its ability and commitment to understand and handle the potential impact.

In 1992, a Social Controlling and Information Association (abbreviated as TEIT) was established on the initiative of the nuclear power plant Paks, with the participation of 13 villages located within a 12 km radius of the plant. The main objective was to gain confidence and acceptance for the construction of the interim storage facility for spent fuel.

The municipalities - with aims similar to these of the TEIT - founded their own Associations in the surveyed areas for the disposal of low and intermediate level waste (Social Association of Control and Information) and for the disposal of high level waste (West-Mecsek Information Association).

In the vicinity of the operational Püspökszilágy Waste Treatment and Disposal Facility (only for institutional wastes), the municipalities formed in 1998 the Isotope Information Association with objectives similar to those mentioned above.

5.12 Ireland

In Ireland, no decommissioning activities have to be considered as the country has no nuclear facilities.

5.13 Italy

In Italy, after the referendum held on November 8, 1987, the Interministerial Committee for Economical Planning (CIPE), a governmental body in charge of strategic decisions relating to nuclear power plants, decided in 1988 that all nuclear power plants should be closed and instructed the National Electric Company (ENEL) to start the decommissioning process according to a strategy of safe enclosure.

This strategy was not supported by the necessary adequate acts. Funding mechanisms were not available and the problem what to do with the radioactive wastes was not solved. There was no final solution for the disposal of low and intermediate level wastes and the foreseen centralized interim storage for spent fuel and high level wastes was not available.

Following issuing of the Legislative Decree No. 230 in 1995, the Italian strategy for decommissioning was reconsidered, taking into account the following main aspects:

- The lack of significant occupational dose reductions resulting from a strategy of deferred decommissioning for decades, after the initial decay.
- The risk of losing the necessary specific competences in a country without an active nuclear programme for energy generation.
- The possibility of reuse of the sites for industrial purposes, claimed also by many Local Authorities.

Finally, on December 14, 1999, in an announcement of the Ministry of Industry, the Italian Government outlined strategic choices and plans to manage the problems connected with the closure of all nuclear activities in the country. The statement of the Government's outlined the following main goals:

- Treatment and conditioning, within a period of 10 years, of all liquid and solid radioactive wastes currently in on-site storage, mostly produced during plant operations.
- Site selection and construction of a national repository for low and intermediate level wastes, also within a period of 10 years. The same site would be used for temporary storage of long-life high level wastes, particularly spent fuel and wastes resulting from reprocessing.
- Decommissioning of the nuclear plants, proceeding directly to the dismantling stage in order to reach clearance of the site without radiological constraints in about 20 years ("prompt decommissioning" or DECON strategy).
- Decommissioning of the other nuclear facilities in 15 years with the same strategy.

The statement of the Government also outlined two main instruments:

- A national company for the decommissioning of all national nuclear plants and facilities that were shut down.
- A national agency for centralised storage and disposal of all radioactive wastes.

The policy for immediate dismantling was confirmed in a decree of the Ministry of Industry on May 7, 2001. This decree also confirmed the main objectives outlined in 1999.

The new decommissioning programme divided the decommissioning projects into three main phases, the duration of which would depend on the availability of a national repository for low and intermediate level wastes:

- A first phase, until the year 2005 (the date initially planned for the beginning of the construction of the national repository), during which activities would be carried out in order to ensure a possible delay in the construction of the national repository to result in limited additional costs.
- A second phase, from 2006 to 2008 (the date initially planned for the completion of the national repository), during which activities would be carried out in preparation for the decommissioning of the nuclear island. Possible delays in the construction of the national repository could result in more significant additional costs. However, the radioactive waste materials produced during this period could still be managed on site.

- A third phase, starting from 2009, involving the actual decommissioning of the nuclear island and for which a delay in the availability of the national repository would necessarily result in a postponement of the related works and in significant additional costs, which would also largely be due to the requirement for extraordinary "on site" management of radioactive waste materials.

The current status of the decommissioning of the Italian nuclear installations may be summarised as follows:

- **Garigliano nuclear power plant,** 150 MWe BWR (1963-1978). All spent fuel has been removed from the plant and several activities have been performed such as a soft decontamination and drainage of the vessel, the primary circuit and the spent fuel pit; dry low level operational waste compaction; cementation of liquid and semi-liquid (sludge) radioactive wastes; refurbishing of the reactor sphere. All the activities have been performed in anticipation of the approval of a global decommissioning plan.
- **Latina nuclear power plant,** 153 MWe GCR (1962-1987). All spent fuel has been removed from the plant. The primary circuit has been filled with dry air, and blowers and portions of the primary circuit outside the reactor building are dismantled in anticipation of the approval of a global decommissioning plan.
- **Trino nuclear power plant,** 260 MWe PWR (1965-1987). A limited quantity of spent fuel is still present in the spent fuel pool. No major decommissioning activities have been performed yet. Approval of a global decommissioning plan by the Authorities is still ongoing.
- **Caorso nuclear power plant,** 860 MWe BWR (1981-1986). All spent fuel is still present in the spent fuel pool. No major decommissioning activities have been performed yet. Approval of a global decommissioning plan by the Authorities is still ongoing.
- **IFEC**, a pilot fuel fabrication facility, located at Saluggia, was operated by ENEA from the early sixties till the late eighties to fabricate MTR fuel reloads for the Italian research reactors, as well as the fuel bundles for the HWR CIRENE. Starting from 1990, all equipment has been decontaminated and removed. All operating halls have been decontaminated and cleared for conventional purposes. This is the only facility that has been completely dismantled.
- **FN (Fabbricazioni Nucleari)**, an industrial scale plant for LWR fuel fabrication located at Bosco Marengo, operated from 1973 to 1995. Most of the nuclear material has been transferred to other sites and the dry radioactive wastes from operations have been supercompacted. A remaining quantity of fresh fuel scrap will shortly be removed from the site, Approval of the decommissioning plan by the Authorities is pending.
- **EUREX** pilot reprocessing facility, located at Saluggia, operated from 1970 to 1974 (MTR fuel) and from 1980 to 1983 (CANDU fuel). Currently, the main task is to treat and condition liquid wastes produced during the reprocessing of the MTR and the CANDU fuel (some 120 m^3 of intermediate level waste and some 100 m^3 of low level waste) and to transfer into dry storage a limited quantity of spent fuel currently still available in the pool.
- **ITREC** pilot reprocessing facility, located in the southern part of Italy (Trisaia), operated by ENEA in the "70s (uranium-thorium cycle fuels from the US Elk River reactor). After performing the cementation of the high level waste produced during the reprocessing of a limited number of U-Th fuel elements, the current task is to solidify the U-Th solutions, to manage the historical wastes and to transfer into dry storage the fuel currently still available in the pool.

- **PLUTONIUM** pilot MOX fuel fabrication facility, located at the Casaccia Centre, operated from 1968 to 1974 (process development) and from 1977 to the early 80s (MOX fuel fabrication experimental campaigns). After treatment of the many radioactive waste streams (mostly high plutonium bearing liquids), the dismantling of glove boxes will be carried out by means of a special remotely handled installation being completed.
- **OPEC 1** post-irradiation examination facility, located in the Casaccia Centre, operated from 1962 to 1990. From 1992 to 1998 the activities have been focussed on the encapsulation of spent fuel scrap and the decontamination of hot cells. The main decommissioning issue is the repackaging and the disposal of spent fuel scrap.

Considering funding for decommissioning, ENEL created in the "80s a fund for the decommissioning of the plants and a fund for the management of irradiated fuel. A pluri-annual plan was defined for creating provisions.

As a consequence of the ongoing liberalisation process according to the EU Council Directive 96/92 and to the ENEL privatisation process, ENEL S.p.A., which has been from its constitution a fully vertically integrated utility, has been split in different companies within the ENEL holding.

In this context, the ENEL liabilities and assets (and all capabilities and resources) relating to nuclear power have been assigned to the newly established company Società Gestione Impianti Nucleari (SOGIN). SOGIN has been operational since November 1, 1999. On November 3, 2000, its shares were transferred to the Ministry of Treasury. SOGIN acts according to guidelines issued by the Ministry of Industry, however.

The mission of SOGIN covers:

- The decommissioning of the nuclear power plants in Italy. Furthermore, SOGIN has been allowed to act with joint ventures, consortia or similar co-operative initiatives in order to dismantle any other nuclear related structure in Italy (with particular reference to the ENEA and FN fuel cycle facilities).
- The closure of the back end of the fuel cycle.
- The valorisation of the assets such as sites, components, resources.
- Providing engineering and consultancy services in the nuclear field within the domestic and the international market.

Following the separation of SOGIN from ENEL, the funding mechanism was modified to provide resources for the additional costs resulting from the different economic conditions (new discount rates and taxes), from the management costs for the new company, and from the change in strategy from deferred dismantling to prompt decommissioning.

A Decree of the Ministry of Industry issued on January 26, 2000, states that the above mentioned extra costs for SOGIN shall be financed by a levy on the price of the sold kWh.

Every year SOGIN presents a programme of future activities with associated costs. Based on this information, the national Authority for Electric Energy and Gas (the national body which defines tariff politics) re-evaluates the levy on the sold kWh resulting from the SOGIN activities for the next three years. This re-evaluation will take into account criteria of economic efficiency.

The same procedure is foreseen by the Decree in order to finance the SOGIN activities for the additional costs relating to the dismantling of the nuclear fuel cycle installations that are now the property of the ENEA provided a suitable agreement has been achieved. In this context, recently a Consortium has been established between ENEA and SOGIN.

Available assessments indicate that a total amount of about 2,500 MEuro will be necessary for the total decommissioning of the 4 nuclear power plants (constant money 2000, including waste management costs).

The public opinion is strongly concerned about the related nuclear activities, and in Italy this is enhanced by the previous decisions about the future of nuclear energy.

All future activities and mainly the siting and building of a final repository for radioactive wastes can only be performed if a wide consensus is reached. This implies an effort of communication and transparency. Moreover, a consensus has to be acquired through a strong co-operation between national and local authorities and between technical and political bodies.

Two kinds of initiatives are implemented in Italy:

- The Government has concluded an agreement with regional Authorities in order to make progress towards the localisation of a final repository and to guarantee the required transparency to the general public. Moreover, the Ministry of Industry has created a "national table" with similar purposes, open to nuclear operators, regulatory authorities, trade unions, representatives of the Regions and Municipalities and, possibly, other Non-Governmental Organisations.
- Since its first day of activities, SOGIN has organised meetings with local authorities in the plants (a kind of "open house" days) in order to provide information about the main strategies. Similar initiatives will follow.

5.14 Latvia

The main body involved in the development of policy and regulation in Latvia is the Ministry of Environmental Protection and Regional Development. The regulation of decommissioning is undertaken by the Radiation and Nuclear Safety Control Division of the Environmental State Inspectorate. The organizations involved in the implementation of decommissioning are the Nuclear Research centre (the operator) and the company Environmental Projects (project management).

To date, no regulations on decommissioning have been approved. The proposal is to include the main decommissioning activities in the Radioactive Waste Management regulations. Licensing will be carried out under the same authorization process as any other activity involving radiation sources. Decommissioning licences will be issued by a Commission jointly established by the Ministry of Environmental Protection and Regional Development and the Environmental State Inspectorate in the framework of the Licensing Regulations. There are no plans to establish a decommissioning authority.

At the time the existing research reactor was built, a different legal system was in use which did not require plant design to allow for decommissioning. For its decommissioning the regulatory body provides general guidance and licence conditions, and a partly prescriptive approach requiring that some issues will have to be negotiated with the operator. Detailed licensing conditions are not provided under the Licensing Regulations but will be managed by the supervising team.

As there is only one nuclear facility in Latvia, the decommissioning policy is selected on a case-by-case basis. The period for decay depends on the country that will accept the spent fuel. If it is Russia, it will be approximately 4-5 years. Achievement of IAEA Stage 3 is not obligatory and the definitions used for the stages are: Stage 1, Safe enclosure with minor decommissioning; Stage 2, Restricted site release; and Stage 3, "Green field".

The clearance of materials is not yet regulated. The new regulations will deal with this issue following the EU and IAEA guidelines. Radiometric monitoring of licensees is supervised by the Regulator. Facilities are available for long term storage of radioactive wastes. As transfer of ownership of the facility was implemented close to the start of the decommissioning phase, no licence costs or funding estimates were available. Approval of the funding will be done by approval of the decommissioning concept that will include financial estimates. Under the Licensing Regulation, any licence for nuclear facilities must be examined by a public hearing procedure.

5.15 Lithuania

In Lithuania, there is no explicit definition of the starting point of the decommissioning process. The political decision on the decommissioning of the Ignalina nuclear power plant was incorporated in the National Energy Strategy (2002) and the commitment to shut down the plant was made in the Treaty of Accession to the EU (2003), Protocol No. 4 on the Ignalina Nuclear Power Plant in Lithuania. The exact date for shutting down Unit 1 of the Ignalina nuclear power plant was defined in a Resolution of the Government of the Republic of Lithuania (25 November 2004).

In accordance with the General Requirements on Decommissioning of Nuclear Power Plants (VD-EN-01-99) physical decommissioning starts at final shutdown of the plant.

According to the Final Decommissioning Plan (FDP), the decommissioning of the Ignalina nuclear power plant will end in a "brown field" situation including several radioactive waste storage facilities.

The time scale is described in the Final Decommissioning Plan. "Brown field" for a large part of the Ignalina nuclear power plant must be achieved by the year 2030, meaning that the total duration of the decommissioning activities will be about 26 years after final shut down of Unit 1. "Green field" conditions for the entire Ignalina nuclear power plant will not be reached at that time as:

- Storage of spent fuel and radioactive wastes at the Ignalina nuclear power plant site is expected to last beyond 2050, waiting for final disposal facilities to become available.
- Radioactive waste disposal facilities located at the Ignalina nuclear power plant site (landfill, bituminised waste vaults) will continue to be operated and imply an institutional control period that extends beyond 2050.

The Preliminary Decommissioning Plan (1999) included an analysis of decommissioning options (immediate dismantling, deferred dismantling with different safe enclosure periods, entombment), waste management options, funding needs, etc. Entombment as a decommissioning strategy was rejected for technical and environmental reasons. In order to choose the best decommissioning strategy, the Ministry of Economy asked the management of the Ignalina nuclear power plant to prepare a separate document in which technical and financial aspects were described that influence the selection of the strategy (Technical and Financial Considerations Required to Select an Ignalina Nuclear Power Plant Decommissioning Strategy). Various institutions involved in nuclear matters supplied the main elements that should be explored in the document (mostly based on IAEA recommendations) and evaluated the document. In order to choose the best solution, the Government of the Republic of Lithuania added to the technical and financial analyses (given in the above mentioned document) also social, political and economical arguments. In order to avoid significant long-term social, economic, financial and environmental consequences and having in mind the possibility to employ the Ignalina nuclear power plant personnel for the decommissioning activities, the immediate dismantling strategy was selected on November 26, 2002.

Spent fuel removal, the implementation of some modifications and in-line decontamination will be performed under the operational licence. Also dismantling activities might be performed but only after adequate justification and after authorization from the State Atomic Energy Safety Inspectorate (VATESI). VATESI is the main regulatory authority in the nuclear energy field and is responsible for the supervision of the nuclear safety of operating nuclear facilities, the safety of radioactive waste management activities (including disposal) and the decommissioning of nuclear facilities. A decommissioning licence for the dismantling and decontamination activities at the Ignalina nuclear power plant will be issued by the VATESI after the spent fuel has been removed from the units.

An estimate of the decommissioning costs is required in order to provide funding for the decommissioning activities and a decommissioning plan must be prepared 5 years in advance of the start of the decommissioning of a nuclear facility. This plan has to be approved by several ministries including the local municipality in which the nuclear facility is located.

According to the General Requirements on Decommissioning of Nuclear Power Plants (VD-EN-01-99) for issuing a decommissioning licence, it is required to submit the following documentation to the VATESI (in addition to common documentation):

- A safety analysis report.
- The decommissioning project.
- A project appraisal by the State Expert Appraisal Committee.
- A natural resources user's licence and an emission licence.
- A radiation protection programme.
- A waste management programme.
- An environmental monitoring programme.
- A safe enclosure plan and other associated documentation.
- The organisational structure of the decommissioning organisation.
- The decommissioning and surveillance regulations.
- An emergency preparedness plan.
- A physical security plan.
- The experience and skills acquired during an earlier decommissioning phase, the lessons learned and their implementation during the preparations for the licensing of the next decommissioning phase.

The responsibility for the decommissioning costs lies with the utility/operator.

The document LAND-42 defines levels for the clearance of materials and describes the procedure for the establishment of conditional clearance levels. The document is approved by the Ministry of Environment.

The legislative background to create and manage a decommissioning fund is laid down in:

- The Law on Nuclear Energy (14 November 1996).
- The Law on the State Enterprise Ignalina Nuclear Power Plant Decommissioning Fund (12 July 2001).
- The Resolution on the Approval of the Rules of the State Enterprise Ignalina Nuclear Power Plant Decommissioning Fund and the Expenditures Connected with the Establishment of such a Fund and the Handling of Spent Nuclear Fuel (17 April 2004 - Regulation of the Fund, deduction rate).
- The Resolution on the Establishment of the State Enterprise Ignalina Nuclear Power Plant Decommissioning Fund's Council (7 February 2005).
- The Framework Agreement between the Republic of Lithuania and the European Bank for Reconstruction and Development Relating to the Activities of the Ignalina International Decommissioning Support Fund in Lithuania (5 April 2001).

The collection of money for the National Fund is based on a certain percent of the revenue received from the sales of electricity. At present, this amount is 6.0 percent of the yearly Ignalina nuclear power plant revenue received from sold electricity. The annual contribution in 2004 was 13.8 MEUR. After the shutdown of Unit I it is anticipated to have an annual contribution of 6.9 MEUR.

In addition, contributions for decommissioning and compensating measures for early closure will be available from the Ignalina International Decommissioning Support Fund (IIDSF), to which the European Commission and other donors contribute. The IIDSF is managed by the European Bank for Reconstruction and Decommissioning (EBRD).

The decommissioning fund is managed as a segregated fund. The State Enterprise Ignalina Nuclear Power Plant Decommissioning Fund is managed by the governmental authorities (Ministry of Economy and Ministry of Finance), fully independent from the plant operator.

Decommissioning funds are required to be based on overnight/undiscounted decommissioning costs, while making calculations. The money is transferred to the fund on a quarterly basis. The use of the resources of the Fund is controlled by the State Control. According to the roles of the IIDSF, the financial statements of the Fund are audited by internal and external auditors consistent with the auditing of the ordinary capital resources of the managing organisation (EBRD). The Fund is subject to taxes at the national level. No taxes are paid for the international parts of the Fund.

All imported and local equipment, materials, works and services financed by the Bank with Grants from the Fund are free of taxes, customs, duties or other fees or mandatory payments levied by, or in the territory of, the Republic of Lithuania.

Every year, the decommissioning fund is subject of review, at the national level in order to review the deduction rate for the yearly Ignalina nuclear power plant revenue received from sold electricity, at the international level for approving the annual budget and the financial statement of the budget. The National Fund is reviewed by a governmental organization, the International Fund by the IIDSF - Assembly of Contributors.

An evaluation of the adequacy of the means to cover the decommissioning programme as well as the accuracy of the collection of means is done periodically. The decommissioning plan is updated every three (3) years.

5.16 Luxembourg

Having no nuclear power plants or other nuclear fuel cycle facilities, no research reactors or other facilities generating radioactive substances, Luxembourg has no plans for decommissioning activities in future.

In addition, Luxembourg has no spent nuclear fuel and no high level radioactive waste on its territory. Radioactive waste may only arise from the use of radioactive sources in industry, medicine and to a small extent from the use in education and research. The activities and volumes being very low, the Luxembourg Government considers options for a national radioactive waste management facility or a final disposal facility to be totally unrealistic.

Since 1967, Luxembourg has had a legislation and regulation on radiation protection which covers all relevant nuclear and radiological safety issues. This regulation is revised periodically in order to remain conform to the provisions of the Directives of the European Union. The last revision of the national regulation entered into force in 2000.

5.17 Malta

Malta has no nuclear power plants, no research reactors nor any other nuclear facility. As a result, no decommissioning activities have to be considered.

5.18 Poland

The National Atomic Energy Agency (NAEA) is involved in both the regulation and the development of policy and regulations for decommissioning. The owner and the operator of a nuclear installation are responsible for the implementation of decommissioning activities. Decommissioning can be carried out under an operating licence, under licences being issued by the President of the NAEA and can be transferred to the NAEA Decommissioning

Authority. The Regulatory Body provides only general licence conditions. Plant design is required to allow for decommissioning, however.

A case-by-case evaluation is used for the selection of a strategy for the decommissioning of nuclear facilities with a decay period of up to 3 years. The IAEA Guidelines are applied as follows: Stage 1, Storage with surveillance; Stage 2, Restricted site release; Stage 3, Unrestricted site release. Achievement of Stage 3 is not obligatory.

The clearance of materials is regulated by the NAEA President's Ordinance. Clearance levels are defined based on an annual dose limit of 0.01 mSv to members of the public. Radiometric monitoring by the licensee is controlled independently and at random by the Regulator.

Temporary storage facilities are available for spent fuel and for long-life low and intermediate level waste. A near surface repository is available for short-life low and intermediate level waste. An estimate of the decommissioning costs is required for all decommissioning projects in order to provide funding for the decommissioning activities. Public involvement in the licensing procedure for decommissioning is organised via the procedure relating to the Safety Report.

5.19 Portugal

Portugal has no nuclear power plants, no nuclear research reactors or other nuclear facilities. Only mining and milling facilities relating to the nuclear fuel cycle exist. As a result, no decommissioning activities are considered.

5.20 Slovak Republic

The policy relating to the decommissioning of nuclear facilities and the role of the Nuclear Regulatory Authority of the Slovak Republic in the process are defined in the Act of Peaceful Uses of Nuclear Energy (Atomic Energy Act) in force since December 1, 2004. A definition of decommissioning is given in the relevant part of this act.

In accordance with the legislation, the primary responsibility for the safe handling and disposal of radioactive wastes and for the decommissioning of nuclear facilities belongs technically as well as financially to the licensee under supervision of the national regulatory authorities. Feasibility studies and decommissioning plans are required by law for all nuclear facilities.

The limiting concentrations of individual radio-nuclides permitting the clearance of these materials for reuse are defined by the MoH SR Regulation No. 12/2001 Coll.

The Government Decision No. 190/1994 has defined a basic strategy for the management of radioactive wastes in Slovakia. This strategy is based in the following general steps:

- Conditioning of radioactive wastes into a form suitable for disposal or long-term storage.
- Disposal of low and intermediate level radioactive wastes in a near-surface repository.
- On-site storage of conditioned radioactive waste that is unacceptable for a near-surface repository.
- Research and development in view of creating a deep geological repository.

This general strategy has been complemented with regulatory requirements in order to limit the radioactive waste volumes through the implementation of programmes to reduce the production of radioactive wastes (ÚJD Decree No. 190/2000 Coll) and regulations relating to the release of materials to the environment.

The Ministry of Health is the authority establishing generally applicable standards for the residual radioactivity of cleared materials (Act No. 272/1994 Coll. on Protection of

Population Health, amended by 290/1996, 470/2000 and 578/2003). Clearance is based on an individual effective dose limit of 10 μSv/y and a collective effective dose limit of 1 man.Sv/y. Upon permission of the Authorities, it allows the clearance of materials with higher activity levels than the derived generic clearance limits if the reuse of the related materials results in a lower dose uptake than the referred dose limits.

Revised clearance levels were issued in 2001 in accordance with the IAEA guidelines on exemption/clearance principles (TECDOC 855 and Safety Series 89), based on maximum nuclide specific mass or surface activities. The nuclides are grouped in 5 classes according to their radiotoxicity.

On January 1, 1996, within Slovak Electric plc the organization SE-VYZ was created to take responsibility for the management of radioactive wastes (predisposal and disposal phases) and for the decommissioning of nuclear facilities.

Since 1995 the State fund for the decommissioning of nuclear power plants, including handling and disposal of spent fuel and radioactive wastes, has been established by Act No. 294/1994 Coll. The owners of nuclear power plants must contribute to this fund 10 % of the market price of the energy sold to the grid. A State grant is another source of income to the fund. The existence of this fund has enabled many activities to be implemented relating to the decommissioning of the HWGCR A-1 and the preparation of the documentation for the decommissioning of WWER reactors in Slovakia.

The Act No. 127/1994 on Environmental Impact Assessments of the National Council of the Slovak Republic establishes the responsibility of the Ministry of Environment to accommodate proposals for decommissioning alternatives before starting decommissioning activities. The requirements of the Nuclear Regulatory Authority, the Ministry of Health and other competent authorities are obligatory.

Prior to a scheduled shutdown of a nuclear installation in view of termination of operations, the licensee shall be liable to present the documentation pursuant to the Act No.127/1994 on Environmental Impact Assessments of the National Council of the Slovak Republic, as amended, and to provide additional documents in order to meet the requirements on the content of a conceptual decommissioning plan.

At present the first phase in the decommissioning of the nuclear power plant A-1 is ongoing and shutdown and decommissioning of the nuclear power plant V-1 is in preparation.

The nuclear power plant A1 was commissioned in December 1972. After an accident (INES level 4) in February 1977, the operation of A1 was interrupted. Technical, economical and safety analyses were performed. Based on the results of these analyses the Government decided that nuclear power plant A-1 should be decommissioned (Resolution No. 135/79).

The activities in view of the decommissioning of the nuclear power plant A-1 were started. Due to the absence of legislation related to the decommissioning of nuclear power plants, problems were partially solved on a case-by-case basis and individual steps were approved as modifications affecting the nuclear safety.

Updated documentation for the initial phase of decommissioning was prepared in the years 1994 to 1996. After approval of a safety report prepared in 1996 and after completion of the transfer of spent fuel to the Russian Federation, the ÚJD SR issued in 1999 the permit for the first phase of the decommissioning activities based on the Atomic Act No. 130/1998.

In addition, the Slovak Republic undertook a commitment to shut down Units 1 & 2 of the Jaslovské Bohunice V1 nuclear power plant in 2006 and 2008 respectively, adopting Resolution No. 801/99 of the Slovak Government on 14 September 1999.

Based on lessons learned during the decommissioning of the nuclear power plant A-1, a thorough and timely approach was selected for preparing the decommissioning of the WWER nuclear power plant. Feasibility studies resulted in the selection of a preferred decommissioning option.

The following five decommissioning options were analysed in detail:

- Immediate dismantling of the nuclear power plant after final shutdown.
- Safe enclosure of parts of the reactor building, "hermetic area" for each unit separately.
- Safe enclosure of the reactor cavity for each reactor separately.
- Safe enclosure of the whole reactor building.
- Closure under surveillance of the nuclear power plant (Stage 1 according to the IAEA classification).

It should be emphasized that the final goal for the options 2 to 5 was deferred dismantling to achieve "green field" conditions after a period of 70 years. The results of these technical, economic and safety analyses of the various decommissioning options for V-1 served as basic input for the decision making process.

A multi-attribute analysis was used for the complex assessment of the results and the selection of the preferred option. In general, for WWER nuclear power plants options including a safe enclosure period are selected, but a final decision will only be taken at the time the facility will be permanently shut down.

According to Slovak legislation, the decommissioning strategy should be defined in a Conceptual Decommissioning Plan and in an Environmental Impact Assessment Report of Decommissioning.

In April 2002, the document "Updating of the Conceptual V1 NPP Decommissioning Plan" for Bohunice V1 was developed, in which "Closure and Surveillance" was chosen as the preferred alternative (closure under surveillance of active constructions and subsequent dismantling with clearance of the site for other purposes). The document pointed out that this conclusion was not a final one because (1) according to the Slovak legislation the Environmental Impact Assessment should analyse each of the alternatives and select the preferred one, and (2) interconnections between the decommissioning of the nuclear power plant A-1, and the current operation and later decommissioning of the nuclear power plant V2 should be taken into account.

The Government Resolution No. 974/2000 established that, in addition to the development of the Conceptual Decommissioning Plan, SE a.s. had to study by the end of 2004 the potential economic use of the buildings and the technological equipment of the V1 nuclear power plant and analyse a redevelopment of the site following termination of the operations of V1. In October 2004, the document "V1 NPP Redevelopment" was finalised. It was approved by the SE a.s. and included the most up-to-date analysis of the decommissioning alternatives. The main conclusion of the analysis was to recommend immediate dismantling as the preferred decommissioning alternative in order to undertake site redevelopment as soon as possible.

Nevertheless, within the framework of the Bohunice International Decommissioning Support Fund (BIDSF) managed by the European Bank for Reconstruction and Development (EBRD), a new "V1 NPP Conceptual Decommissioning Plan" and an "Environmental Impact Assessment Report of V1 NPP Decommissioning" are being developed.

The Environmental Impact Assessment Report will provide the basis for public consultation on the proposed activities relating to the decommissioning of the V1 nuclear power plant and the associated environmental impacts. As a result of the Environmental Impact Assessment Report EIA, MZP will issue a "Final Statement" with the more appropriate or recommended alternative and the additional conditions required for implementing the decommissioning process for the V1 nuclear power plant.

5.21 Slovenia

In Slovenia, the decommissioning of a nuclear power plant must undergo the same licensing process and approvals as siting, construction and operation of such a plant. The laws applicable are mainly the ARP, the Act on Radiation Protection and the Safe Use of Nuclear Energy (1984); the EPA, the Environmental Protection Act (1993); as well as other acts on the Liability for Nuclear Damage (1978), the Performance of Radiation Protection (1980) and the Ratification of the Nuclear Safety Convention (1996).

The present legislation does not cover all aspects of decommissioning, however.

If the operator of the nuclear power plant intends to shut down the plant permanently, he is obliged to submit prior notification to the Authorities. No decommissioning work can be carried out under the operation licence. The operator has to prepare a decommissioning plan, including a detailed radiological characterization of the plant and the site and suggesting the stages and terms for implementing the decommissioning activities.

The funding of decommissioning is covered by the AFD, the Act on the Funding of the Decommissioning of the Krsko Nuclear power Plant and the Disposal of the Radioactive Waste.

So far it has not been specified who should implement the decommissioning activities of the nuclear power plant Krsko.

There are two plants operating in Slovenia:

- The nuclear power plant Krsko, 640 MWe PWR. It has a projected lifetime of 40 years. Shutdown is foreseen in 2023. A decommissioning plan has been prepared by the NIS Ingenieur GmbH, Germany, for the Ministry of Economic Affairs in 1996. This plan is reviewed periodically. According to the document "Development of a specific decommissioning plan", the alternative decommissioning strategies considered are immediate dismantling, later dismantling, entombment.

  Immediate dismantling was chosen as the best option for the decommissioning of the Krsko nuclear power plant. Dismantling within this strategy will be completed in 14 years. To reduce the amount of intermediate level waste, the activated internals, the activated and the highly contaminated components will be transported in one piece to a special on-site decay storage building for a period of 82 years. At the end of the storage period, the components can be handled and cut manually. Expensive remote-controlled techniques will no longer be necessary.
- The research reactor TRIGA MARK 2 (250 kWt), for which no shutdown date or decommissioning strategy has been chosen.

5.22 Spain

Spain possesses the infrastructure required for the management of spent fuel and radioactive wastes from the administrative, technical and economic-financial points of view.

According to the national regulation, decommissioning is the process by which the licensee of a facility, having obtained the corresponding authorisation, carries out the activities of decontamination, the disassembly of equipment, the demolition of structures and the removal of materials with the ultimate aim to enable the complete or restricted clearance of the site.

Regulatory framework

The Spanish Legal System related to nuclear matters is characterised by the existence of a general law, the Nuclear Energy Act, Law 25/1964, of April 29, 1964 (Ley de Energía Nuclear: LEN), complemented by laws, regulations and Ministerial Orders on specific issues.

RD 1836/1999 about the regulation related to nuclear and radioactive facilities (Reglamento de Instalaciones Nucleares y Radiactivas, RINR) considers the EU normative and more specifically Directive 96/29/EURATOM. Among other issues, it establishes the main stages within the system of licensing of nuclear and radioactive facilities in Spain: preliminary or site authorisation; construction permit; operating permit; authorisation for modifications; decommissioning permit.

Royal Decree 783/2001 about Regulation on Protection against Ionising Radiations. This Regulation complements the previous one from the point of view of health care and environmental protection against ionising radiations. It partially transposes the Community Directive 96/29/EURATOM and is aimed at establishing standards relating to the protection of workers and the members of the public against the risks arising from exposure to ionising radiations.

Law 15/1980 about the creation of CSN includes the functions of this organisation. It has been partially modified by the law regulating the National Electricity Industry, Law 40/1997, and by Law 14/1999 on Public Prices and Tariffs for services rendered by the CSN.

Law 62/2003 has recently modified certain aspects of the 1964 LEN. Article 93 of the Law 62/2003 of December 31, 2003 on Fiscal, Administrative and Social Measures, modifies the LEN by introducing within its scope of application, in relation to the system of authorisations for nuclear facilities, nuclear devices and facilities for the development of new energy sources.

This same Law 62/2003 implies a modification to the 1980 Law by which the CSN was created. This modification refers to the filing and custody of CSN documentation and affects the documentation to be submitted to the CSN by the licensees of nuclear power plant operating permits on termination of their practices and prior to the transfer of ownership and awarding of the authorisation for the dismantling of their facilities.

Royal Decree 1522/1984 authorised the constitution of ENRESA for the management of the radioactive wastes generated in Spain and for the dismantling of nuclear and radioactive facilities. The functions of ENRESA have been modified by Royal Decree 1349/2003 about the ENRESA's activities and their financing, applicable to radioactive waste management and to the decommissioning and dismantling of nuclear and radioactive facilities. It has been added to the provisions of Royal Decree Law 5/2005 about the Measures for the Promotion of Productivity and the Improvement of Public Contracting. This RD-Law modifies as well the Electricity Industry Act, Law 54/1997, specifically everything related to the financing of radioactive waste management activities. From April 1, 2005 the licensees of nuclear power plants shall bear the costs attributable to their operation. The way in which the operators contribute to covering these costs is determined by the RD-Law itself.

Another novelty introduced by this RD-Law 5/2005 is that the Spanish State accepts the ownership of radioactive wastes once these have been finally disposed of, as well as the surveillance required following the closure of nuclear or radioactive facilities subsequent to the period established in the corresponding statement.

Law 38/1995 about the right to access to environmental information. This Law transposes Community Directive 90/313/CEE to the national legal system, and is of maximum interest with respect to the participation of citizens in decision-making relating to the management of radioactive wastes.

Royal Legislative Decree 1302/1986 on Assessment of Environmental Impact modified by Law 6/2001.

National institutions involved in the decommissioning process

The national institutions involved in the decommissioning process are:

- The Ministry of Industry, Tourism and Trade (MITYC) which plays the main role in controlling nuclear activities and is the organisation responsible for granting of the corresponding permits and licences. The Government is also responsible for defining the policy relating to the management of radioactive wastes and spent nuclear fuel.
- The Nuclear Safety Council (CSN) which is solely responsible for nuclear safety and radiation protection. All authorisations issued by the MITYC are subject to an obligatory and binding report from the CSN. Jointly with the Nuclear Safety Council the Ministry of the Environment (MIMA) participates in the licensing process, drawing up the Environmental Impact Statement.
- The Empresa Nacional de Residuos Radiactivos, S.A. (ENRESA) which is the company authorised in Spain for the management of radioactive wastes, providing, among others, services in the area of radioactive waste and spent nuclear fuel storage and disposal, and transport and handling services. ENRESA was created by Royal Decree in 1984 and has as its shareholders CIEMAT, a national research centre reporting to the Ministry of Education and Science, and the State industrial holding company Sociedad Española de Participaciones Industriales (SEPI), which reports to the Ministry of Economy and Finances.

Current status

Nowadays, Spain counts on seven nuclear power plants with nine nuclear reactors in operation: José Cabrera, Santa María de Garoña, Almaraz I and II, Ascó I and II, Cofrentes, Vandellós-II and Trillo. Spain has also other operating nuclear facilities: the fuel manufacturing facility at Juzbado, in Salamanca; the CIEMAT nuclear facility in Madrid; and the solid radioactive waste disposal facility at Sierra Albarrana (El Cabril) in the province of Córdoba.

In April 2006 the nuclear power plant José Cabrera will be shut down and it is expected that the dismantling stage will start three years later (2009). On the other hand, CIEMAT has got the authorisation for the decommissioning of its nuclear facilities.

In the decommissioning phase are the shutdown nuclear power plant Vandellós-I (Tarragona), the Elefante Plant for the production of uranium concentrates and the mining installations, the last two facilities located at Saelices el Chico (Salamanca). Already decommissioned are the Andújar Uranium Mill in the province of Jaén and the Argos and Arbi experimental nuclear reactors, in Barcelona and Bilbao, respectively.

Dismantling organisation and responsibilities

According to RD 1349/2003, ENRESA has the responsibility for the management of the operations arising as a result of the decommissioning of nuclear facilities. The operating permit of a nuclear facility having expired, the responsibility for decommissioning is initially to the licensee himself who, prior to granting of the corresponding authorisation, undertakes the so-called pre-dismantling activities:

- Conditioning of the radioactive wastes from the operation of the installation.
- Unloading of the fuel from the reactor and from the irradiated fuel storage pools or, otherwise, for having available a spent fuel management plan approved by the MITYC, following a report from the CSN.

The reference contract between ENRESA and the nuclear power plants, approved by the MITYC, establishes in greater detail the responsibilities of the licensee and the scope of work to be performed in order to plan the dismantling of the facility.

The procedures and mechanisms relating to the transfer of trusteeship of the facility are established on a contractual basis between the licensee and ENRESA, the terms being formalised in the so-called Transfer of Ownership document.

With the support of the operator of nuclear power plant, ENRESA is in charge of submitting the dismantling and decommissioning plan for the nuclear power plant to the MITYC, in order to apply for the authorisation for decommissioning. The documentation that has to be attached to the request for authorisation comprises:

- A Safety Case with:
  - An updated description of the installation, the site and the surrounding area.
  - A General Decommissioning Plan (radiological characterization of the facility and the site, the scope of the proposal for decommissioning and a description of the expected state of the facility during and after its execution).
  - A Safety Analysis for the Decommissioning Plan (safety criteria, legislation, accident analysis, identification of the foreseen risks as well as the prevention measures).
  - An Environmental Impact Assessment for the dismantling stage, which will include the environmental radioactive surveillance programme.
- The Operational Rules, which will include the organization and norms for normal or abnormal situations.
- The technical specifications for the decommissioning phase.
- A Quality Assurance Manual.
- A Radiological Protection Manual.
- An Emergency Plan.
- A Radioactive Waste Management Plan (waste inventory, characterization, treatment, conditioning and storage as well as the proposed clearance levels).
- A Site Restoration Plan (surveillance of the radiation levels and the contamination of the areas to be cleared from regulatory control).
- A Financial Study for Decommissioning.

The decommissioning authorisation is awarded by the MITYC following a favourable report by the CSN on the decommissioning plan proposed by the licensee, and a positive evaluation of the environmental impact by the Ministry of Environment. It allows the licensee to implement the mentioned plan and to initiate activities relating to the decontamination and disassembly of equipment, the demolition of structures and the removal of materials, ultimately allowing for the total or restricted clearance of the site.

On completion of the pre-dismantling activities and following awarding of the corresponding authorisation for dismantling, ENRESA undertakes the responsibility for the performance of the dismantling and decommissioning activities scheduled in the authorised plan. Likewise, on completion of performance of the dismantling and decommissioning plan, ENRESA shall submit to the MITYC a request for the declaration of the closure of the facility.

The closure statement is awarded by the MITYC on completion of the dismantling activities, following a favourable report by the CSN, once the latter has checked that the conditions established in the dismantling programme have been met, especially the provisions of the waste management plan and the site restoration plan.

Financing of dismantling

The dismantling of nuclear power plants and other facilities involved in the manufacturing of uranium concentrates and nuclear fuels is financed through part of the funds that the licensee companies transfer to ENRESA throughout the operating lifetime of their facilities, as payment for the services rendered by the latter pursuant to the Royal Decree by which it was created.

In this respect, Royal Decree 1899/1984 on the Ordering of fuel cycle activities requires and regulates the contracts drawn up between ENRESA and the companies owning this type of nuclear facilities.

The Royal Decree Law 5/2005 about Reforms for the Promotion of Productivity and Improvement of Public Contracting modifies the electricity industry act, Law 54/1997, in relation to the financing of dismantling activities.

From March 31, 2005, the funds to be applied for financing the costs of the dismantling and decommissioning of nuclear power plants attributable to the operation of these facilities will be provided by the licensees during the operating lifetime of their installations. In this respect, the part considered to be attributable to operation shall be the proportional part of the dismantling and decommissioning costs corresponding to the operating lifetime of the plant remaining at that date.

In the case of non-commercial nuclear facilities, the payment for the services provided by ENRESA shall be by invoicing.

Strategy

In Spain, the alternative considered for developing calculations and planning regarding the decommissioning of nuclear facilities is total dismantling (Level 3), to be initiated three years after final shutdown of the reactors and following removal of the spent fuel from the pools. This strategy will be followed by the José Cabrera nuclear power plant and decommissioning plans are being prepared for the alternative of prompt dismantling.

According to the Spanish Radioactive Waste Plan in force and the foreseen lifetime of these plants (40 years), it will not be necessary to address any further dismantling in the near future, with the exception of the nuclear power plant José Cabrera (Zorita). In the meantime, specific studies and research work will be carried out in order to improve decommissioning and dismantling technologies, optimise the dismantling sequence and timing and reduce the decommissioning costs. Likewise, it is foreseen that the processes of transfer of ownership of the installations will be made systematic and that activities to be carried out prior to such transfer will be articulated, taking into account the lessons learned from the experience acquired in Vandellós-I.

Decommissioning techniques and inspections

Decommissioning is an industrial process that ensures compliance with the standards applied to residual materials, depending on their destination.

One of the key issues during dismantling is the management of materials. As a result, one of the essential points of the project is an exhaustive control of all materials arising at the site in order to segregate those considered clean from those that have radiological implications. Therefore, the materials are classified into two groups: those coming from conventional areas and those from radioactive areas. The legal standards in force in Spain are applied for the removal from site and subsequent recycling or disposal at authorised landfills.

Materials from radioactive areas are subdivided in declassifiable materials, which possibly may be managed as conventional wastes, and radioactive materials. This is accomplished through a Declassification Process in order to demonstrate the absence of activity levels in excess of those authorised by the CSN. Radioactive materials are meticulously characterised and conditioned for subsequent removal to the Low and Intermediate Level Waste Disposal Facility at El Cabril (Córdoba).

Material is moved around the site in containers along controlled routes, in all cases in their corresponding "Authorised Handling Unit" docket which includes historical, radiometric and operating data to ensure optimum management.

The process is controlled with a Waste Management Information System, consisting of a computer based corporate system that records all internal movements of material, from disassembly to removal.

Radioactive waste management

The integral management of the radioactive wastes produced during the decommissioning of nuclear installations is the sole responsibility of ENRESA.

Low and intermediate level wastes are sent to the El Cabril facility, where they are conditioned and disposed of. The facility counts on an integrated management system that includes not only waste disposal, but also collection, transport, treatment and conditioning, as well as accurate information on the waste inventory, radiological characterisation and quality assurance.

The storage capacity of the facility is 50,000 m^3 of low and intermediate level waste. At the end of 2003, 24,572 m^3 of low and intermediate level wastes had been disposed at the El Cabril facility, which represents about 50 % of the total capacity. The flow of wastes is about 2,000 m^3 per year. A new disposal facility for Very Low Level Wastes is currently under the licence process at El Cabril; its capacity will be around 120.000m^3.

In Spain there is currently no disposal facility for wastes that belong to higher categories such as a reactor vessel (or parts of it) and reactor internals. An alternative solution under consideration is the construction of surface or near-surface "Centralised Temporary Storage" facilities (ATC). Another alternative is individual temporary storage facilities on each site.

Public information

Informing the general public about radioactive waste management in general and about decommissioning of nuclear installations in particular, is one of the responsibilities of ENRESA. For this purpose, the company has developed an active and transparent policy with political groups, the media and the scientific community, based on dialogue and information transfer. The general population living close to the installations at which ENRESA carries out its activities is a preferential target as regards this policy. For this purpose the company has five information centres, at El Cabril, Córdoba, Vandellós and Madrid, which are daily visited by students and other general groups. Documentation and educational information is produced using different support media.

5.23 Sweden

Nuclear safety and radiation protection in Sweden are governed by the following Acts: (1) the Act on Nuclear Activities (February 1984); (2) the Act on Radiation Protection (July 1988); (3) the Environmental Code (1998); (4) the Act on the Financing of Future Expenses on Spent Nuclear Fuel (1992); and (5) parts of the Control of Dual-use Items and Technical Assistance Act (2000).

According to the Acts, the licensee is responsible for the safe operation and the decommissioning and dismantling of nuclear facilities, including the management of the wastes that are generated. The Act on Nuclear Activities assigns the financial responsibility for the management of all generated wastes, including spent fuel and decommissioning wastes, to the licensee. The Act on the Financing of Future Expenses on Spent Nuclear Fuel lays down the principles for the financing of the expenses for decommissioning.

Two separate regulatory bodies have been established: the Swedish Nuclear Power Inspectorate (SKI) for nuclear safety and the Swedish Radiation Protection Institute (SSI) for radiation protection. Both bodies have mandates to inspect nuclear sites and installations and to issue and enforce regulations. Regulations regarding decommissioning are published in the Swedish Nuclear Inspectorate's Regulations concerning Safety in Nuclear Facilities, SKI FS 2004:1 (SKI general regulations) and in the Swedish Radiation Protection Authority's

Regulations on Planning for and during Decommissioning of Nuclear Facilities, SSI FS 2004:2.

In the revised general regulations SKIFS 2004:1 a chapter on decommissioning has been added with requirements on a decommissioning plan and a specific operational safety assessment to be implemented as soon as a decision has been taken on the final closure of a facility. The SSI Regulations on Planning for and during Decommissioning of Nuclear Facilities (SSI FS 2002:4) comprise requirements for decommissioning with respect to documentation, alternative actions and waste management.

The regulations do not prescribe how or when decommissioning shall be performed, but demand that the licensee investigates different possible options in order to make an optimised choice. The standpoint of the regulating authorities from a safety and a radiation protection view is that a shutdown power reactor should be dismantled, demolished and the site cleared for unrestricted use in a timeframe of about 5 to 15 years. Twin reactors with common safety systems could be a motivation for deferral of dismantling if only one of the two reactors is shut down.

The loss of competent personnel, the inevitable degradation of closed facilities, the issue of understanding and keeping relevant documentation are some important factors. In Sweden, there is a common understanding that the generations that benefited from nuclear power should finance and take care of the wastes from both operations and decommissioning.

Decommissioning plans must be submitted to the SKI for approval before decommissioning and dismantling activities may be started. So far only generic decommissioning plans have been developed for the Swedish nuclear power plants as part of the basis for the annual cost estimates.

Considering the closure of the nuclear power unit Barsebäck 1 in November 1999, detailed planning for decommissioning is ongoing and is being closely monitored by the regulatory bodies. However, the comprehensive dismantling and demolition work in Barsebäck 1 will not be initiated until the other unit at the site, Barsebäck 2, has been permanently shut down and all spent nuclear fuel removed. Barsebäck *2* was finally shut down on May, 2005, and the spent fuel will be stored in the fuel pool at the unit at least until the end of 2006 before being transported to the CLAB facility. According to the current plans, large scale dismantling and demolishing work will begin not sooner than 10 to 15 years from now on.

Svensk Kärnbränslehatering AB (SKB), the Swedish Nuclear Fuel and Waste Management Company will have a major role in the work relating to the decommissioning of the Swedish nuclear power plants. While the power utilities bear the principal responsibility for dismantling the actual facilities, SKB is responsible for the management and the disposal of the resultant radioactive wastes. SKB is also responsible for conducting general decommissioning studies in order to ensure that the overall necessary competence exists and that cost calculations associated with future decommissioning are carried out according to the requirements.

A number of facilities at the Studsvik site are also in the process of being decommissioned and/or dismantled: the central active laboratory (ACL), the tank and silo facility (TS), the research reactors R2 and R2-0. Before the actual decommissioning activities started, plans for the decommissioning and dismantling of these facilities have been prepared by the licence-holders and submitted to the SKI for evaluation and approval, according to requirements in the general regulations.

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

There is no specific licence required for the decommissioning activities, but according to the Environmental Code (1998) prior permission is needed for decommissioning and dismantling since all changes in construction and operation must be reviewed and approved. The decommissioning activities are in fact reviewed by the regulatory bodies.

The decommissioning of the Swedish nuclear power plants will cost more than SEK 12 billion, which is about one billion per reactor. The disposal of waste will cost an additional SEK 3 billion for all the nuclear power plants. Each year the owners of the nuclear power plants provide an amount of money in a fund that will pay for the decommissioning of the plants. The money is deposited in the Nuclear Waste Fund's account with the National Debt Office. The charge is just under 1 öre (SEK 0.01) per kWh generated and is established each year by the Government based on the cost calculations submitted by SKB to the Swedish Nuclear Power Inspectorate. In this way, annually around SEK 500 million flows into the fund. Approximately 25 % of this money will go to decommissioning. In addition, also the research and development work of the SKB is paid from the Fund.

Despite the fact that the nuclear power plants may operate between 40 to 60 years, each plant will have paid its share in the fund after some 25 years. This will ensure that there is enough money for the decommissioning of the plant even if it is shut down prematurely.

Ultimately it is up to the power utilities to decide whether the reactors are to be dismantled immediately or whether they will be "mothballed". Practical activities will not start earlier than 2015, since both the design and the licensing for final disposal of radioactive wastes require a joint national planning.

Two of the Swedish nuclear power plants are located on the eastern coastline of the Baltic Sea at quite remote and sparsely populated areas. This means that they are an important source of employment in their regions. Shutdown and decommissioning of the plants will reduce the work force and have considerable social impact in the region on a longer time scale. The two plants in the south and west part of Sweden are situated in more densely populated regions with better job opportunities for the plant work force when a permanent shutdown is imminent. From an environmental point of view they are more sensitive, however. This is due to the proximity to major cities as Copenhagen, Malmö and Gothenburg. Sweden's dependence on nuclear power is currently little less than 50 %. Substituting nuclear power with other sources of energy needs consideration of environmental consequences.

The SKB is on behalf of the power plant operators planning final repositories for spent fuel and radioactive waste. This is done under a research and development programme that the SKI and the SSI review every third year. The process is now focussing on the final repository for spent fuel, SFL-2. In the municipalities with suitable geological conditions for a final repository, extensive hearings with members of the public are performed according to inter alia the environmental legal requirements. Public confidence is of crucial importance for the SKB and the KBS-3 concept. The SKI and the SSI have a special obligation to inform the public in an objective way about nuclear and radiological issues.

5.24 The Netherlands

In 1997 the Dodewaard nuclear power plant was shut down after 28 years of operation. Since that time the plant is in a state of decommissioning. All spent fuel has been removed from the reactor and shipped to the United Kingdom for reprocessing. Work is in progress to bring the plant in a state of safe enclosure and this was expected to be completed in 2005. The safe enclosure phase is foreseen to last for 40 years.

The decision by the Electricity Generating Board to take the plant out of operation was taken for two main reasons:

- It was felt that there was no longer any perspective for nuclear energy in the Netherlands in the foreseeable future.
- The plant had been built primarily as a means of gaining experience with nuclear energy and was never meant to operate economically. In a liberalised electricity market, which was introduced in the Netherlands in 2001, the Dodewaard plant would be a liability.

All activities relating to the import, transport, use, storage, disposal and export of radioactive material are subject to the provisions of the Nuclear Energy Act (1963, last revised in 2003). This includes the construction and operation of nuclear power plants and recently also the decommissioning of these facilities.

The licence for the decommissioning of the Dodewaard nuclear power plant was granted in 2002. The Environmental Protection Act requires that prior to the actual dismantling of a nuclear facility an Environmental Impact Assessment (EIA) be performed, describing alternative decommissioning options. The EIA report for the decommissioning of the Dodewaard nuclear power plant was submitted as a supporting document in the above mentioned licensing procedure.

International consensus exists that there are three different strategies for the decommissioning of nuclear power plants: (1) rapid dismantling within a period of ten years; (2) postponed dismantling within 50 years after bringing the facility in a safe enclosure status; (3) "in situ" decommissioning.

The three dismantling strategies were considered within the EIA for the Dodewaard nuclear power plant. The least expensive strategy, i. e., postponed dismantling with a safe enclosure period of 40 years is foreseen. Although the government had for various reasons a slight preference for direct dismantling, no objection was raised against the decision of the operator. After dismantling of all structures of the nuclear power plant, the end point will be the "green field" situation, meaning that the area will be decontaminated to such low levels of residual radioactivity that it can be cleared for unrestricted use.

The Nuclear Energy Act stipulates that a licensee can only dispose of wastes if disposal is specifically approved in a licence or by handing the waste materials over to the authorized waste management organization. As such, the central Organization for Radioactive Waste, COVRA, is the only organization authorized by the Government of the Netherlands.

COVRA N.V. is a state owned company, responsible for the treatment and storage of all kinds of radioactive wastes (low, intermediate and high level waste as well as spent fuel). This comprises also the wastes associated with the dismantling of nuclear facilities.

Although a strict legal requirement to ensure that adequate funding is available for decommissioning does not exist, there is a general understanding that the "polluter pays principle" applies. Consequently, the operators of nuclear power plants have made financial provisions for decommissioning.

For the last nuclear power plant in operation (Borsele), no final decommissioning plan has been established yet. It is envisaged that the same procedure will be selected as for the Dodewaard site, i. e., a waiting period of some 40 years.

Relating to the Dutch nuclear facilities in Petten, including hot cell laboratories and a decontamination plant, a decommissioning strategy is currently under development. Contrary to the policy of deferred dismantling for the nuclear power plants, it is expected that these facilities will be decommissioned immediately after closure. For HFR, which is owned by the European Commission, up to now no decommissioning plan has been prepared.

5.25 United Kingdom

The lead government department in formulating the radioactive waste management policy in the United Kingdom is the Department for the Environment, Transport and the Regions (DETR). Decommissioning is recognized as an important aspect of this policy. The Department of Trade and Industry (DTI) generally represents the views of the nuclear industry in this process. Other government departments and the regulators are also involved.

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

Nuclear sites are licensed under the NIA by the NII, who attach conditions to the site licence in the interests of safety and in respect of the handling, treatment and storage of radioactive materials. The conditions relating to waste management and decommissioning require arrangements to ensure that generation of wastes is minimised, that wastes are properly contained and that the wastes are stored in a controlled manner. When a nuclear licence is granted, the operator is required to make arrangements to comply with the conditions attached to the licence. As part of this compliance, the licensee has to demonstrate the safety of the facility at all stages of its operation, from the start of construction through to the completion of decommissioning, in a sequence of safety reports. These safety reports have to be periodically reviewed and updated.

In addition, the licenses have to prepare decommissioning plans that define the operator's strategy for decommissioning and managing the wastes produced at each stage and consider all practical options for managing each waste arising, including any secondary waste from the decommissioning operations.

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

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

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

Nuclear reactors

The United Kingdom's current strategy for decommissioning nuclear power stations is that it should be done in three stages: Stage 1, Defuelling immediately on shutdown; Stage 2, Dismantling buildings external to the reactor shield 5 to 10 years later; and Stage 3, Demolishing the reactor itself 100 years after shutdown.

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

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

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

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

The 1995 White Paper concluded that in general, the process of decommissioning nuclear power plants should be undertaken as soon as it is reasonably practical to do so, taking into account all relevant factors. Since regulatory approval will continue to be required on a case-by-case basis, it would be unwise for the operators of nuclear power plants to take steps which would foreclose technically or economically the option of completing stages 2 and 3 on an earlier timescale should that be required. Nevertheless, the Government believed that there were a number of potentially feasible and acceptable decommissioning strategies for nuclear power plants including Safestore.

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

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

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

Chemical plants

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

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

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

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

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

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

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

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

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

In November 2001, the Government announced its intention to radically change the arrangements for cleaning up the United Kingdom's civil nuclear liabilities. The "White Paper" published in July 2002, subsequently set out the Government's proposals and commitment to improving the way in which the clean-up is managed. A Liabilities Management Unit (LMU) was created paving the way for the Nuclear Decommissioning Authority (NDA), previously called Liabilities Management Authority (LMA). The Liabilities Management Unit is part of the Department of Trade and Industry (DTI), and the

Nuclear Decommissioning Authority (NDA) is a Non-Departmental Public Body, not directly part of the Government but responsible to the Government.

The NDA has been charged with the clean-up of the country's civil nuclear liabilities after the NDA was inherited on 1 April 2005. The prime task of the NDA is to secure the decommissioning of:

- The nuclear sites and facilities formerly operated by the United Kingdom Atomic Energy Authority (UKAEA) and British Nuclear Fuel Limited (BNFL).
- Liabilities arising from the Joint European Torus (JET).
- The Magnox fleet of nuclear power plants operated by BNFL, as well as the plant and facilities at Sellafield used for the reprocessing of Magnox fuel.

The strategy of NDA for cleaning up the United Kingdom's nuclear legacy is still at the draft stage and will heavily be affected by the stage of final disposal solution which is expected to be recommended by the Committee on Radioactive Waste Management (CoRWM) in July 2006. The government's response (or lack of it) to CoRWM's recommendation is therefore one of several critically important events for the NDA that will take place next year. Another key event next year will be the findings of the European Commission's (EC's) state aid investigation into the NDA. The EC is looking into the legality of the transfer of some of BNFL's assets (such as THORP and the Magnox stations) and associated liabilities to the NDA.

Table 5.4 Decommissioning status of specific United Kingdom nuclear facilities

Plant/Installation	Name	Type*	Operating Period	IAEA Decommissioning Stage
Large power reactors	DFR Dounreay	FBR	1963 – 1977	1
	WAGR Windscale	AGR	1962 – 1981	2
	SGHWR Winfrith	HWR	1968 – 1990	1
	PFR Dounreay	FBR	1975 – 1994	1
	Berkeley 1	GCR	1961 – 1989	1
	Berkeley 2	GCR	1961 – 1988	1
	Hunterstone A1	GCR	1964 – 1990	1
	Hunterstone A2	GCR	1964 – 1989	1
	Trawsfynydd 1	GCR	1965 – 1993	1
	Trawsfynydd 2	GCR	1965 – 1993	1
	Hinkley Point A	GCR	1965 – 2000	1
	Bradwell	GCR	1962 - 2002	1
Small reactor plants	Windscale Pile 1	GR	1950 – 1957	½
	Windscale Pile 2	GR	1951 – 1958	½
	Merlin Aldermaston	PR	1959 – 1962	1
	BEPO Harwell	GR	1948 – 1968	1
	DMTR Dounreay	HWR	1958 – 1969	1
	Dragon Winfrith	HTR	1965 – 1976	1
	ZEBRA Winfrith		1967 – 1982	2
	DIDO Harwell	HWR	1956 – 1990	1
	PLUTO Harwell	HWR	1956 – 1990	1
	GLEEP Harwell	GR	1947 - 1990	2
Other installations	B212 Caesium plant (Sellafield)	-	1956 – 1958	3
	B206 solvent recovery plant (Sellafield)	-	1952 – 1963	3
	B29 fuel storage plant (Sellafield)	-	1952 – 1964	1
	B207 uranium purification plant (Sellafield)	-	1952 – 1973	3
	Uranium enrichment (diffusion) plant (Capenhurst)	-	1953 - 1982	3

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

The "White Paper" sets out two options for funding clean-up, i. e., a segregated fund and a statutory segregated account. A segregated fund would be akin to a pension fund which holds investments. Money paid into the fund would be invested and the accumulated assets used to meet future decommissioning and clean up costs.

A statutory segregated account would be a "savings account" established in legislation and kept by the Secretary of State. It could be used to fund the Liabilities Management Authority's clean-up programme and directly associated expenditures, for example, research and skills programmes.

The present status of the United Kingdom nuclear facilities undergoing decommissioning is shown in Table 5.4.

5.26 Bulgaria

In Bulgaria, the Committee on the Use of Atomic Energy for Peaceful Purposes (CUAEPP) develops the policy and the regulations for decommissioning and has up to now been involved in its implementation as well.

Decommissioning can be controlled by the terms of an operating licence. Decommissioning licences are issued by the CUAEPP. In future it is possible that a Decommissioning Authority could be created to which the licence is transferred. This has still to be defined.

Plant design was not required to consider for decommissioning but the design allows for decommissioning without major complications. The Regulation of 2004 for issuing licences and permits for the safety of nuclear energy comprises requirements for the licensing process and for the documentation relating to the licence application, including the requirements about the structure and the contents of a decommissioning plan.

There is no published policy on decommissioning as until now only preliminary studies have been developed. There are no officially published decommissioning stages but it is likely that the IAEA Stages will be adopted. Achievement of Stage 3 is not obligatory however.

The clearance of materials is regulated by Ordinance No. 7 issued by the CUAEPP (currently the BNSA) in 1992. Waste is classified according to the activity content and/or surface contamination. Waste materials with activity content below these limits can be cleared without restrictions. Radiometric monitoring is reported to the regulator on a monthly basis and reviewed by the BNSA. Periodically, the BNSA performs independent controls of the materials prepared for clearance. Independent controls by specialized control organizations can also be carried out according to the Bulgarian legislation. Operational waste storage facilities were erected with the nuclear power plants and a special location has been defined for the temporary storage of treated radioactive wastes. No disposal facilities are available for operational waste or for future arising of decommissioning waste. A concept to establish a national repository for the final disposal of radioactive waste exists, however.

Funding of decommissioning is defined in the framework of the national legislation by the ASUNE (Act on the Safe Use of Nuclear Energy), which defines the establishment of a Nuclear Facility Decommissioning Fund, managed by the Minister of Energy and Energy Resources. A new Regulation for the procedure for assessment, collection, spending and control of the financial resources and definition of the amount of contributions required in the Nuclear Facilities Decommissioning Fund was issued in December 2003. This Regulation supersedes the Regulation from 1999, described in the first national report.

Bulgaria operates the Kozloduy nuclear power plant. The country is required to shut down Kozloduy Units 3 and 4 as a pre-condition for entering the EU. Therefore, these units will not be operated until the end of their designated lifetime, which is 30 years. Units 1 and 2 were closed at the end of 2002 in compliance with Decision No. 848 of the Council of Ministers of the Republic of Bulgaria (19 December 2002). The plants are currently maintained in an operating state, characterized by a lack of fuel in the reactor core.

The decommissioning plan for Units 1 and 2 of the Kozloduy nuclear power plant, developed in 2000, comprised the following stages:

- Final shutdown (duration 3 years).
- Preparation for safe closure (duration 2 years).
- Safe enclosure (duration 35 years).
- Postponed dismantling, including liquidation of the safe enclosure (the term has not yet been evaluated).

At the end of 2004 this plan was updated. The main change considered the extension of the post-operational period until the commissioning of the dry spent fuel storage, currently planned for 2009.

EU financial assistance in support of the decommissioning efforts under the Special Phare Programme amounts to € 550 million for the period 2000 to 2009. The Kozloduy International Decommissioning Support Fund (KIDSF), managed by the European Bank for Reconstruction and Development (EBRD), is the main channel for assistance granted under the Special Phare Programme.

The operation of the IRT-200 pool type research reactor was finally terminated by Decision No. 332 (17 May 1999) of the Council of Ministries. Based on a detailed cost-to-benefit analysis of the necessity of a reactor for educational and scientific purposes, the Council of Ministers adopted Decision No. 552 (6 July 2001) for the reconstruction of ITR-2000 into a low capacity reactor (200 kW). In this case, the decommissioning strategy for this reactor is limited to the required activities in view of the necessary reconstruction work.

5.27 Romania

In Romania, the organization involved in the development of policies and regulations on the decommissioning of nuclear installations is the National Commission for Nuclear Activities Control. This organisation is also responsible for the regulation of decommissioning activities. The implementation of decommissioning activities is the task of the operator of the nuclear facility.

The decommissioning activities are controlled under an operating licence that is issued by the National Commission for Nuclear Activities Control. There is no specific authority for decommissioning but the Law does not allow the licence to be transferred to any other organization than the operator. Plant design must take account of decommissioning and the regulatory body is planning to provide general guidance and general licence conditions.

A decommissioning policy for nuclear installations is planned to be issued in the near future. Currently the decay period for radio-nuclides with a half life of less than 30 years is 10 years. The provisions of the IAEA guidelines are not obligatory but adoption of these guidelines is envisaged in the near future.

According to the National Nuclear Safety Regulations the clearance of materials is regulated by the licence. Clearance levels have not been established and to date limits have been used on a case-by-case basis. Limits are expected to be provided when the regulations are revised. The licensee's radiometric monitoring is controlled independently by both the regulators and a third party.

A disposal facility for operational waste is available but this facility cannot accept wastes from decommissioning. There is also an interim storage facility for low and intermediate level wastes at the Cernavoda nuclear power plant.

Licence costs must be paid by the licence applicant, who is required to have adequate and sufficient financial arrangements for the collection, transport, treatment, conditioning and storage of radioactive wastes generated from his own activities, including for the activities relating to the decommissioning of these facilities.

A public hearing is required within the procedure for issuing the environmental licence.

5.28 Switzerland

Based on a referendum, the Swiss population voted in 1957 for an addendum to the Swiss Constitution enabling the peaceful use of nuclear energy. In 1959 the Atomic Energy Act was put into force, attributing to the Federal Council (the Federal Government) the exclusive competence to grant licences for the construction, operation and modification of nuclear installations. For geological waste repositories, additional cantonal laws have to be taken into account.

The Atomic Energy Act from 1959 was revisited and a new Nuclear Energy Law came into force on February 1, 2005. Also the corresponding Nuclear Energy Ordinance came into force on February 1, 2005. The new Nuclear Energy Law and its Ordinance include a regulation for the procedures for the decommissioning of Swiss nuclear facilities.

Licences are based on a detailed review and an assessment of the nuclear safety. The supervision of nuclear installations implies that the legal competence is available to take at any time the appropriate measures to enforce compliance with the licensing conditions.

Nuclear power plants

To date four different Swiss leading utilities are involved in the production of electricity based on nuclear energy in five units, contributing to about 40 % of the total Swiss electricity production: Beznau I and II, Mühleberg, Gösgen and Leibstadt. The start-up dates and the nominal power output of these facilities are given in Table 5.5.

Table 5.5 Start-up dates and nominal power output of the Swiss nuclear power plants

Plant Name	Utility	Synchron. to Grid	Power (MWe)
Beznau I	Axpo-NOK	1969	365
Beznau II	Axpo-NOK	1971	365
Goesgen	Atel	1979	970
Leibstadt	Axpo-NOK	1984	1,165
Muehleberg	BKW	1971	355

For none of these units decommissioning is planned in the near future. Nevertheless, already in 1984 Switzerland established a decommissioning fund that is administrated by a commission allocated to the government. The Swiss utilities have to deposit annual contributions to this fund, which are based on studies relating to the decommissioning of the individual units. The state owned federal research facilities are exempted from contributing to the decommissioning fund.

Nuclear research institutions

The major part of the nuclear research activities in Switzerland is performed at the Paul Scherrer Institute (PSI). The work in the Paul Scherrer Institute is carried out in co-operation with other national and international research institutes and with the industry.

Considering decommissioning, only the research reactor DIORIT at PSI and a pilot reactor at LUCENS have been decommissioned. DIORIT was completely dismantled and all arising radioactive wastes have been conditioned for final disposal, including the reflector/moderator graphite. The spent fuel assemblies that since 1983 were stored on site in a CASTOR cask have been transported to the Swiss Central Interim Storage Facility ZWILAG in 2004.

The site of the prototype reactor at LUCENS was released from nuclear supervision in 2004, after the last size reduced and packaged core components had been sent to the ZWILAG Central Interim Storage Facility in 2003. The site is an example of partial site reuse for non-nuclear purposes.

The research reactor SAPHIR at the Paul Scherrer Institute is in the stage of safe enclosure for decommissioning. The dismantling project has been approved by the Swiss Federal Nuclear Safety Inspectorate (HSK) and licensed by the Federal Government.

National policy and regulations for decommissioning

In February 2005 a new Swiss Nuclear Energy Law came into force replacing the old Atomic Energy Act from 1959 in which no specific reference was made to decommissioning.

In four articles, the new Nuclear Energy Law regulates explicitly the obligations of the owner relating to the decommissioning of a facility, the role of the authorities and the official end state of a decommissioning project.

In addition, the Ordinance on Nuclear Energy defines the provisions for the decommissioning of nuclear installations considering mandatory documentation, scope, phases, duration, radioactive releases, monitoring, organisation, authorization activities, reporting, etc. relating to decommissioning projects.

Neither the Nuclear Energy Law nor the Ordinance on Nuclear Energy provide prescriptions or recommendations in view of selecting a decommissioning strategy. It is required, however, to investigate options of different sequences of decommissioning steps and to justify a selected strategy. An environmental impact assessment is obligatory.

Decommissioning strategy

For research facilities or pilot reactors, different decommissioning strategies have been applied, reflecting the individual constraints and operational conditions of the facility. The decommissioning and dismantling of the pilot reactor at LUCENS took only three years. The decisions how to proceed further, the entombment of the remaining structures, the final sealing of the underground caverns and the removal from site of the last packaged and stored activated components took an additional 30 years.

A similar timetable applied to the research reactor DIORIT including periods of safe enclosure.

The duration of the decommissioning of the research reactor SAPHIR, including a period of safe enclosure, has not yet been defined but will be about another 8 years.

Considering the future decommissioning of the nuclear power plants, it is expected that no single recommended strategy will be defined. Specific individual circumstances will be taken in consideration. There is a growing opinion that too long delays before starting decommissioning activities should be avoided in order to ensure that the availability of staff with detailed knowledge of the plant from its construction and operational phases could be effectively used in securing the safety of the decommissioning and dismantling activities. The knowledge of the status and the history of the nuclear facility is considered to be essential for successful planning of decommissioning, for the selection of a decommissioning strategy and for the implementation of the decommissioning activities from both the safety and the technical point of view.

Currently, neither the start of decommissioning, nor the end point for the decommissioning activities have been regulated or defined. In 2001 the time schedule used for estimating the decommissioning costs was updated, assuming that the nuclear power plant Beznau should be shut down in 2010, Mühleberg in 2012, Gösgen in 2019 and Leibstadt in 2024. Per definition, the decommissioning of a nuclear power plant should start when the operating licence for the facility is terminated. The Swiss nuclear power plant operators are discussing a plant life extension up to 60 years, however.

Decommissioning techniques and inspection

Decommissioning of nuclear facilities requires judicious use of decontamination techniques either to reduce the radiation levels or to minimise the volumes of radioactive wastes generated when a facility is dismantled. The choice of techniques depends on individual circumstances. In decommissioning programmes, the objectives of decontamination may be to reduce radiation exposure; to salvage equipment and materials; to reduce the volumes of equipment and materials requiring storage and disposal in licensed disposal facilities; to reduce the building area for safe enclosure or to minimize long-term monitoring and surveillance requirements; to restore the site and the facility, or parts thereof, in a condition enabling unconditional clearance from regulatory control; or others.

In order to achieve these objectives, the dismantling of the Swiss research reactors was performed in the following steps:

- Removal of unnecessary equipment.
- Removal of activated and contaminated parts of the reactor.
- Dismantling of the remaining structures from the inner to the outer side of the buildings.

The decommissioning of the research facilities and the pilot reactors is carried out on the basis of a project approved by the regulatory authorities. A nuclear installation that is being decommissioned remains subject to the Nuclear Energy Law and to the regulatory supervision of the Swiss Federal Nuclear Safety Inspectorate (HSK). On a routine basis, inspections are carried out during the various decommissioning and dismantling steps in order to monitor radioactive waste arising, to monitor materials and the site in view of clearance from regulatory control, and when specific circumstances require specific inspections.

Radioactive waste management - Interim storage and conditioning

The Central Interim Storage Facility ZWILAG was constructed for the collection and conditioning of all kinds of operational radioactive wastes and has been in operation since 2001. Also some types of decommissioning wastes could be stored in the facility. In addition, all Swiss nuclear power plants have on-site interim storage capacity which is intended to be used for operational wastes but not for waste materials resulting from decommissioning activities, however. The large amounts of decommissioning wastes should be disposed of directly in an underground repository without the need for post-closure monitoring or control.

In order to reduce the generation of radioactive wastes, decontamination of materials up to clearance levels should be envisaged as mentioned before. Remaining radioactive materials must be conditioned and disposed of as radioactive waste. Optimization measures are required as the costs for decontamination and the worker doses have to be weighed against the advantages of lower volumes for final disposal.

Clearance of materials from regulatory control is supervised by the regulatory authority. The clearance procedure is currently based on work instructions. The procedure for clearance is regulated by means of HSK Guideline R-13.

The Federal Government is responsible for the research reactors at the Paul Scherrer Institute. Waste arising from the dismantling of these reactors is conditioned and stored on site up to the moment a final repository will become available.

The radioactive material resulting from the dismantling projects is subdivided into four categories:

- Materials to be decontaminated;
- Materials with remaining activity levels below the current clearance limits;
- Materials that are expected to decay within 30 years to below the current clearance limits;
- Radioactive wastes that have to be conditioned.

Table 5.6 Estimated disposal volumes and disposal costs for wastes from the decommissioning of Swiss nuclear power plants

Plant	Volume (m^3)	Cost (Million CHF)
Beznau I and II	12,400	65
Mühleberg	4,320	21
Gösgen	5,470	27
Leibstadt	9,870	48

The bulk of waste materials from dismantling is put in concrete containers and embedded in concrete for storage on site. In case the existing on-site waste treatment installations do not match the requirements for size reduction and packaging of the arising decommissioning waste materials, these installations have to be appropriately adapted.

The estimated volumes resulting from the decommissioning operations are for the various power plants shown in Table 5.6. The estimated disposal costs are given as well.

Disposal of radioactive wastes

In 1993, the Swiss National Disposal Management Organisation (Nagra) concluded from site investigations, that the area of Wellenberg could be suitable for the location of a repository for low and intermediate level radioactive wastes. The Swiss Government and its experts concurred in 1994 with these conclusions. In January 1995, the necessary mining licence for the facility was granted by the Canton Government. However, the decision was not validated due to a cantonal vote in June 1995. A new application for a mining concession was submitted in January 2001, this time only relating to the construction of an exploratory tunnel. However, also this application was rejected in a cantonal referendum in September 2002. Subsequently, the nuclear power plant operators decided to withdraw from the Wellenberg site.

Final disposal of high level wastes (direct disposal of spent fuel and vitrified wastes from reprocessing) is intended to be implemented in an underground facility, the host rock of which being an opalinus clay formation. The results of related studies of the Swiss National Disposal Management Organisation (Nagra) are published in a report, known as the "Entsorgungsnachweis hochaktive Abfälle". The report has been submitted to the Government in 2005.

Funding

In 1984 a decommissioning fund for the dismantling of the nuclear power plants in Switzerland was established, into which all nuclear power plants (utilities) make financial contributions. The fund is administered and managed by the Federal Government under supervision of a joint Government/Utility Board. Dismantling of the research reactors is funded by the Government.

The financial means collected in the fund from the plant operators accumulated by the end of the year 2004 up to 1’054 Mio CHF. The total amount of money necessary for the dismantling of the Swiss nuclear power plants was estimated in various decommissioning studies. The most recent estimate (2003) considers that the required amount of money in the fund should be further increased to 1’835 Mio CHF. The required money for a specific nuclear power plant must be available when the plant is finally shut down for decommissioning.

The decommissioning cost estimates as indicated above include the costs for (Art. 5, Decommissioning Fund Regulation):

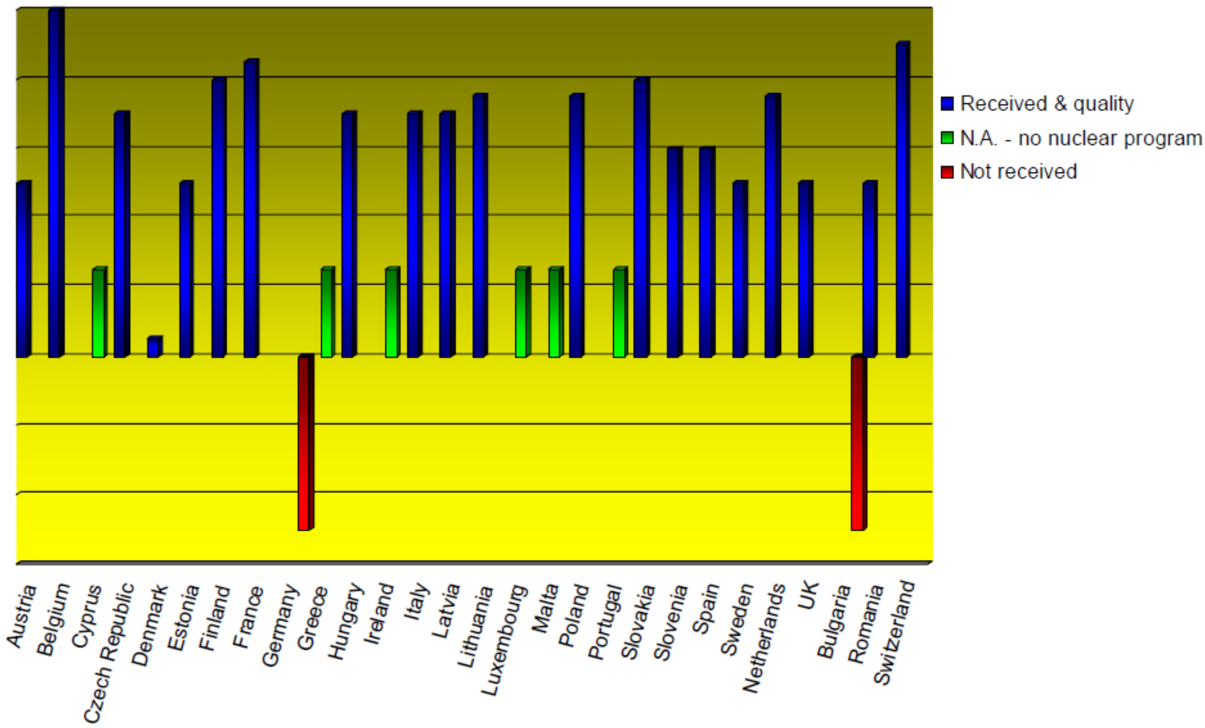
- The technical preparation for decommissioning;
- The inclusion, conservation, maintenance and security of the plant;
- The decontamination or dismantling and size reduction of activated and contaminated parts;
- The conditioning, packaging, interim storage, transport and disposal of radioactive wastes;
- The demolition of buildings and the disposal of non-radioactive waste materials;
- Planning, project management and supervision;
- Radiation protection and work protection measures;
- Licensing and supervision by the Authorities;
- Insurances.

6 Detailed overview of collected information on policies, strategies and funding for decommissioning

As indicated in Section 3, "Data collection and assessment", detailed and appropriately pre-completed questionnaires have been sent to relevant organisations from the 25 Member States and the 2 Candidate Countries of the European Union as defined in Section 3.1, "Inception phase", as well as to the relevant organisation in Switzerland, with the aim to collect information on the factors that influence the selection of strategies for the decommissioning of nuclear installations in the countries.

The responses to the questionnaires were compiled into a database that was considered to comprise the special information that was collected from all the affected stakeholders relating to the strategies, policies and funding principles for decommissioning adopted in the various countries/projects, paying adequate attention to the factors influencing the selection of strategies for decommissioning projects that should be further analysed. An overview of the status of the responses of the various countries to the questionnaire is given in Figure 6.1.

Figure 6.1 Status of the responses of the various countries to the questionnaire



The collected data were analysed in order to select a sufficiently large number of representative respondents that would be subject of an in-depth analysis, optimising the use of the available budget resources.

The results of the additional consultation process have been analysed, separating those which resulted to be site specific from those which are common to most of the decommissioning projects.

A detailed description of the results and the experiences collected during the consultation and analysis stages, including the conclusions that were drawn, the site specific issues and the generally applicable information relating to the adopted policies, strategies and funding for decommissioning in the various countries/projects is given in the following sections.

6.1 Decommissioning policies

It is widely accepted that the roadway to the removal of regulatory controls from nuclear facilities and its structures and materials depends on various factors and may involve various stages and interim situations. National policies may differ widely and are influenced in different ways by matters such as the future use of nuclear power, the continued availability of trained staff, societal issues associated with the effects of the shutdown of a facility, safety, costs and the broader financial issues such as best use of available funds and the time to deploy the funds.

Decommissioning policy, in the context of this study, refers to the government policy, and includes all governmental choices (national or regional) as described in laws, regulations, standards and mandatory requirements that will influence the framework in which the decommissioning activities are implemented. For example, requirements regarding the use of decommissioned sites, waste management policies, policies for re-use and recycling of materials, public and worker health and safety policies, environmental safety policies, regional development aspects, etc., have to be seen as elements of the decommissioning policy.

The following review and analysis is mainly based on the answers to the questionnaire received from the twenty-five EU Member States, from the Candidate Countries Romania and Bulgaria, and from Switzerland as a non-EU country. A number of questions in this questionnaire aimed at identifying the existence and the details of a decommissioning policy in these countries (see Annex 1, Questions QP1 - QP21).

It should be noted that the selection of potentially important policy issues was not unbiased or exhaustive. A pre-selection of policy issues was performed when the questionnaire was prepared with a view to include those issues which were thought to have the greatest impact on costs or to be of particular interest to governmental bodies.

Information from the respondents was requested regarding the following policy issues:

- A national definition of decommissioning;
- The scope and the time scale of the decommissioning activities;
- The requirements for the selection and optimisation of strategies;
- The licensing requirements, documentation, de-licensing and future liabilities;
- The responsibility for the decommissioning costs and the decommissioning activities;
- The trans-boundary movements of materials;
- The management of materials, radioactive and non-radioactive wastes;
- The availability of final repositories;
- The availability of clearance levels and the possibilities for the recycling of materials.

Although the respondents provided extensive information on most of the topics included in the questionnaire, the answers varied in the degree of details and coverage and, moreover, did not always cover the full scope of information envisaged by the drafters of the questionnaire. Therefore, the information presented in this report should be considered to be indicative for the approaches adopted in the various countries and by the various industrial operators. Similarly, the analyses and findings are illustrative for the generic trends and are not intended to serve as a basis for comparisons between countries and operators.

6.1.1 Scope and time scale of the decommissioning activities

6.1.1.1 National definition of decommissioning

The national policy requirements define and delimit, in scope and sometimes in time, the decommissioning of a nuclear facility. A possible delimiter of the scope of decommissioning could be the national definition of decommissioning. In about 50 % of the responding countries, a definition of the term "decommissioning" has been given. Some examples are:

- *"The complete set of administrative and technical operations enabling a nuclear facility to be withdrawn from the list of classified installations as defined in terms of the dispositions of the Royal Decree of 20 July 2001"* (Belgium, Royal Decree of 20 July 2001, article 2, Definitions).
- *"Decommissioning means activities aimed at releasing nuclear installations or workplaces where radiation practices were performed, for their utilization for other purpose"* (Czech Republic, Act No. 18/1997 Coll. on Peaceful Utilization of Nuclear Energy and Ionizing Radiation and Decree No. 185/2003 Coll. on Decommissioning of Nuclear Installations or Category III or IV Workplace).
- *"The term "decommissioning" is used to describe all measures taken by the licensees after final shutdown of a facility in order to dismantle the facility in a safe manner, as well as handle the nuclear material and the nuclear waste at the facility site, with the intention to reduce the amount of radioactive substances in the land and building structures to levels that permit release of the site and any buildings left behind"* (Sweden).
- "*Decommissioning refers to administrative and technical actions taken to allow removal of some or all the regulatory controls from a nuclear facility. The objective of decommissioning is to remove the hazard the facility poses progressively, giving due regard to security considerations, the safety of workers and the general public and protecting the environment, while in the longer term reducing the number of sites and acreage of land which remain under regulatory control"* (United Kingdom).

The common features of the different definitions are that decommissioning refers to the actions taken to reduce the residual hazards (radiological or other) after termination of the operation of a facility with the aim to achieve a stable and safe end state (unrestricted use, restricted use or a new nuclear facility). Often the definitions include a specific reference to the safety of workers and the public and to the protection of the environment during and after the decommissioning process.

6.1.1.2 Required starting and end points of decommissioning

If specified in the national policy, the required starting and end points of decommissioning activities have a direct impact on the scope of work included in "decommissioning" and as such on the development or selection of a decommissioning strategy. The responses to the questionnaire illustrate a wide range of situations regarding this issue. Sometimes, intermediate, post-closure stages are mentioned which are not always well defined or separated from other stages.

More than half of the respondents answered that there is a definition of the starting point of decommissioning, while one third gave the opposite answer.

In many cases, the starting point is the requirement to change from an operating licence to a decommissioning licence. It should be noted, however, that in some countries, like in Finland, Sweden and the United Kingdom, no specific decommissioning licence is needed. The decommissioning activities are performed under the operating licence.

More than 60 % of the responding countries answered that a required end point of decommissioning has been defined. Some respondents answered that the national policy does not require a specific end point but that the end point is specified in the decommissioning application (Belgium) or agreed upon between the plant operator and the decommissioning operator (Spain). In some countries (Switzerland) "green-field" conditions, i. e., unrestricted release of the site, are assumed to be the end point for the purpose of cost estimates.

The respondents were also asked to give a short description of the required end point, if defined. The answers confirm that different kinds of end points are possible. Six responding countries (Finland, Hungary, Italy, the Netherlands, Czech Republic and Switzerland) answered that the required end point is unrestricted use of the site (all contamination and radioactive sources above clearance levels removed), or "green-field". In the United Kingdom and the Slovak Republic unrestricted use, restricted use or use for a new nuclear facility are viable options.

6.1.1.3 Mandatory time scale

Twelve countries answered that a mandatory time scale is defined by which the end point of decommissioning must be achieved. In Italy, where nuclear energy production has been stopped since 1987 and even before for some units, the objective of the national policy is to finalise the decommissioning activities before the year 2020. For the ten other countries with mandatory time scales, the end point must be achieved within periods ranging from 40 to 100 years after shutdown.

Considering the information mentioned above, it is clear that the scope of the actual decommissioning work may vary from one country to another and even from one decommissioning project to another. It is observed that different starting and - perhaps more importantly - end points are allowed within national legislations for decommissioning. In only less than one third of the countries, including countries where the end point is defined by legal requirements but only assumed for the purpose of strategy definition and cost estimates, the option of unrestricted use of the decommissioned site is singled out.

Without additional details about clearance levels and de-licensing requirements it is difficult to evaluate the precise impact of the varying requirements on the selection of a decommissioning strategy. An influence does exist, however, as there are many variations of an acceptable end state for a decommissioned nuclear facility. Therefore, the starting and end points as well as the time schedule of the decommissioning activities should be known and taken into account when comparing cost estimates for specific projects or when trying to analyze the reasons for the variability of costs between different projects and countries.

6.1.2 Licensing requirements

The control of decommissioning activities to ensure that they are performed according to the legal requirements varies from country to country according to the national regulations. A regulatory authority can control the decommissioning activities in many different ways: by a single overall decommissioning licence, by separated licences applying to discrete sets of activities, or by direct control of a regulatory body. In some federal countries, the national governments and the governments of the individual States or Provinces of the federation share the regulatory responsibilities. Different regulatory bodies may also be responsible for different aspects, such as planning, health and safety of workers and the public, waste disposal and environmental protection issues.

Experience has shown that considering decommissioning issues at the earliest stage in the life time of a nuclear facility is essential to facilitate the decommissioning activities and reduce the decommissioning costs. Today, plans and procedures for decommissioning are key features in the design of new nuclear facilities. A decommissioning plan, to be reviewed and updated at regular times, is often required before an operating licence is issued for nuclear facilities that are commissioned. Although this was not usually the case when many of the existing nuclear power plants were built, decommissioning plans and systems for their recurrent reviews have now also been introduced for these plants.

The responses to the questionnaire provide information on how decommissioning is licensed in the countries considered in the study. The main questions on this topic addressed the need, or not, for a new licence to shut down and/or decommission a nuclear facility and the documentation requested by the authorities in order that the operator may gain consent to proceed with the decommissioning activities.

6.1.2.1 Licence to shut down a nuclear facility, decommissioning licence

In eight of the twenty-eight countries participating in the study, a specific licence, different from the operating licence, is required to shut down a facility. In nearly 80 % of the countries, a specific decommissioning licence is required. Only in a few countries, for example in Finland, Sweden and the United Kingdom the decommissioning activities can proceed without a specific decommissioning licence. In that case the operating licence applies to decommissioning activities as well. For example, in Sweden, the operating licence also covers the future decommissioning and dismantling activities but specific requirements have to be fulfilled.

6.1.2.2 Documents required in order to gain consent to proceed with decommissioning

In order to proceed with the decommissioning and dismantling activities, certain documents are required by the national authorities. The requirements for reporting and the regulatory review process of decommissioning plans and safety management issues may vary from country to country. Some requirements are common to the countries that participated in the study, however. For example, with a few exceptions, a safety case or a safety report must be presented to the authorities. In addition to this, an environmental impact assessment is often required.

The countries of the European Union are bound by the terms of the European Commission legislation to perform an environmental impact assessment (EIA) in connection with the decommissioning of nuclear power plants. In this European Union framework, specific measures are taken to inform and involve the public and the neighbouring countries.

If a new licence is needed for the decommissioning activities, the application should invariably be supplemented with a decommissioning plan, and supplementary documents such as a safety case, a radiation protection programme, requirements/guarantees of funding, environmental impact assessment, quality assurance plan, technical descriptions, time plans, etc. Sometimes the requested documentation is quite extensive.

In the countries where no new licence is required to proceed with the decommissioning activities, reports are usually required at a few fixed, pre-determined occasions.

The fact that a new licence has to be issued in order to exclude the possibility for continued operation of a nuclear facility, could sometimes be economically advantageous for the operator as earlier mandatory safety measures and provisions applicable to a plant in operation might no longer be needed during decommissioning. However, as mandatory regulatory requirements may exist even in the absence of the need for a specific licence, it is difficult to draw any firm conclusions about the impact on the effectiveness of regulatory control of the fact that a specific decommissioning licence is required or not to proceed with decommissioning.

For example, in Sweden, regulatory requirements are issued by different health and safety authorities and have to be fulfilled, sometimes in the form of a stepwise authorisation, in order to start decommissioning although no new licence is needed. It is important, however, to note that in that case a flexible, stepwise process of authorisation is possible, reflecting the changing physical situation in the plant and the related evolution of hazards during the different decommissioning stages.

6.1.3 Requirements for selecting a strategy, de-licensing and liabilities

6.1.3.1 Selection of a strategy; guidance provided; required options/alternatives to be considered

In more than half of the responding countries, the utilities/operators are explicitly requested to perform a broad based strategy optimisation before selecting a decommissioning plan. In some of these countries, guidance is given on how to perform this optimisation. It should be observed that some of the responding countries remark that even if no formal request exists for the selection of a strategy, such optimisation is assumed to be performed.

In the Member States of the European Union different decommissioning alternatives are assessed in the framework of an Environmental Impact Assessment and guidance on the alternatives to be considered is given by designated national bodies.

6.1.3.2 Requirements for de-licensing a site; future liabilities

A few countries still have to define requirements for future de-licensing of sites. Some countries answered that de-licensing can be performed when all radioactive and other hazardous materials are removed from the site, including all radioactive contamination above some pre-determined levels. Other countries answered that the absence of radioactive materials has to be controlled and confirmed by a suitable authority and reference is made to clearance levels or legal documents containing such clearance levels. Sometimes the applicable clearance levels are included in the decommissioning licence and could be specific for an actual decommissioning project.

Six of the responding countries have addressed the question of liability for costs of managing radioactive materials discovered after de-licensing. For these respondents, the former operator/owner of the plant remains responsible. In some countries, however, such as Hungary, the State/Government is the owner/operator of the plant. In all cases, according to the International Convention on Nuclear Safety, the State has the ultimate responsibility for handling radioactive materials and covers any associated costs if the plant operator/owner/legally responsible organisation does not exist any more.

The provided information shows that many countries have well-developed systems for de-licensing a site but that there is no consensus within EU countries on a preferred set of clearance criteria for sites or even on the form of such criteria. The participation of the civil society, including all stakeholders together with the operator and the regulator, in the selection of procedures for surveys and clearance criteria for sites is important for the transparency and the public acceptance of the decommissioning process.

6.1.4 Material and waste management

Large volumes of materials arise during the decommissioning activities and the costs for radioactive material and waste management and disposal could make up a substantial part of the overall decommissioning costs and influence the selection of a decommissioning strategy.

Identifying clearly and preparing the different treatment and re-use or disposal routes for each type of materials and wastes issued from the decommissioning activities is a key issue relating to cost effectiveness, minimization of waste volumes and toxicity as well as safety and radiation protection of workers. For countries that foresee decommissioning and dismantling without extended periods of safe enclosure it is of prime concern to find site(s) for waste disposal, and design and construct repositories.

Examples of categories of materials and wastes to be considered include radioactive and non-radioactive wastes; materials for authorized reuse; materials to be recycled within the nuclear industry; and materials for re-use outside of the nuclear industry.

In order to collect information on these issues, the respondents to the questionnaire were asked if repositories for all types of radioactive waste arising from decommissioning are available. They were also asked to provide information about the repositories available for decommissioning waste and about any planned repositories for decommissioning waste. In addition, the respondents were asked to provide information about the national policy relating to hazardous, non-radioactive waste and "mixed waste", i. e., radioactive waste comprising hazardous non-radioactive materials. Finally, the respondents were asked if specific clearance levels and/or procedures for categorizing decommissioning waste materials as non-radioactive or for clearing such materials from any regular control exist in their countries.

6.1.4.1 Repositories for radioactive decommissioning waste

None of the twenty-eight countries that participated in the study has repositories for all types of decommissioning waste. The categories of existing radioactive wastes that cannot be disposed of are stored in interim facilities at the site of the nuclear facility or in specially designed national interim storage facilities. Pending construction and commissioning of suitable repositories for radioactive and other hazardous waste materials, dismantling activities are sometimes deferred. Since estimating decommissioning costs requires assumptions regarding waste disposal costs, the lack of a repository for some waste categories increases the range of uncertainty relating to the total decommissioning costs as well as the variability from one country to another.

In some countries, e. g., in Switzerland, the national decommissioning work is planned in such a way that a repository is expected to be available at the time of decommissioning. In other countries, like in Germany, interim storage facilities for radioactive wastes have been constructed at sites where decommissioning activities are implemented in order to proceed with decommissioning before the actual repositories are available.

In five of the responding countries, repositories exist that can accept low or intermediate level wastes from decommissioning and these will often remain in operation for many future years. The information provided about these repositories is summarized in Table 6.1. Restrictions on the specific activity, on the dose rates at the surface of the waste packages and on the content of long-life radionuclides and alpha-emitters apply to those repositories. Usually some restrictions also exist relating to chemicals, asbestos, graphite, free liquid, brass, or pure forms of carbon, magnesium, bismuth or fluorine.

The maximum dose rate in contact with accepted waste packages is often restricted to 2 mSv/h, a requirement resulting from the international transport regulations. In some countries however, the use of shipping packages has enabled the disposal of waste items with considerably higher contact dose rates.

In more than 50 % of the countries that responded, repositories for radioactive wastes from decommissioning are planned. In France, Hungary, Italy, Romania, Slovenia, and Spain new repositories for very low and/or low and intermediate level radioactive wastes are planned to come in operation within the next ten years. In Finland and Sweden, existing repositories for operational radioactive wastes are planned to be extended in order to accommodate decommissioning wastes.

In Germany, the Konrad mine received a licence for the disposal of "non-heat-generating wastes" in June 2002, which means that it could accommodate all types of radioactive wastes, including decommissioning wastes, but except fuel and solidified high level wastes from reprocessing. The licence is now subject to litigation, however. As a result radioactive wastes can only be disposed of after all court cases have been resolved.

Table 6.1 Summary of existing repositories that accept radioactive decommissioning wastes

Country	Location (Type)	Opening year	Anticipated closing year	Characteristics of the waste limiting acceptability	Special materials not accepted at the repository
Czech Republic	Dukovany (Low and intermediate level waste from nuclear power plants)	1995	2100	Max. β, γ: 1 x 10^{12} Bq/m^3 α: 3 x 10^7 Bq/m^3 Max. 0,9 Sv/h in contact No limits on size of package; handling technique adapted to 200 (400) dm^3 drums Max weight: 550 kg	Free liquids; pyrophoric and/or explosive materials; hazardous chemical substances and preparations (e. g., PCB, asbestos, lead).
	Richard Litoměřice (Low and intermediate level waste from institutions)	1964	2070	Max. β, γ: 1 x 10^{11} Bq/m^3 α: 2 x 10^8 Bq/m^3 Max. 1 mSv/h in contact Max. size of package: 200 dm^3 drums Max. weight: 600 kg	
France	Centre de l'Aube, Soulaines	1994		Max: 1 x 10^6 Curie (for the total repository) Max. size of package: 4 m^3 Max. weight: 10 tonnes	Graphite; "long-life" wastes.
Slovak Republic	2 km northwest of Mochovce nuclear power plant	2001	2031	Max. 2 mSv/h in contact (fibre reinforced concrete container) Package size: 1,7 x 1,7 x 1,7 m^3 Max. weight: 15 tonnes	Free liquids; biodegradable substances (gas developing); phyrophoric substances and substances producing exothermic reactions with water; toxic or hazardous non radioactive wastes.
Spain	El Cabril, Córdoba	1992		Max. α-emitters: 3,700 Bq/g Max. 50 mSv/h in contact (before conditioning) Max. size of package: 1,3 m^3 Max. weight: 1,5 to 2,0 tonnes	Acceptance criteria are related to activity levels, half-life and size.
United Kingdom	Drigg, Cumbria (Low level waste)	1959	~ 2050	Max. α-emitters: 4 GBq/te Max. non-α: 12 GBq/te No additional shielding allowed, 2 mSv/h in contact at transport Max. width: 2,438 m Max. length: 6,058 m Max. height: 1,320 m Max. weight: 35 te delivered/pre-grouting 42 te post grouting/emplacement	Will accept some solid low level decommissioning waste. Decommissioning wastes may not be accepted if they have a significant impact on the available capacity (could apply to graphite due to high C^{14} content).

6.1.4.2 Hazardous, non-radioactive waste

Decommissioning of nuclear facilities also involves the management of large quantities of non-radioactive wastes. These materials have either never been contaminated or activated or have been cleared from any nuclear regulatory control (see "*Clearance levels*"). Such waste materials may include hazardous substances such as toxic chemical compounds, asbestos, or other materials that require a specific management scheme.

In most countries, the same rules apply to the non-radioactive, hazardous wastes resulting from the decommissioning of nuclear facilities as to the hazardous wastes resulting from other industrial activities. This was either directly stated in the responses to the questionnaire or reference has been given to the applicable national or regional legislation for such waste materials. In some countries like in Belgium, communal, regional or provincial norms, policies, and rules apply to the non-radioactive hazardous wastes. In Spain special authorized enterprises are responsible for the management of these wastes off-site. In a few countries, the question still has to be addressed.

6.1.4.3 Non-radioactive hazards associated with radioactive wastes

All types of radioactive waste may contain non-radioactive hazardous substances at varying concentrations. If the amount of hazardous substances exceeds predetermined levels, in some countries such waste materials are defined as "mixed wastes". These mixed wastes require special attention, in particular when they have to be disposed of in near surface repositories.

In about one third of the countries, no specific national policy for mixed wastes exists. In about 25 % of the countries the management of mixed wastes is part of the processing of radioactive wastes. In the Slovak Republic, mixed wastes will be stored in the long-term interim storage. In Sweden, the disposal of mixed wastes is limited by the specific waste acceptance criteria of each waste repository.

Germany has no definition of a mixed waste category. The German policy is to dispose radioactive wastes in geological formations. The operation of near surface repositories is not foreseen. The non-radioactive hazards associated with radioactive wastes have been considered within the safety assessment for the Konrad mine. It was found that hazardous materials associated with radioactive wastes do not pose an additional hazard to the safety of present and future generations and can be disposed of safely in this deep geological repository.

6.1.4.4 Clearance levels

In about 60 % of the countries specific national clearance levels have been defined, or other ways to categorize decommissioning waste materials as "non-radioactive", enabling these materials to be cleared from any nuclear regulatory control. Belgium (in the early 90s), Italy, and Spain are examples of countries in which clearance levels have been specified for a site or a decommissioning project or for a number of specific activities at a site (e. g., Caorso, Italy). Belgium, Germany and the United Kingdom are examples of countries with general clearance levels stipulated in the national legislation.

The costs for the management and the disposal of radioactive wastes can be a substantial part of the overall decommissioning costs. Therefore, the availability and the acceptance criteria of existing or planned repositories, the need for on-site interim storage facilities and the applicable clearance levels have a significant impact on the selection of a decommissioning strategy. This should be recognized when comparing estimated or actual costs between different decommissioning projects.

6.2 Decommissioning strategies

As defined in Section 4, Current Developments Relating to Decommissioning Policies, Strategies and Funding, the term "decommissioning strategy" for the purpose of this report relates to the industrial approaches of owners of nuclear sites and operators of nuclear facilities in view of the application of a decommissioning policy. It covers specific plans and assumptions made in the context of decommissioning projects, in particular relating to the factors that might influence the selection of a decommissioning strategy.

In order to gather relevant information, a number of questions relating to decommissioning strategies and details of sites of nuclear facilities were included in the questionnaire (see Annex 1, Questions QS I-1 to QS V-4), including:

- Outline of data and details of facilities;
- The decommissioning strategies that have been considered;
- The identification and completeness of stakeholders;

- A description of legal background;
- The impact on the environment;
- Public acceptance, social and ethical impacts;
- The availability of funding;
- Project risks evaluation;
- The methodology for defining the preferred strategy and the main factors considered;
- Dismantling and waste disposal plans.

All information provided in response to the questionnaire has been collated and compared in order to prepare an overview as indicated in the following sections. It should be noted that not always complete answers were provided to each question for each reactor site or each reactor or nuclear facility and that there was some variability in the presentation of some of the answers. Some countries provided data for reference or generic reactor types rather than for specific reactor sites. Consequently, the trends as reported below should be considered to be indicative while individual data points may illustrate the variability of the information provided.

6.2.1 Information relating to reactor sites

Responses to the questions on decommissioning strategies were received from almost all relevant countries, covering over 130 reactors on over 80 sites, with the numbers of reactors per site varying between 1 (e. g., Latina, Italy) to 6 (France). Most responses refer to a specific nuclear power plant in a given country. Some respondents provided more generic data that are representative for nuclear power plants in their respective countries. Germany and Spain provided data for a reference PWR and a reference BWR, and France provided a single data set covering 58 PWR reactors. In the following analysis, the German, Spanish and French data has been treated as being representative for a single reactor unit although it is recognised that they are representative for a number of units.

6.2.1.1 Reactor information

In order to support the analysis relating to information on issues of decommissioning strategies, a number of questions relating to technical data on reactor units were included in the questionnaire. The responses to these questions cover 5 different types of reactors with sizes varying from 49 MWe (Calder Hall/Chapelcross in the United Kingdom) to 1 455 MWe (Chooz B in France). The reactor types and the number of reported reactors are shown in Figure 6.2. The range of reported plant capacities (in MWe) are for each reactor type given in Figure 6.3. This indicates that in general, for the reactor types considered, gas cooled reactors (GCR) have the lowest capacity, while RBMK reactors the largest.

The majority of the reactors considered have steel reactor pressure vessels. 12 % are reactors utilising pressure tubes and 9 % have concrete reactor pressure vessels.

The majority of the reactors for which information was provided are still in operation. About 20 % have been shut down. Information on actual or predicted shutdown dates was provided for about 60 % of the reactors considered. The shutdown profile for these reactors is presented in Figure 6.4. The figure shows that the number of reactors that will be shut down is gradually increasing between 2005 and the year 2030 when most of them will have terminated their operational life time. It should be noted that the shutdown dates for the reactors that are still in operation are those assumed for costing purposes and are not necessarily the ultimate dates of the shutdown of the facility.

Figure 6.2 Reactor types in the countries under review

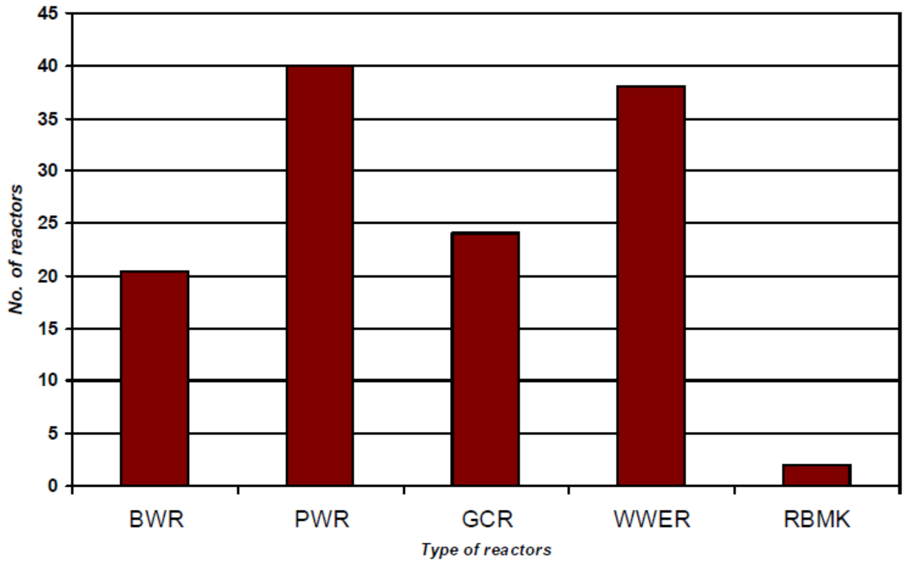


Figure 6.3 Nuclear power plant power output (MWe)

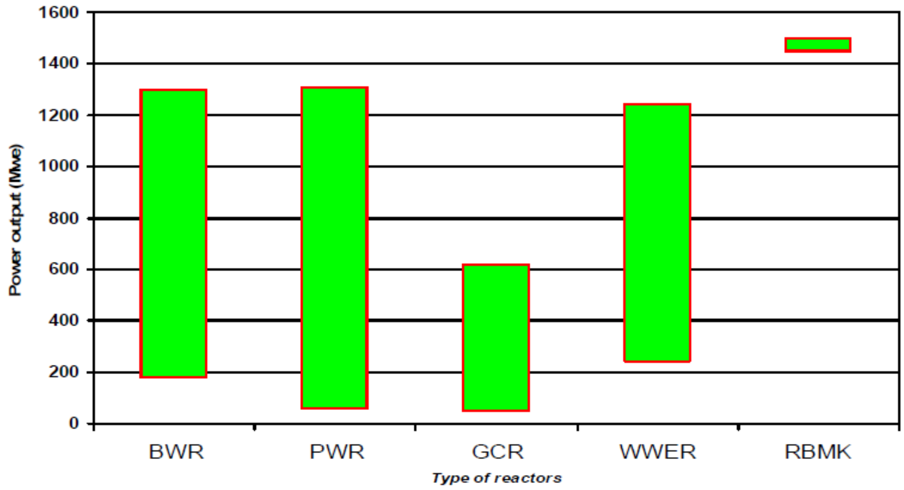
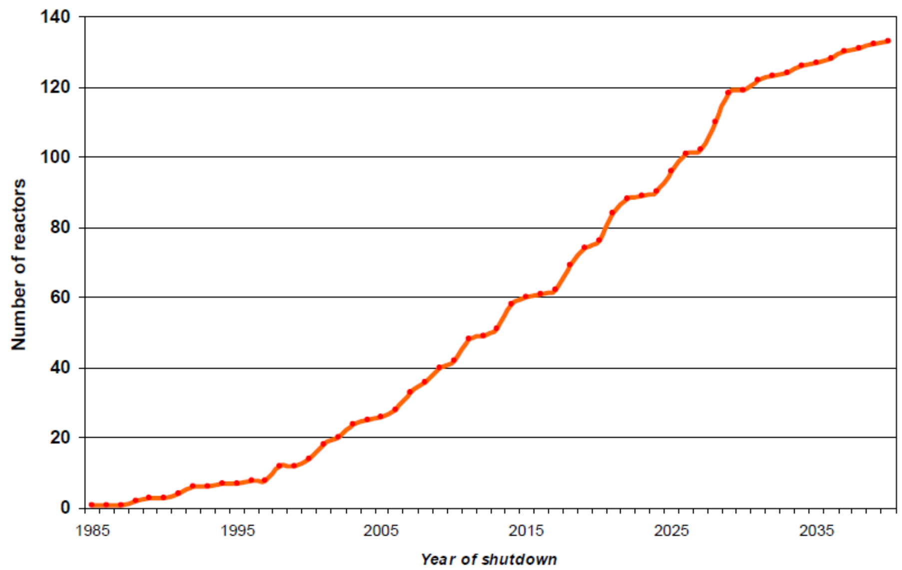


Figure 6.4 Prognoses of shutdown dates for the reactors under investigation



Some information was provided by respondents to the questionnaire on the operational history of the nuclear facilities in order to evaluate events that might influence the selection of a decommissioning strategy. No significant operational incidents were reported for the considered facilities, other than a turbine hall fire (in Vandellos, Spain). It was noted that some plants had been subject to refurbishment or replacement activities (Dukovany, Czech Republic; Borssele, The Netherlands; Bohunice, Slovak Republic; and Krsko, Slovenia), some had suffered minor leaks (Paks, Hungary) and not all had continuously operated (Italy).

6.2.1.2 Waste quantities

A wide variety of reactor types, sizes and structures have been covered in this study. This has an impact on the quantities and types of radioactive and non-radioactive materials that are reported to result from the decommissioning activities. In the questionnaire, it was requested to provide information on both radioactive and non-radioactive materials with the aim to address the whole of the reactor site, including the conventional, non-radioactive plant and buildings.

As different countries and utilities have different conventions on how to present data relating to decommissioning wastes, there was a large variability in the answers to the questionnaire. For example, some of the responses only related to the reactor island whereas others addressed the whole of the reactor site, including the conventional, non-radioactive plant and buildings, e. g., turbine halls. In order to make comparisons between reactors and reactor types, a detailed analysis of the data has therefore been focused on the quantities of radioactive materials generated as the information provided relating to these kind of materials proved to be most consistent.

6.2.2 Responsibility for decommissioning

A question was raised in order to learn whether the responsibility for a reactor site changes when moving from the operational to the decommissioning state. The majority of countries responded that the responsibility for decommissioning remained with the utility or the operator. In five countries (Estonia, Hungary, Italy, Spain and the United Kingdom) the responsibility for decommissioning is transferred to a different national body. In principle, the transfer of responsibility should not affect costs. However, it may have an impact on the contingency margins included in the cost estimates.

With respect to the responsibility for selecting a decommissioning strategy, most utilities or countries identified that this responsibility is with the utility/operator. A few countries indicated that the decision is made by the Government.

6.2.3 Selection of a decommissioning strategy

In the questionnaire, a number of questions were included to identify how the preferred decommissioning strategy is selected. The questions covered the activities included within the assumed scope of decommissioning, the considered options relating to the decommissioning strategy, the factors taken into account and the process used.

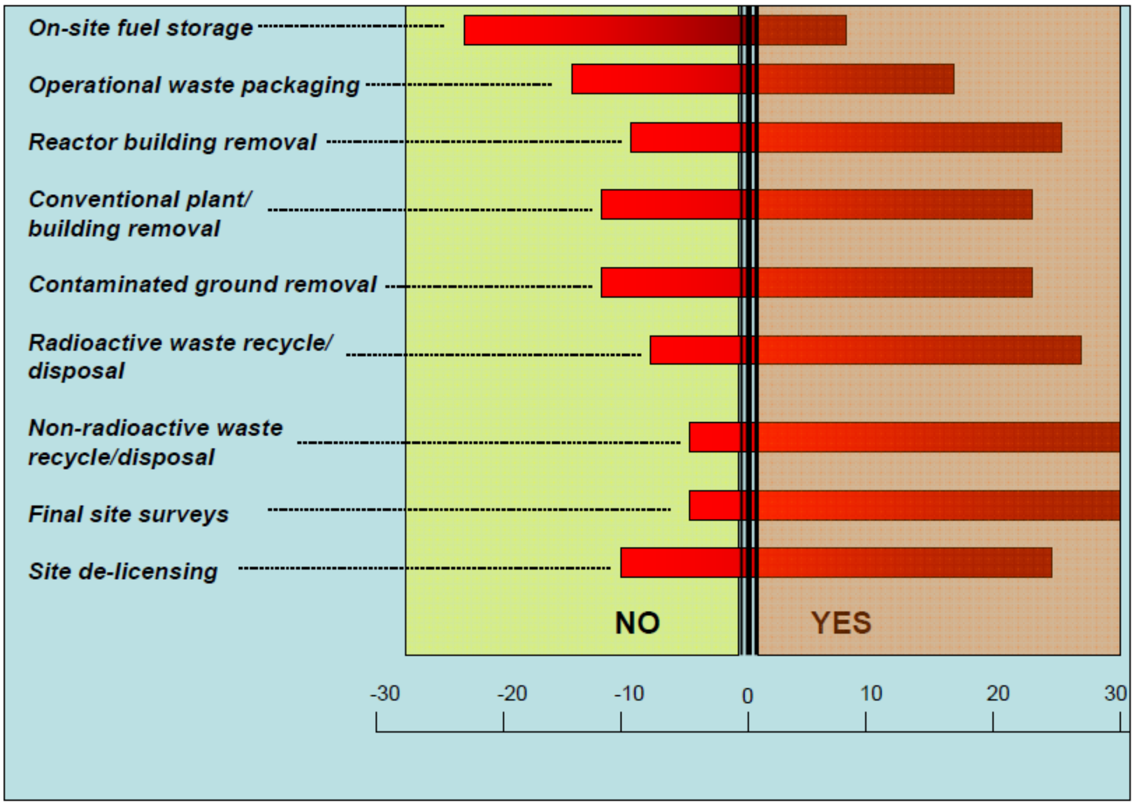
6.2.3.1 Assumed scope of decommissioning

In order to understand the scope of decommissioning assumed by the respondents, it was requested to identify whether specific significant activities were included, such as on-site fuel storage, the removal of buildings, the disposal or recycling of non-radioactive waste materials and de-licensing of the site. The result of the responses is shown in Figure 6.5.

Although answers were provided for each reactor site, the answers were generally the same for all reactor sites in a country. Differences might exist between utilities in a country. Therefore the answers have been grouped into about 40 utilities/countries rather than being presented in terms of all of the about 80 reactor sites covered by the responses to the questionnaire.

It can be seen from Figure 6.5 that most of the nine activities were included in the scope of the decommissioning strategy considered by most respondents. As a main exception, most respondents did not include on-site fuel storage within the assumed scope. In addition, in a significant number of cases, packaging of operational radioactive wastes is not included in the scope either. It should also be noted that all activities received a number of negative responses, indicating that there is quite variability between utilities/countries relating to the activities included within the assumed scope of decommissioning.

Figure 6.5 Factors included in the scope of decommissioning



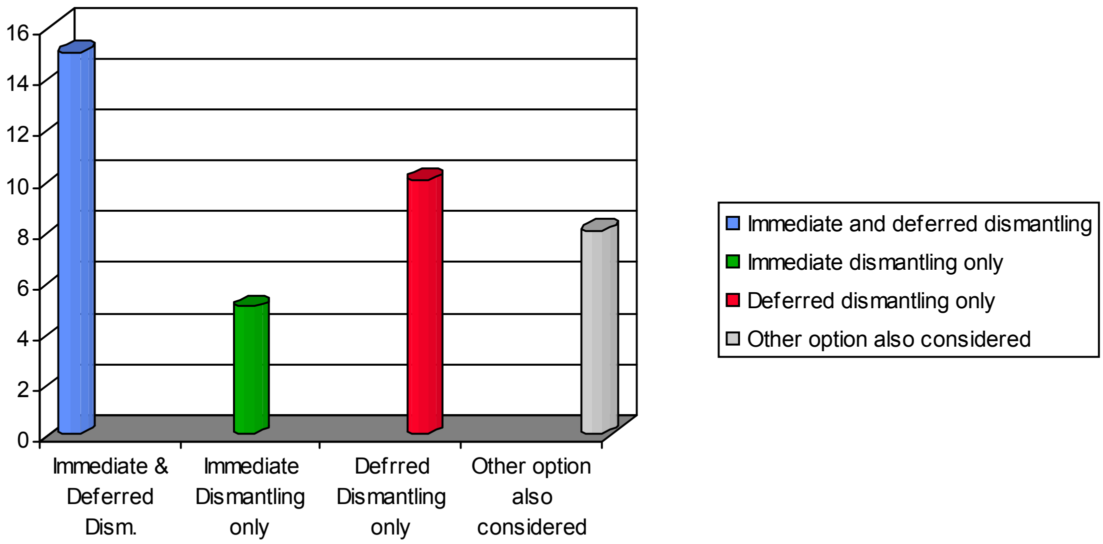
6.2.3.2 Options for a decommissioning strategy

The respondents were also asked which decommissioning options had been considered in selecting a decommissioning strategy, i. e., global immediate dismantling following shutdown and/or deferred dismantling including a period of safe enclosure, or other options. The responses are presented in Figure 6.6, indicating that the largest number of respondents considered both the immediate and the deferred strategies. Only a smaller number considered only immediate dismantling or only deferred dismantling.

The respondents who considered the deferred dismantling option were requested to indicate which deferral periods were taken into account. The responses indicate that in most cases only a single deferral period has been considered, ranging up to 70 years in Hungary. Some utilities indicated that a range of deferral periods has been considered, e. g., 25 to 50 years in France, 40 to 100 years in the Netherlands and 35 to 135 years in the United Kingdom.

In specific cases, other options such as "entombment" and "on-site disposal" have been considered.

Figure 6.6 Considered options for a decommissioning strategy



6.2.3.3 Selection of the decommissioning strategy

Considering the selection of the preferred decommissioning strategy the respondents identified the process used and the factors considered. In almost all countries, aspects as assessment of regulatory constraints, characterization of the facility after shutdown, identification of key influencing factors, evaluation of alternatives, immediate/deferred strategy, deferral period, clearance levels have been taken into consideration. In case tools were used for defining and optimizing the decommissioning strategy, a multi-attribute analysis was used in combination with a methodology for cost estimating based on the *Proposed Standardized List of Items for Costing Purposes* (Ref. [22]) as in Czech Republic, Slovakia, Slovenia and Romania. Austria used a cost-benefit analysis. Hungary and Latvia only used the methodology for cost estimating based on the *Proposed Standardized List of Items for Costing Purposes* (Ref. [22]), while Finland based the analysis on sound engineering rather than on systematic analytic tools. Estonia, Italy, Lithuania and Sweden did not use any tool.

The respondents were also requested to indicate whether or not some specific factors are considered such as I, "Decision making, social-economic and public shareholder acceptance"; II, "The availability of information, human, financial and technology sources"; III, "A selection and optimization process as a basis for a decommissioning plan"; IV, "A decommissioning strategy selection and optimization process as a basis for a decommissioning plan"; V, "Site, facility type and process relevant parameters". The list of factors and the range of responses received are indicated in the Figures 6.7 to 6.10. An analysis of the responses as indicated in these figures showed that a majority of the factors were considered by most of the utilities/countries. Only Czech Republic and Germany indicated that they considered all the listed factors.

Care should be taken in interpreting these responses, however, as the respondents were only indicating the primary factors considered in defining the preferred decommissioning strategy. As an example, the fact that some respondents indicated that they had not considered safety does not mean that they considered safety to be irrelevant for decommissioning. Safety is always a very important factor. No decommissioning strategy would be considered if not safe. Hence, safety is not necessarily a determining factor when selecting between decommissioning options that are all safe.

Figure 6.7 Factors considered in defining the preferred decommissioning strategy: legal, ownership and regulatory issues, social-economic and public stakeholder acceptance

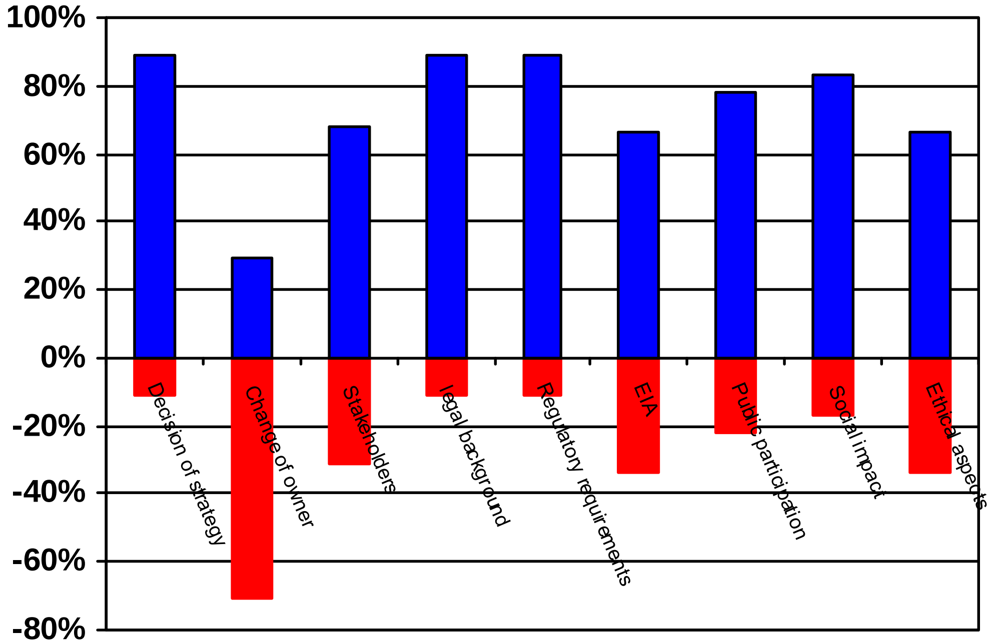


Figure 6.8 Factors included in the decommissioning strategy: availability of information, human, financial and technology sources

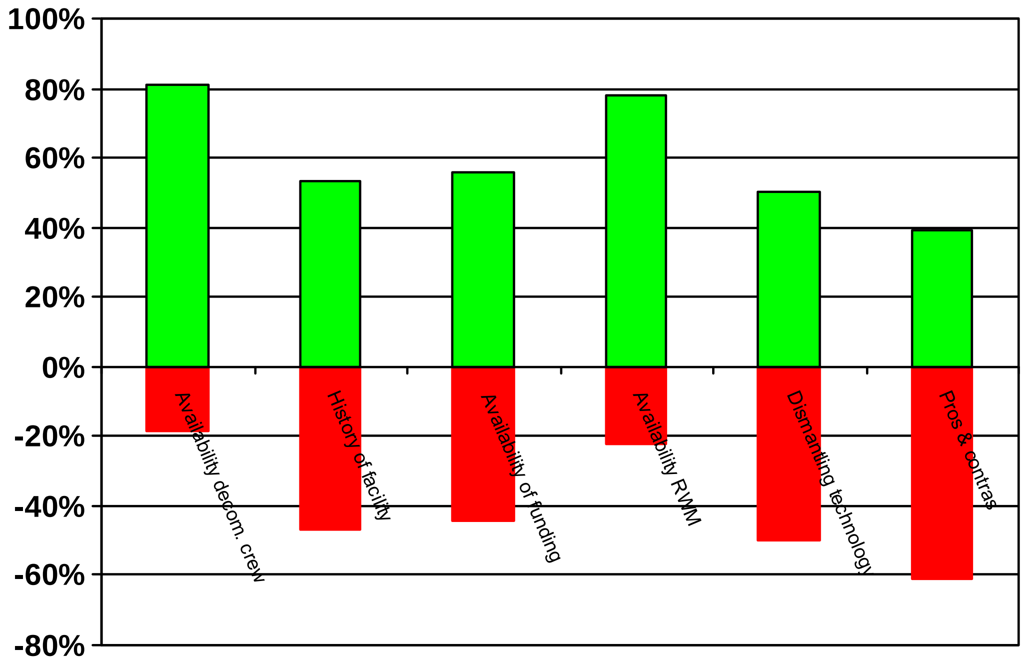


Figure 6.9 Factors included in the decommissioning strategy: selection and optimization process as a basis for the decommissioning plan

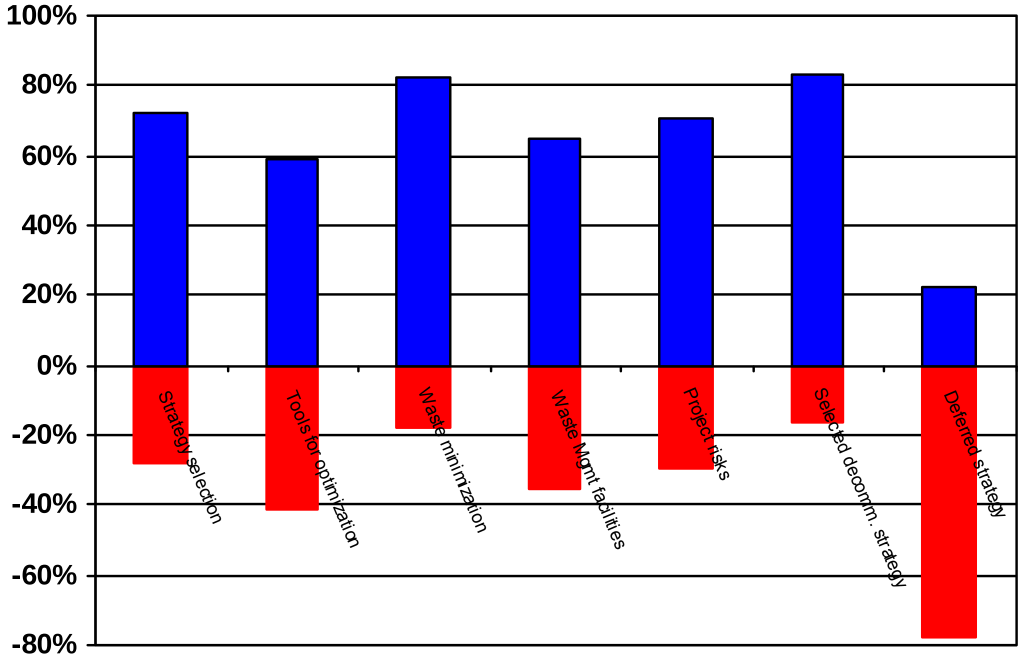
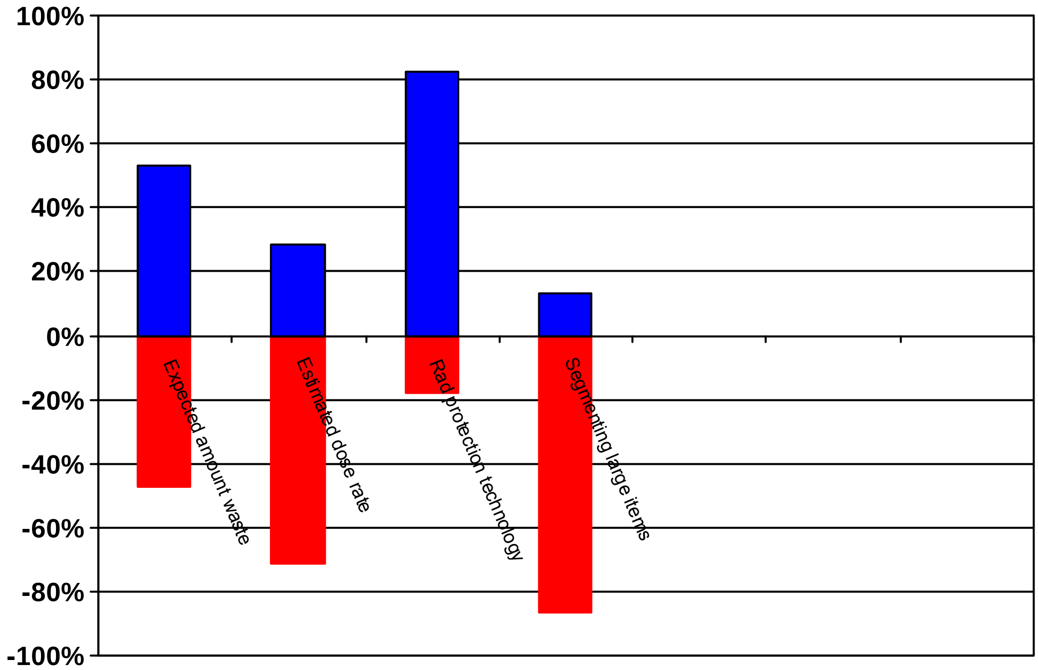


Figure 6.10 Factors included in the decommissioning strategy: site, facility type and process relevant parameters



Factors that were reported as not being used as determining factors varied between utilities/countries. Some of the factors received a greater proportion of negative responses than others. The availability of funds was one of these factors. The majority of respondents that mentioned funding not to be a determining factor did consider costs as a factor, however. The reason for this is likely to be that the required funds are normally determined based on the costs that are defined once a decommissioning strategy has been selected and not before. Another factor is uncertainties (e. g., on future regulations). In general, the negative responses relating to this factor were equally distributed between respondents who only considered immediate dismantling as an option on the one hand and respondents who only, or also, considered deferred dismantling as an option. Some respondents indicated that they had not considered uncertainties as a separate item but included uncertainties as part of the cost factors.

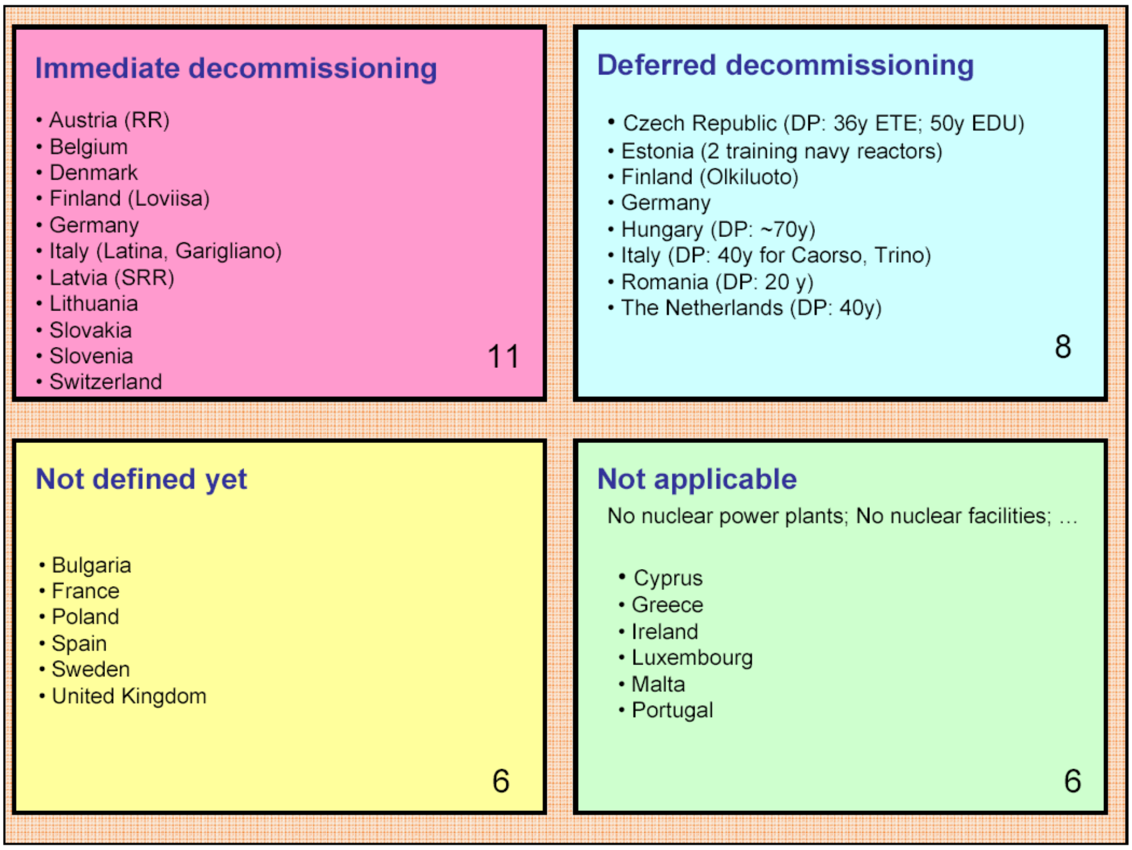
Some of the differing responses can be related to specific national approaches. For example, one country (Italy) provided a negative response to all questions relating to the identified factors other than "social and political factors". The policy of the Italian Government only includes immediate dismantling as an alternative, indeed, and hence the utilities need not consider any of the other factors in determining the decommissioning strategy that should be applied. Some countries also identified "site reuse" as a key consideration. This reflects the intent of some countries to reuse the sites for continued nuclear operation (France).

A number of respondents indicated that they considered other factors than those specifically identified in the questionnaire, the main responses pointing to environmental factors, although it should be considered that all other respondents will actually have considered this factor, e. g., as required by national regulations and European recommendations.

6.2.3.4 Stakeholder involvement

The respondents were also requested to indicate which stakeholders were consulted during the decision making process relating to the decommissioning strategy. The most commonly mentioned stakeholders were governments and regulators, followed by the public.

Figure 6.11 Selected decommissioning strategies



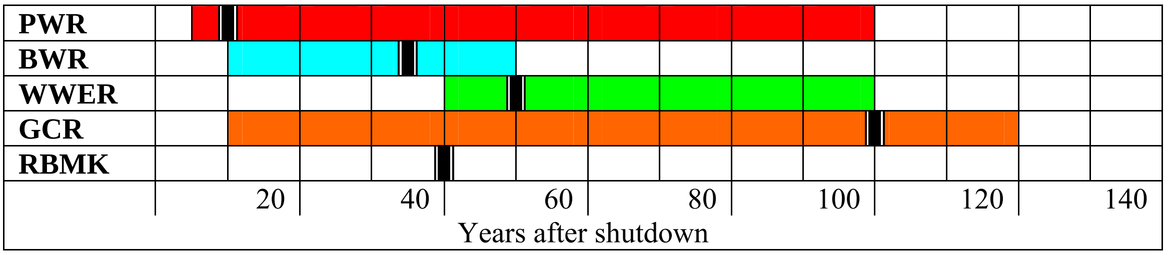
6.2.3.5 Selected decommissioning strategy

A further question considered the decommissioning strategy option that has finally been selected. The responses are indicated in Figure 6.11, showing that 11 countries identified immediate dismantling as the preferred option, while 8 countries identified deferred dismantling and Finland, Italy and Germany mentioned that both options may be selected for particular nuclear facilities (plants). No utility or country identified any other option (such as entombment) to be the finally selected strategy.

6.2.3.6 Deferral periods

The information provided relating to the duration of the deferral periods assumed in the selected decommissioning strategies is presented in Figure 6.12 by reactor types, immediate dismantling being classified as a strategy with a deferral period equal to 0 years.

Figure 6.12 Duration of the deferral period for different types of plants

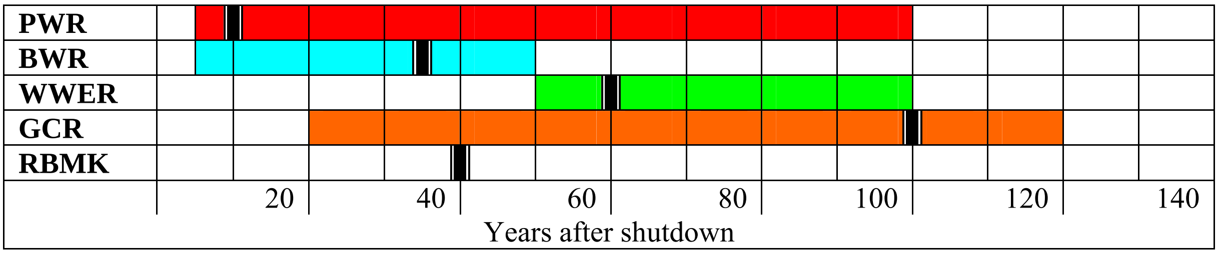


The figure shows that the longest deferral periods are associated with gas-cooled reactors. Pressurised water reactors also appear to have long deferral periods. This is dominated by two countries, however, i. e., Hungary and Czech Republic, assuming a 70 and a 50 years deferral period respectively. In general, when excluding these pressurised water reactors and gas-cooled reactors, the range of quoted deferral periods for all other reactor types is from 0 to 50 years.

The quoted deferral periods are not presented on the same basis for all reactors, however. The deferral periods quoted by some utilities, for example, only relate to a dormancy period in which no activities are performed, i. e., excluding any period in which major decommissioning or dismantling activities are implemented. Other utilities refer to a deferral period as being the time from reactor shutdown to the start of the final dismantling period, i. e., including both an effective dormancy period but also periods of major decommissioning activities. Such differences in definitions of deferral periods can result in significantly different figures that are quoted for essentially the same overall duration of the decommissioning activities. For example, for some reactors where immediate dismantling is the proposed strategy, it is indicated that it will take 30 to 40 years from reactor shutdown to complete all the decommissioning work. In contrast, for some reactors where a deferral period of 30 years is quoted (meaning a dormancy period limited to 30 years) the overall duration from shutdown to the end of decommissioning is also predicted to be 40 years. In this example there is no difference in overall decommissioning duration between what is called an immediate dismantling strategy and what is called a deferred dismantling strategy.

In order to bring decommissioning periods on the same time basis and to make a more adequate comparison, Figure 6.13 presents the same information as given in Figure 6.12, showing the predicted range of periods from reactor shutdown to the end of the decommissioning activities for each of the reactor types. Figure 6.13 indicates a higher average "effective deferral period" than suggested in Figure 6.12, considering the complete time period from reactor shutdown to the end of the decommissioning activities for all reactor types. As a result 40 to 50 years for completion of decommissioning is not unusual.

Figure 6.13 Duration of the deferral period for different types of plants:
adjusted to the same time basis



It should be noted that the decommissioning strategies identified by the respondents as the preferred strategies are those assumed for costing purposes. They are not necessarily the results of firm or final decisions. For example, one utility (in the United Kingdom) has a declared strategy with a maximum of 50 years deferral period for the decommissioning of a pressurized water reactor, but prudently assumes for costing purposes a significantly shorter deferral period of 10 years. In some cases the declared deferral periods are quoted as maximum periods, in other cases as minimum periods (United Kingdom).

6.2.4 Decommissioning and radioactive waste management activities

A number of questions were asked about general decommissioning and radioactive waste management activities.

6.2.4.1 Dismantling techniques

The majority of the respondents indicated that the reactors, which are the most radioactive and highest radiation dose rate items handled during decommissioning, would be dismantled by fully remote means, possibly involving a degree of semi-remote operations for some parts of the reactors (Finland, Italy, Lithuania and Slovakia). Generally, the only utilities suggesting reactor dismantling using hands-on work were those with gas-cooled reactors (United Kingdom) or research reactors (Estonia, Latvia). They propose a long deferral period to allow radiation dose rates to decay before starting the reactor dismantling work. In comparison, the majority of the respondents suggested that semi-remote dismantling operations could be used on primary circuit components such as heat exchangers, some indicating that hands-on work would be possible. Remote dismantling work will be more expensive than the use of semi-remote techniques, with hands-on work expected to be the least expensive.

6.2.4.2 Waste packaging

With respect to the required degree of dismantling, most respondents indicated that it would be necessary to size reduce reactors and primary circuit components into small pieces for packaging and disposal in a range of standard sized packages. A small number of respondents indicated that these items could be removed and disposed of as a whole, or in large pieces (Finland, Romania). Most respondents indicated that it would be necessary for voids in waste packages to be filled with cement grout or similar. The extent of size reduction required will have an impact on the extent of work involved and hence on the costs of decommissioning. Avoiding size reduction likely would reduce decommissioning costs but implies that waste repositories that can accept large size packages are available.

6.2.4.3 Development status

Respondents were asked if the decommissioning work has been or is intended to be performed as a research or a development project. Only two respondents indicated that this was the case. All others indicated that it was or would be a fully commercial activity. This reflects the maturity of today's nuclear decommissioning industry.

6.2.4.4 Waste disposal

With respect to radioactive waste disposal, most respondents indicated that they were assuming that radioactive waste would be disposed of directly in a repository (Belgium, Finland, Hungary, Latvia, Lithuania, Slovakia, Slovenia, Romania), with only a few respondents indicating that some period of either on-site or off-site storage following dismantling would be necessary pending the availability of a disposal site (Austria, Czech Republic, Estonia, Italy). It should be noted, however, that the responses to the policy section of the questionnaire indicated that currently no country has suitable waste repositories for all waste materials expected to arise from the decommissioning activities.

The availability, or non-availability, of suitable waste repositories for decommissioning wastes can be expected to have an impact on the decommissioning strategy that will finally be implemented, and on the actual timing of dismantling. This is recognised in some countries where, for example, immediate dismantling options are preferred but reactor dismantling will be delayed should a repository not be available (Italy).

6.3 Approaches to decommissioning funding

6.3.1 Funding aspects

As some decommissioning expenses will be incurred long after a nuclear power plant has been shut down, decommissioning costs constitute a future financial liability. With the implementation of the nuclear energy programmes proceeding, in the late 1970s it was recognized that consideration should be given to ensure that funds will be available to cover future costs for decommissioning when needed. For this purpose, decommissioning costs should be estimated in a reliable way and transparent accounting principles should be agreed upon by governments, industries and stakeholders and adequately applied in order to establish and maintain adequate decommissioning funds.

The State and the owners/operators of nuclear power plants have their respective responsibilities regarding decommissioning liability funds. While the State has to ensure that the consequences of its energy policy will not harm present or future generations, the owners/operators of nuclear power plants are responsible for fully covering the costs of decommissioning. Specific issues that may be raised by national policy decisions, such as premature shut down of nuclear power plants resulting from a phase-out of nuclear energy, must be addressed by each country on an ad-hoc basis.

Similarly to technical and managerial actions taken to regulate the use of radioactive materials, safety, radiation protection and the protection of man and its environment, adequate policy actions have to be taken to guarantee that economic liabilities foreseen in the future can be discharged with money provided during the operational lifetime of nuclear power plants. The establishment of a fund and guaranteeing of its availability when needed can be seen as a response to the "Polluter Pays Principle".

6.3.2 How is the liability accounted for?

The detailed methods for calculating and reporting liabilities for the decommissioning of nuclear facilities differ from one country to another and sometimes between operators in a given country. In practice, two main methods - current value and net present value - and sometimes variations of these are generally used for calculating future financial liabilities associated with decommissioning. In both methods, the value of the liability is adjusted periodically as the cost estimates evolve owing to technology progress, regulatory changes and inflation, as applicable.

The current value method evaluates the financial liability based upon what decommissioning would cost today if the expenses were incurred at present. In that case, the value of the liability is equal to the decommissioning cost estimate and does not depend on the timing of decommissioning activities; it is independent of the time at which the expenses will occur.

The net present value method evaluates the liability based upon the discounted decommissioning costs, taking into account the expected expense schedule. The estimate requires assuming a discount rate and depends on the timing of decommissioning activities and the associated expenses: the later the expense will be incurred the lower its net present value is.

The main difference between the two methods is that the net present value accumulates the funds more slowly and is more sensitive to assumptions on expense schedules and rates of return on capital set aside. In the current value method, since the provisions are set up faster, the interest generated by the accumulated provisions is higher and, if the provisions are tax deductible, the charge for the owner/operator is alleviated.

In countries like in Bulgaria, Czech Republic, Finland, France, Italy, Lithuania and Slovakia, the decommissioning funds are based on overnight, undiscounted costs. In other countries like in Belgium, Germany, Hungary, Spain, Switzerland and the United Kingdom, decommissioning funds are based on the net present value, a discount rate usually ranging between 2 and 5.5 %. For a few countries, no specific policy was reported.

6.3.3 Who pays the costs?

In nearly all countries, the operator/utility is responsible for the decommissioning costs. In cases where nuclear power plants or facilities are state-owned, the responsibilities may be distributed between the operator and the State as the owner. For example, in Estonia and in Poland the Government is responsible for decommissioning liabilities. In Hungary, where the nuclear power plant is state-owned, the responsibility is shared by the Government and the operating organization. A similar situation exists in Lithuania.

At the writing of this document, in the United Kingdom a new Energy Bill is making its way through Parliament. The current Energy Bill was published on 27 November 2003 following publication in July 2002 of the White Paper "Managing the Nuclear Legacy". Part 1 of the Energy Bill defines the framework for the new Nuclear Decommissioning Authority (NDA) which should in future oversee the decommissioning of all nuclear sites in the United Kingdom. The Nuclear Decommissioning Authority will be a quasi-governmental body. It will operate "at arm’s length from the government". Ministers should "exercise strategic control over its activities and be accountable for its actions".

The Secretary of State will create a Nuclear Decommissioning Funding Account. The account will be ring-fenced and will be used effectively as a trading account by the Nuclear Decommissioning Authority. The money required for the continuing operation of certain sites or for the decommissioning of sites will be withdrawn from the fund. Any profit made by the Nuclear Decommissioning Authority from the operation of a site or through risk sharing opportunities on a decommissioning programme will be reimbursed to the fund. The fund is managed independently and arrangements have been made to ensure that British Energy (BE) makes as big a contribution as it can.

In Switzerland, the owners of the nuclear facilities are required to make financial contributions to a joint decommissioning fund which is under supervision of the Government. The Board of the joint fund is responsible for ensuring that the contributions are adequate for covering the decommissioning costs in due course.

6.3.4 When do decommissioning funds have to be provided?

In Finland, Germany and Sweden the total decommissioning funds should be accumulated within 25 to 30 years. In Belgium this should be done within 40 years after start-up of the nuclear power plant. In about 50 % of the countries, the funds should be available when the plant is shut down. In some countries, the licensee can select between different options and sometimes the regulator accepts a mixture of options. In some cases, guarantees have to be provided for covering the expenses arising when a unit has to be shut down before the foreseen period of collecting funds, or in case at shutdown the funds are not sufficient.

Considering that the four nuclear power plants were shut down before the operators could accumulate sufficient funds, in Italy extra funds have to be raised during the decommissioning period. As in Italy, for some plants this is a requirement. Otherwise the funds should be available at the time the plant is permanently shut down.

6.3.5 How are decommissioning funds required to be raised, held and managed?

In nearly 60 % of the countries, the funds are collected by a charge included in the electricity price (with the exception of the United Kingdom). This is also the case in Lithuania and Slovak Republic, but in these countries also additional means are used and part of the funds is collected by compulsory fees as well as by contributions from donor organizations. In Finland and Sweden compulsory fees are used to raise decommissioning funds.

In most of the countries, the funds are segregated and held by the Government or under Government control. In Belgium the fund is segregated and managed by the utility under control of the Government and in Czech Republic the fund is under utility management on a segregated blocked back account.

6.3.6 Adequacy of decommissioning funding

In many countries, independent funding review and audit systems exist. Sometimes, as in Czech Republic, Finland, Hungary, Lithuania, Slovenia, Spain and Sweden, the licensee cost estimates are reviewed and approved annually. In Slovakia the review is carried out semi-annually. In Belgium (for nuclear power plants), Italy, the United Kingdom and Switzerland the decommissioning costs are subject to revision every third year. The funds for other nuclear facilities in Belgium are reviewed every 5 years.

Discounting raises specific issues in the case of decommissioning costs as the activities and associated expenses may take place over a long period of time, which may last several decades depending on the country policy and the operator strategy. As a result, the choice of a discount rate may have an important impact on the discounted decommissioning costs. Economic theories do not provide robust guidance on relevant discount rates for the very long term. Therefore, a review of the decommissioning costs on a regular basis should also include a review of the discount rate.

While it is legitimate to recognise the time value of money, the application of any, even very low discount rate to expenses that will occur beyond a few decades significantly reduces the present value of these expenses.

7 Analysis of identified factors influencing the selection of strategies for decommissioning

There is a wide variability between countries, utilities and reactor sites in a number of areas related to decommissioning, as shown in the information collected for this study in the responses to the questionnaires that have been sent to relevant organisations from the 25 Member States and 2 Candidate Countries of the European Union as defined in Section 3.1, "Inception Phase", and to the relevant organisation in Switzerland, as well as in the information collected from other international reports. This variability has an impact on the selection of a strategy for decommissioning as provided by countries/utilities.

Following is a list of main issues that seem to be particularly relevant to the selection of a decommissioning strategy, other than the obvious issues of safety and the availability of practical decommissioning techniques:

- The basic decommissioning options; the scope of the decommissioning activities.
- The reactor type; the reactor size; the number of units on a site; the operational history.
- Project planning; analysis of material flow.
- Regulatory and policy requirements (timing; clearance criteria).
- Socio-economic issues.
- Provisions for waste management.
- Funding arrangements.
- Availability of staff and personnel issues.
- Knowledge retention.
- Site re-use.
- Strategy selection process (e. g., multi-attribute analysis, etc.).
- Stakeholders; decision makers, regulators and the public.
- Spent fuel and waste management systems.
- Health, safety and environmental impacts.
- Suitable technologies and techniques.

Although some of the issues relate to physical characteristics (such as the type and the size of the reactors), others relate to different approaches (such as decommissioning strategies) and different conventions applied by different countries and utilities (such as which activities or items are included in the decommissioning cost estimates and which are included elsewhere).

In all their variety, these issues comprise the sources for explaining why there are for example real and apparent differences in decommissioning cost estimates between utilities and countries, even for similar facilities.

A more detailed analysis of the related factors is given in the following sections.

7.1 Options for a decommissioning strategy

As expected, decommissioning strategies were found in this study to vary from one country or utility to another. Although in most cases the assumed strategies tend to be classified as either "immediate dismantling" or "deferred dismantling", quite some variability may be detected within the two categories. For example, some utilities propose what could be considered to be a ‘rapid’ immediate dismantling with all work being completed in about

10 years, while others are considering a more prolonged dismantling period of 20 to 40 years, but still classifying this as immediate dismantling.

Under the option "deferred dismantling" a variety of deferral or dormancy periods are being considered which results in dismantling being completed in periods ranging from about 40 to around 100 years.

There is also a variability in the extent of the parts of the plant for which deferred dismantling is considered. In some decommissioning projects, it is effectively the dismantling of all significant plant and buildings that is deferred, but in others it is just the dismantling of significant parts of the radioactive plant and structures, such as the reactor, that is considered to be deferred, with all other parts of plant and buildings being dismantled immediately.

For the facilities that are subject to a deferred decommissioning strategy, the extent of work and the on-site staffing assumed during the dormancy period, and hence the costs, are variable. For example, for some facilities it is assumed that 24 hour on-site staffing will be required while for other facilities some kind of remote surveillance is provided. Some utilities consider that, following a deferral period, radiation levels will have reduced sufficiently to allow simpler reactor dismantling technologies to be used, e. g. that fully remote operations will not be required any more. This is particularly the case for gas-cooled, graphite moderated reactors.

7.2 Scope of decommissioning activities

The assumed scope of decommissioning, including the assumed starting point and the assumed end point of decommissioning, has a significant effect on the decision making relating to a decommissioning strategy. The assumed scope, starting and end point, identified in this report have been found to be quite variable.

Some of the activities included by some utilities in the assumed scope of decommissioning and hence included in the related decommissioning costs, are excluded from the scope of decommissioning by other utilities: de-fuelling; on-site fuel storage; retrieval and packaging of accumulated operational wastes; on-site storage of radioactive waste; radioactive waste transport and disposal (all costs); removal of conventional plant systems; removal of non-radioactive structures above ground level; removal of non-radioactive structures below ground level; contaminated ground remediation; landscaping and site de-licensing.

Although some of these activities are not included within the scope and the costs for decommissioning of some utilities, it does not mean that these activities are not considered at all. For example, some utilities treat de-fuelling as an operational activity and not as a task to be considered under decommissioning activities.

7.3 Reactor type

There are quite a number of different reactor types in use (5 types have been referred to in this report) and these can have significant physical differences. For example, light water reactors tend to be compact in size whereas gas-cooled reactors tend to be physically much larger. Some reactors use water as a moderator, others use graphite. Some use liquid metal as a coolant rather than water or gas. Some reactor designs are replicated on a number of sites whereas others are unique and require individual decommissioning plans. The extent of the auxiliary systems and the "conventional part of the plant", and the extent to which these parts become radioactive, varies between reactor types. For example, boiling water reactors have steam turbines integrated in the primary reactor loop and will become radioactively contaminated, which is normally not the case for other reactor types.

Light water reactor vessels are compact in size and are designed to enable the top to be fully removed, giving direct access to the full diameter of the reactor and allowing all fuel to be removed in a short period of time. As a consequence, de-fuelling at the end of the life time of a light water reactor tends to be considered a final operational activity and not a decommissioning activity that needs to be included in the decommissioning costs. The reactor internals in light water reactors are also designed to be (easily) removed. This ready access to the reactor vessel assists decommissioning activities.

In contrast, gas-cooled reactors are not only large, but also have a non-removable top with only limited access to the reactor vessel designed for fuelling and de-fuelling purposes via small diameter penetrations. This means that reactor de-fuelling at the end of life can take a number of years and is sometimes effectively classified as part of decommissioning, and hence included within the decommissioning costs. The lack of a readily removable top to the reactor vessel also means that reactor dismantling is more difficult, time consuming and expensive.

7.4 Reactor size

There is a large variability in reactor sizes, not just in physical terms but also in power output. For example, a modern pressurised water reactor of 1 200 MWe output has a reactor vessel with an internal diameter of 4.4 m whereas an older 150 MWe gas-cooled reactor has a reactor vessel with a diameter of 20 m. The reactor size in combination with the reactor type and the construction materials dictate the quantities and the nature of the radioactive wastes that will result from the decommissioning operations, as well as the required scale of dismantling.

The radioactivity levels remaining in the reactor materials at the end of the operational life of the plant depend on the reactor size, the global reactor power output and the material composition. More modern, high output but compact reactors, such as light water reactors using predominantly stainless steel materials, will have much higher residual radioactivity levels than lower output, physically larger reactors such as gas-cooled reactors constructed from mild steel and graphite. This can affect the complexity of the dismantling activities, and the potential for natural radioactive decay to reduce radiation levels to beneficially lower values. For example, radiation levels within gas-cooled, graphite moderated reactors are predicted to decay to levels enabling personnel access within about 70 to 90 years after shutdown. In the more compact light water reactors, the decay period would need to be significantly longer. When compared to gas-cooled reactors, less benefit would therefore be gained by deferring the dismantling of light water reactors.

7.5 Number of units on site

As indicated earlier in this report, the number of reactor units on individual sites can vary (from one to eight as indicated in the responses to the questionnaire). This can have an effect on the decommissioning costs when considered in terms of costs per unit. More units on a single site means that the costs relating to supporting facilities and site operations, including the costs incurred during a decommissioning period, are shared and hence lower when considered on the basis of a reactor unit.

If some units on a site remain in operation while others are shut down and decommissioned the decommissioning costs may be lower. For example, if the dismantling of a reactor unit is deferred while other units on the same site remain in operation, the care and maintenance costs for the shutdown reactor during a dormancy period may only represent a marginal cost on top of the costs of further operation of the other reactors. If all the plants on a site are shut down, the full maintenance costs for the site would be attributed to decommissioning, resulting in a significantly higher decommissioning cost.

7.6 Operating history

The operating history of a reactor can have a large impact on decommissioning, for example an accident or an incident on the site that resulted in damage or spread of contamination and may require different or more extensive decommissioning efforts. There are not many such examples, however, and there were no examples reported in the questionnaires discussed within this study.

Other history related issues that might affect decommissioning costs include fuel leakage and water chemistry events as well as the reactor operating load factor during its lifetime. Fuel leakage events can result in the dispersion of alpha-emitting radio-nuclides within the primary circuit that will complicate the decommissioning and dismantling process. Water chemistry control issues can result in excessive spread of various radio-nuclides, especially ^{60}Co, in piping scale and hot spots. Water chemistry control can also have effect on fuel leakage.

Some reactors have experienced relatively low load factors over their lifetime whereas others have had high ones. This can have an effect on the residual radioactivity levels at shutdown. Also, some plants have undergone refurbishment or replacement programmes during their lifetime. This may have resulted in extra radioactive plant or materials being stored on the site, e. g., redundant heat exchangers, which then have to be included within the decommissioning plans, which will increase the overall costs.

7.7 Planning/Analysis of materials flow

Detailed project planning is of essential importance and careful analysis of materials flow is a helpful tool with regard to decommissioning activities. Differences can be observed between the decommissioning of plants that have reached their end of life in a "natural" way and those which experienced a premature shutdown as a result of societal decisions.

It is also recognized that regulatory or policy requirements are key inputs to project planning. Any requirement relating to the timing of decommissioning and dismantling operations, to the management of radioactive wastes or to criteria for clearance of the site from regulatory control will provide practical support when planning decommissioning activities.

7.8 Regulatory standards

Clearance levels are one example of "regulatory standards" that are extremely relevant and important relating to decommissioning activities and costs. Other regulatory standards which may vary from one country to another could also affect decommissioning activities and costs, however, such as allowable radiation doses for workers and the public and allowable radioactivity and chemical discharges from sites. Regulations may also include environmental controls, for example on noise, dust and traffic.

All these regulations will require extensive documentation to be prepared, to be assessed and to be approved, e. g., safety cases and environmental statements. There may also be some element of public consultation as part of these regulatory processes. All these requirements may have an impact on the decision making process relating to a decommissioning strategy.

7.9 Classification of radioactive materials and clearance levels

The clearance levels below which materials can be categorised as non-radioactive vary from one country to another. This will inevitably have an effect on the quantities of materials resulting from decommissioning that will need to be classified as radioactive waste. In some countries the material which is cleared from nuclear sites can be recycled or re-used without additional controls and hence can generate some income and, more importantly, reduce waste disposal costs. In other countries there are greater restrictions on cleared materials, leading to higher volumes of radioactive waste for appropriate disposal, which must be taken into account in the decision making process for developing a decommissioning strategy.

In addition, different classifications exist for materials which are deemed to be considered radioactive. As a result it may vary from one country to another what should happen to such materials. For example, some countries allow slightly radioactive materials to be recycled in a controlled manner within the nuclear industry whereas others require disposal of such material as radioactive waste. In some countries radioactive waste may be disposed of in less engineered near-surface repositories, whereas other countries will require the same material to be disposed of in a more engineered and more expensive surface disposal or deep geological disposal facility. These differences will affect the decision making process for developing a decommissioning strategy.

In about 60 % of the countries specific clearance levels have been defined at the national level in order to categorize decommissioning materials as "non-radioactive", enabling these materials to be removed from any further (radiological) control by the regulatory body. Belgium (in the early phases), Italy, and Spain are examples of countries in which clearance levels were specified for a site/decommissioning project or for a number of specific activities on a site (e. g., Caorso, Italy). In the meantime, Belgium, Germany and the United Kingdom are examples of countries with general clearance levels stipulated in national legislation.

7.10 Socio-economic and political issues and stakeholder involvement

Social and political factors need to be taken into account and can also have a significant impact on the selection of a decommissioning strategy, on the development of decommissioning plans and hence on the related decommissioning costs. As an example, nuclear sites tend to be erected at remote locations and are often the major employer in the vicinity. Therefore, the social responsibilities to the local communities need to be considered in determining proposals relating to plans for decommissioning. At specific sites, this has resulted in a plan to proceed with early decommissioning in order to maintain local employment levels.

Similarly, political factors are relevant and require considerations that affect decommissioning plans and costs. For example, national political decisions may imply immediate dismantling to be mandatory, whereas otherwise the operator of a nuclear unit would have chosen a deferred strategy. Also, the overall nuclear energy policy of a country, e. g., a moratorium on new nuclear units, accelerated phase-out or continued deployment, has an impact on decommissioning strategies and costs.

Respondents were also asked which stakeholders were consulted during the strategy decision making process. This means that during the planning stage of a decommissioning project the concerns, issues and views of the different stakeholders are taken into consideration. Most commonly the Government and the Regulator were mentioned, followed by the public.

Environmental and social impacts play an essential role in the implementation of any large project. To be successful, a decommissioning project needs to be open, transparent and clear to all stakeholders. The most important factor to gain public acceptance might be to establish a dialogue between the interested partners and to organise public meetings in which the proposals and decisions are discussed. An open and transparent process involving all stakeholders at a very early stage of the decommissioning project is increasingly considered to be essential.

7.11 Amount of waste materials

The quantities of radioactive waste materials resulting from decommissioning can vary significantly from one site to another. This can, for example, be affected by the type and the size of the reactors, the extent of supporting plant and the allowable clearance levels.

Not only the quantities of radioactive waste materials but also the types of the materials may vary. Some reactors use materials that may require special treatment, handling or disposal, e. g., heavy water, liquid metal coolant and graphite. Some reactor sites may have accumulated operational waste on site that will require retrieval, processing and packaging during the decommissioning period. This is necessary to be considered in decisions relevant to a decommissioning strategy.

In addition to radioactive waste materials, there will be variability in the quantities and types of non-radioactive waste materials that result from the decommissioning operations. Some of these waste materials may require special treatment. This is the case for asbestos, for example, which was used extensively as an insulating material in the older facilities. Also lead, contaminated or not, will require special handling if it is classified as waste for disposal. This also has to be considered in the process for selecting a decommissioning strategy.

7.12 Availability of radioactive waste repositories

Decommissioning produces significant quantities, and different types, of radioactive waste materials that will ultimately require disposal in a suitable repository. The availability of such repositories can have a significant impact on the selection of a decommissioning strategy, in particular on the timing of dismantling. Most utilities are assuming that repositories will be available when they plan to start the decommissioning operations, even if this is currently not the case or if such repositories have not been planned yet. If the required repositories are not available at the time they are needed, dismantling may need to be deferred longer than intended or interim waste storage facilities will need to be provided.

The assumed design and location of repositories varies, some being near-surface, some deep geological facilities, some being located close to or actually on the reactor site and some being located at significant distance of the reactor site.

The acceptance criteria also vary from repository to repository, e. g., in terms of allowable activity levels and radiation dose rates, and package sizes. Some repositories will be able to accommodate large packages, including a whole reactor vessel. Others will only accept much smaller packages. This will all affect the extent of the required dismantling and packaging work and all these factors may influence the decisions to be made in the process of selecting a decommissioning strategy.

In addition to the differences between assumed repository types, there is also variability in the proportion of the expected disposal costs that are included within the quoted decommissioning cost estimates. Some utilities include in their decommissioning cost estimates the full cost of radioactive waste disposal, including those for accumulated operational wastes as well as those for decommissioning wastes. Other utilities only include part of the disposal costs in their decommissioning cost estimates. Some utilities do not include any cost for the management of decommissioning wastes in their cost estimates at all. In particular cases where disposal costs are not or only partially included in the decommissioning cost estimates, these costs are in general accounted for separately and are included in another fund than the one directly associated with the decommissioning activities.

7.13 Funding arrangements

In almost all cases, the responsibility for the funding of decommissioning and dismantling of nuclear facilities lies with the owner of the facility. For commercial facilities in most of the EU Member States, it is a requirement established either directly in the legislation or stipulated in the operating licence, that operators create and maintain funds or financial guarantees for this purpose.

For other nuclear facilities, such as the early research and development facilities and demonstration plants for which no specific provisions were made, the costs for decommissioning and dismantling generally fall to the State and the funds have to be raised by other means, such as general taxation.

The accumulation and the management of the funds vary from one country to another. In general, the funds are created from business revenues and in almost all cases the size of the necessary fund is reviewed on a regular basis, generally between 1 and 5 years. It is then agreed with the government, either directly or indirectly via the regulator body or the waste management body. In some countries, the calculated amount of money for decommissioning and dismantling, corrected on a regular basis for inflation and changes of technology, is accumulated year by year over the planned lifetime of the facility. In other countries, where the possibility of a premature shutdown of the facility is recognized, a deadline in advance of the planned shutdown is set for having the necessary funds available.

Some countries allow operators to accumulate and manage their own funds under appropriate supervision, while in other countries the funds are collected from the operators and managed by separate, independent bodies. In Spain for example, ENRESA collects and manages funds, because the responsibility for carrying out the decommissioning and dismantling operations belongs to this organisation. In Sweden, the regulatory body is responsible for proposing the size of annual fees to the Government, which then establishes the fee, and an independent Board of the Nuclear Waste Fund manages the fund. In Finland, a State Nuclear Waste Management Fund, under the Ministry of Trade and Industry, collects, holds, and invests the funds. It is administered by a Board of Governors that is responsible for certifying that the funds meet the Ministry targets, for ascertaining that the operators meet their obligations to the fund and for holding and investing the funds in a profitable and secure way. In Switzerland and Hungary, however, the fund is collected and administered directly by the national Government.

There are some concerns about ensuring that sufficient funds will be available for decommissioning and dismantling operations when they are actually required. There are also concerns that segregated funds accumulated by a charge on electricity sales, for example, might be diverted for current requirements without sufficient guarantee of their availability when required for decommissioning and dismantling. The prevailing opinion seems to be that a truly independent fund managing body has advantages over plant operating companies, which may become bankrupt, or even Governments, whose priorities for funding may result in the funds being used for other purposes. Even in case of an independent body, it is thought that there could be hazards to the long-term availability of funds. These hazards range from errors in assumptions about inflation or discount rates used for estimating the required funds, to a simple loss in value of the assets held by the fund. These uncertainties might lead to the conclusion that, if sufficient funds are available, and other relevant conditions are satisfied, decommissioning and dismantling should be started as soon as possible. This seems to be an important strategic consideration.

7.14 Availability of staff and personnel issues

There are several alternatives to carry out the decommissioning and dismantling operations and there are certain effects that may impact the envisaged strategy. The main options consider the use of in-house staff, contractors, or a completely separate body. In addition to the advantages of in-house staff that have retained knowledge of plant and systems, it seems that savings might be made in avoiding the training and management costs associated with the introduction of new staff for the decommissioning and dismantling operations. A similar benefit might be achieved, however, when choosing the alternative of contractors who are specialising in decommissioning and dismantling work.

7.15 Knowledge retention

Knowledge of the status and the history of the nuclear facility is essential for successful planning of decommissioning, selection of a decommissioning strategy and execution of the decommissioning activities from both the safety and the technical point of view. It is desirable to ensure that measures are taken during the entire operational phase to document the physical inventory of equipment, the inventory of hazardous materials and the radiological inventory.

Particular attention should be given to keeping members of the operational staff employed in the facility as long as possible in order to preserve the facility and operational knowledge. In addition, their presence can help to avoid any loss of morale associated with the idea that decommissioning of a facility is less important than operation of a facility, notwithstanding the fact that it may possibly lead to site closure. In general, the retention of staff with detailed knowledge of the plant during its construction and operational phases is judged to be a key element in securing the continuing safety of dismantling and decommissioning activities.

7.16 Site reuse

The assumptions relating to the re-use of a site at the end of decommissioning can vary and affect the extent of the required decommissioning operations and the costs. Some countries that are committed to further use of nuclear power generation intend to re-use the existing sites for these purposes. This may involve that an immediate dismantling strategy is selected, but that the extent of the dismantling activities should not be that large as for a site that will not be re-used. If some plants and buildings might be re-used, it will not be necessary to undertake the required extensive monitoring and site remediation in order to clear the site from any regular control and remove it from the list of classified installations.

If it is not the intention to use a site for further nuclear purposes, alternatives could be, for example, using the site for other non-nuclear industrial purposes or returning the site to "green field" conditions.

Plans for the re-use of a site clearly affect the scope, the schedule and the end point of the decommissioning operations.

7.17 The process for selecting a strategy

Experience resulting from the decommissioning projects completed so far around the world shows that there is no single decommissioning strategy that might be universally applicable.

The selection of a strategy and the definition of the end state of a facility reaching its end of life is a complicated process involving a lot of parameters that cannot be resolved in one formula. There are objective factors like technology, cost and risk assessment, and subjective factors like socio-economic or aesthetic factors, which can produce different scenarios starting from very similar situations.

In general, the choice of a preferred decommissioning alternative is based on optimization studies using decision making techniques like cost-to-benefit or multi-attribute analyses. The choice is not obvious. Many factors have to be taken into account. A systematic methodology that may be considered for the decision making process in order to select a decommissioning strategy should include:

- An assessment of the regulatory constraints;
- A characterization of the facility;
- The identification of the key factors affecting the decision making;
- An evaluation of alternatives.

Detailed planning of the decommissioning activities should start some five years before the planned transition from operations to decommissioning.

Whenever possible, planning for decommissioning should be considered part of the design and construction activities. Early decision making concerning the end state of the nuclear facility and the associated site may result in economic optimization of the life cycle of the nuclear facility.

7.18 Regulators and decision-makers

Member State legislative and regulatory requirements may to some extent dictate the strategy to be followed and may take into account some of the factors that are discussed in this section. These requirements may prohibit certain strategies from being considered. They may also impose certain conditions, such as time limits on a safe enclosure period.

The type of legislation which is developed to implement the decommissioning requirements depends very much on the legal system in the country. In some systems, legislation is goal setting. In other cases, legislation is very detailed and prescriptive. In addition, there may also be regional requirements. For example, within the European Union relevant Directives on radiation protection and environmental impact assessment must be incorporated into the legislation of Member States. The way this is done will depend on the individual legal system of a State. Therefore, the regulatory regimes in different countries may vary significantly. However, they share the overall objective of safe decommissioning.

It must be noted that the proposed EC Safety Directive included in the Nuclear Package makes no proposals concerning the choice of the strategy to be followed for decommissioning, neither about the time it should start, the speed at which it should be achieved, or the status of the site at the end of the process.

Nevertheless, the EC considers that there is a need for a Community Strategy on decommissioning aiming at the development of a common approach in Member States and encouraging them to work towards a harmonization of decommissioning strategies and practices wherever possible.

An additional regulatory factor that could influence the strategy chosen by the operator of a nuclear installation is the uncertainty on the stability in the long term of the given legislation. An operator can never be sure of the stability of the existing legislation, although he can be sure that if there is a change, it will lead to more strict constraints and higher costs.

It can be concluded that the selection of a decommissioning strategy depends on many factors that are often specific to the country, to the local policy, to Government guidelines or policies, etc. There is no "universal" good strategy and the selection has to take account of various parameters, ensuring that decommissioning operations are undertaken safely.

7.19 Spent fuel and waste management systemcope of decommissioning activities

Ideally, spent fuel and waste management systems, including final repositories for all types of waste materials, should be available at the time of decommissioning. If this is not the case, firm planning for these types of facilities is regarded as a priority with establishment within reasonable timescales. Meanwhile, appropriate solutions for waste processing and interim storage are required to allow for conditioned waste to be stored safely. The discussion and dialogue with all stakeholders will strongly depend on the availability of such facilities/plans.

Compared to normal operation of a facility, during decommissioning large amounts or even new types of waste materials will arise. These materials will exhibit very low levels of activity or could be readily decontaminated to achieve such levels. The amounts and the types of waste materials created during decommissioning will be a factor in the selection of a decommissioning strategy. Radiological criteria and associated activity levels (preferably internationally harmonized guidance according to which such materials can be cleared from any regulatory control) are key factors in assessing the radioactive waste volumes. In general, there are several ways of removing materials and wastes from a facility:

- Clearance for unrestricted reuse or disposal;
- Authorized release to the environment;
- Reuse within the nuclear industry;
- Regulated disposal under controlled and monitored conditions.

7.20 Health, safety and environmental impact

The current situation, the possible deterioration of structures, systems and components, and the radiological characteristics of a facility may constitute a health and safety risk that could have an influence on the selection of a decommissioning strategy.

Comparative radiological and environmental impact assessments based on viable decommissioning strategies and associated radiological characteristics, are key inputs to the process of selecting a strategy. These assessments should evaluate the impact in terms of occupational and public exposure and safety hazards associated with the main decommissioning actions as well as environmental impacts. The selected decommissioning strategy should also be subjected to a review of the specific methodologies and techniques in order to optimize the protection of the workforce and the public.

7.21 Suitable technologies and techniques

The availability and the use of suitable technology are important factors in planning for decommissioning and can influence the selection of a decommissioning strategy. Site-specific features may demand development and adaptation of technology, but in many cases mature technology is commercially available.

8 Conclusions and recommendations

The purpose of this study was to identify and analyse the factors influencing the selection of strategies for the decommissioning of nuclear installations in the 25 European Union (EU) Member States as well as in the Candidate Countries Bulgaria and Romania. In addition, Switzerland was included in the comparison as a non-European Union Country.

A consultation was performed by means of detailed and appropriately pre-completed questionnaires that were sent to relevant sources of information among the affected stakeholders. The study also took into account relevant publicly available publications relating to the selection of strategies for the decommissioning of nuclear facilities, with the aim to avoid duplication of work and provide clear added value to the existing publications on the subject.

In addition to safety and the availability of practical decommissioning techniques, the following issues were identified to be particularly relevant to the selection of a strategy:

- The basic decommissioning options; the scope of the decommissioning activities.
- The reactor type; the reactor size; the number of units on a site; the operational history.
- Project planning; analysis of material flow.
- Regulatory and policy requirements (timing; release criteria).
- Socio-economic issues.
- Waste management provisions.
- Funding arrangements.
- Staff availability and personnel issues.
- Knowledge retention.
- Site reuse.
- Strategy selection process (e. g., multi-attribute analysis, etc.).
- Stakeholders; decision makers, regulators and the public.

The most commonly mentioned stakeholders consulted during the decision making process for a decommissioning strategy were decision makers, governments, regulators, and the public.

Based on the experience collected within appropriate and representative decommissioning projects within the investigated countries, the following recommendations relating to guidelines of general application for the selection of a decommissioning strategy may be addressed:

- All nuclear installations should be decommissioned after permanent shutdown and the management of waste should be adequately addressed.
- Legal and regulatory infrastructures relating to decommissioning need to be established as soon as practicable.
- Due attention should be paid to cases in which for historical reasons special solutions will have to be considered in order to define the most appropriate strategy.
- Factors have been identified and evaluated that influence decommissioning strategies to a larger or to a lesser extent. The selection of a decommissioning strategy needs to be based on an evaluation of all relevant factors. Techniques used for such an evaluation may be multi-attribute analyses that would consider all relevant factors, constraints and conditions, their interactions and weights in order to select the

appropriate strategy. In site specific evaluations, it may be important to include other conditions and constraints.

- When constraints occur, the management has to take proactive steps in order to remove such constraints or, if impossible, to eliminate or minimize the impacts.
- The only viable strategy in the case of reuse of a facility or a site is generally immediate dismantling, in which case the following may be considered:
  - Actions and criteria to clear materials, structures and the site to enable reuse of the site for either nuclear or non-nuclear purposes;
  - The possibility of interference between the construction of the new facility and the dismantling and demolition of the existing facility.
- When the legal/regulatory framework is inadequate, immediate dismantling in compliance with international practice may be selected as the preferred strategy. Deferred dismantling may also be an option under these circumstances, but entombment may be a less favourable solution. In these cases the following actions may be considered:
  - Back-up or alternative solutions may be required in order to limit the impact of changes in legislation and regulations. This is particularly important for deferred dismantling as such changes are most likely to occur during a deferral period.
  - Delaying any tendering or contracting process until all relevant licensing requirements and criteria exist. Contracts may include flexibility in the case of changes in regulations.
  - The regulatory body may be developing the licensing approach as the project advances; early discussion and resolution of issues will help the regulator and expedite the project.
  - Promoting public involvement in defining/developing the project and a regulatory framework: stakeholder involvement is desirable in the decision-making process at an early stage.
  - The International Atomic Energy Agency (IAEA) will be a reliable source of international experience on typical regulatory frameworks that might be enforced for decommissioning purposes.
- Limitations and conditions associated with financial provisions for decommissioning, the waste management system and human resources could result in the selection of deferred decommissioning as the strategy for decommissioning, independent from other factors. This may result in a decommissioning strategy that is not necessarily the better choice.
- Deferred dismantling caused by the above mentioned insurmountable constraints is generally the result of a lack of decommissioning planning which in turn might be due to insufficient legal or regulatory framework. Authorization of facilities dealing with radioactive materials should include decommissioning considerations starting from the design phase up to the operational and shutdown phases.
- When deferred dismantling is the imposed decommissioning strategy, it should be evaluated that this will not result in the fact that the problems associated with the decommissioning activities are only delayed and in some cases exacerbated.
- In case spent fuel and waste management systems are inadequate, and even in case Member States have well established waste management systems, difficulties may arise in accommodating the large quantities of materials and types of wastes that will be generated during decommissioning and may require ad-hoc authorized disposal routes. The following actions may be considered:

- Public consultation in order to obtain acceptance for the most dedicated material disposition routes and adapted waste repositories.
- Accelerated development of adapted material and waste management systems.
- Enlargement of the on-site capacity for operational waste storage in preparation for deferred dismantling.

- In terms of knowledge retention and resources the following actions may be considered:
  - Maximize the use of operational staff.
  - Update and preserve technical information on the design and operation of the facility.
  - Implement a radiological characterization of the facility using operational experience and facility history.
  - Take initiatives to reduce the radiation levels at the facility as soon as possible after shutdown (e. g., decontamination, removal of active components).
  - Ensure the participation of external organizations in planning and management for decommissioning.

- The impact on the local economy of the decommissioning of a large nuclear facility will be more acute if no other large nuclear facilities remain on the site. This impact can be significant when the site is isolated or in an area of low economic activity. The impact on the local economy may affect many stakeholders and may cover many aspects such as employment rates, tax bases, costs of housing, number of visitors, etc.

  The following may be considered with regard to socio-economic impacts:
  - Involvement of the different stakeholders is a key point for the identification and management of social issues. Social issues need to be considered in the decision-making process and incorporated into the planning for decommissioning. Local economy and social factors become more relevant when a facility is one of the major employers in the area.
  - Local economy and social issues may also play an important role in defining the objectives of and the strategy for decommissioning.
  - Socio-economic impacts associated with the decommissioning of a facility are site and region specific. It is difficult to predict which strategy will have the minimum impact. An evaluation of the socio-economic impact of each of the viable decommissioning strategies is an important consideration in the selection of an adequate strategy. If unemployment of the personnel of the nuclear power plant is an important issue, the decommissioning work may be a way of smoothing its negative effects, regardless of the decided strategy. This approach will usually require a change in culture from operations to decommissioning which may be accomplished with extensive training and incentives. International examples exist where re-employment of the operational staff was a key factor in deciding for immediate dismantling (e. g. Greifswald, Germany).
  - Public involvement through discussions, public hearings, meetings, and open dialogue is essential and may improve public acceptance of the adopted strategy.

- The polluter pays principle should be fully applied throughout the decommissioning of nuclear installations. In this regard, the primary concern of the nuclear operators should be to ensure the availability of adequate financial provisions for safe decommissioning by the time the respective nuclear installation is permanently shut down.

- Cost estimates should be site specific and based upon the best available knowledge and techniques.
- Budgetary planning should be subject to the review of a national body.
- In case a decommissioning project proves to be more expensive than the calculated cost estimates, the operator should cover the additional expenses. This should be carefully handled in case of operator change during or beyond the lifetime of a nuclear installation.
- An external fund should be the preferred option for all nuclear installations. Review of the collected funds on a regular basis by a national body should ensure proper management and use of the funds.
- Financial resources should be used only for the purpose they have been established and managed for. All commercially non-sensitive information should be publicly available.
- If the decommissioning funds are managed internally, a segregated decommissioning fund should be established within the accounts of the operator in order to make the collected resources identifiable and traceable at any given time. If the management of this fund underperforms, the operator should be responsible for ensuring that adequate funds are available when needed.
- As the operator has no influence on the financial management of external decommissioning funds, in this case the value of the investments should be guaranteed by the state in order to ensure that adequate funds are available when required, even if nominal loss is made by the independent manager of the invested amounts by the time these financial resources are to be used. In such cases, the funds should not be supplemented with an amount higher than the loss in the investment.
- When decommissioning funds are inadequate, deferred dismantling may be the more likely strategy, in which case the following actions may be considered:
    - Decisions have to be taken on the collection and the build-up of the funds required for the ultimate implementation of the decommissioning activities.
    - The possibility to get financial support for the decommissioning activities from international financial organizations may be explored.
    - Depending on the type of facility, transition from operations to deferred dismantling and preparations for the deferral period will be planned according to regulatory requirements consistent with international recommendations (IAEA; EC, etc).
    - A cost estimate for the transition period from operation to preparation for deferred dismantling and deferred dismantling itself is important. Depending on the characteristics of the site and on the surrounding population and activities, decontamination, partial dismantling, reduction of hazards and/or remediation actions may be needed, and management of the waste generated should be planned and included in the cost estimate.
    - During deferred decommissioning, a surveillance and maintenance programme must be put in place. A safety assessment is required in order to ensure acceptable public and occupational exposure levels.
    - Stakeholder involvement is important in order to address relevant issues and concerns, and is an increasingly important part of the decision-making process.

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Annex 1

Questionnaire related to the Analysis of the Factors Influencing the Selection of Strategies for Decommissioning of Nuclear Facilities

Questionnaire

Analysis of the Factors Influencing the Selection of Strategies for Decommissioning of Nuclear Facilities

………

General Information to the Questionnaire

General information

The present questionnaire is largely based on previous work carried out in specific evaluations. The request for information had to be simplified, however, taking account of the specific objectives and the scope of the study on “Analysis of the factors influencing the selection of strategies for decommissioning of nuclear installations”.

Practical Instructions

This questionnaire is submitted as an electronic file (MSWord) via e-mail or on a CD and in addition, in a paper version.
Respondents are requested to provide their answers and respond directly in the supplied electronic files. However, if unavoidable, the answers may be provided on paper.
Please note that each question is numbered. We appreciate if you would refer to the number whenever you need to add text outside of the space/box allocated in the questionnaire.
For multiple answers to the same question (e.g., several waste repositories), please make copies of the questions as needed.
For many questions, the answer is "Yes" or "No". Please “bold & highlight" the applicable filed with GREEN colour **"Yes"** or **“No”** and DELETE the field where not applicable in your response.

For your guidance, in some cases where information was known and/or available, answers were already (partially) pre-completed. You are kindly requested to check the content of this information and answers, make corrections and/or adjustments. The pre-completed (partial) answers are highlighted with “RED” colour.

Country: ……………

Coordinator Details

Title: ____________________

Name: ____________________

Affiliation (i.e. company, organization): ___________________________________

Department: ___________________________________

Mailing address: ____________________

____

Phone number: ____________________

Fax number: ____________________

E-mail address: ____________________

Questions relating to Decommissioning Policies

DECOMMISSIONING POLICIES

Decommissioning policy, in the context of this project, is intended to include all governmental (national or regional) requirements as described in laws, regulations, standards and other mandatory rules that may influence the framework within which the decommissioning activities should take place. In order to cover the main issues, please answer questions QP1 to QP21 below.

If your country sent a response to the questionnaire used for preparing the NEA "decommissioning fact sheets", it is attached to the present questionnaire and you may refer to it wherever appropriate and/or modify/complement it with emphasis on issues relevant for the present study.

If you wish to provide a descriptive text covering additional key elements of the actual decommissioning policy in your country, being relevant for decommissioning strategies and costs, and/or if you want to make any reference to documents containing policy statements and legal frameworks, please insert the corresponding text or a reference to a document on the internet, at the end of your answer under the heading "Decommissioning Policy".

QP1		Is there a national definition of decommissioning?
Yes	**No**	
If yes, please provide the definition		
Answer and/or comments:		
Remarks:		

QP2		Is there a definition of the starting point of decommissioning?
Yes	**No**	
If yes, please describe the starting point (e.g. management decision to shutdown, nuclear fuel removed from the reactor, start of closing barriers, i.e., start of (stage 1) decommissioning activities)		
Answer and/or comments:		
Remarks:		

QP3		Is there a definition of the end point of decommissioning?
Yes	**No**	
If yes, please describe the end point (e.g. "green field", "brown field", removal of radioactive materials only, site available for unrestricted use, site available for nuclear use or for other industrial use, etc.		
Answer and/or comments:		
Remarks:		

QP4		What are the conditions that need to be achieved to be able to de-license a site, e.g. to enable all nuclear regulatory restrictions and controls to be removed?
Please indicate if these conditions lead to unrestricted release of the site and whether the operators are liable for the cost of managing any radioactivity discovered after the de-licensing process has been completed		
Answer and/or comments:		
Remarks:		

QP5		Is there a mandatory time scale by which the end point of decommissioning as described in question QP3 must be achieved?
Yes	**No**	
If yes, please indicate the time scale (number of years after shut down).		
Answer and/or comments:		
Remarks:		

QP6		Are utilities / operators required to perform a broad-based strategy optimization before selecting the decommissioning strategy?
Yes	**No**	

1) If yes, is guidance provided on how to perform this optimization?
2) If yes, please describe in more detail the performance of strategy optimization
3) Is this broad-based strategy part of a decommissioning plan?

Answer and/or comments:

Remarks:

QP7		Are specific strategy options/alternatives required to be included in the selection process mentioned above?
Yes	No	
1) If yes, please describe in more detail		
Answer and/or comments:		
2) Are these strategy options part of a decommissioning plan?		
Yes	No	
Answer and/or comments:		
Remarks:		

QP8		Are final repositories available for all radioactive waste types arising from decommissioning (other than spent nuclear fuel)?
Yes	No	

If no, please indicate what is the national approach adopted in order to manage the waste types for which there is no repository available today.

Answer and/or comments:

Remarks:

QP9	Please provide the following information for each radioactive waste repository/entity <u>available</u> for decommissioning waste (including on-site disposal, if applicable):		
Please copy and fill in for each available repository/entity			
Location/entity:			
Opening date:			
Anticipated closing date:			
Characteristics of the acceptability limits for waste (LLW, HLW, heat-generating waste, α- and β/γ waste,…):			
Maximum activitiy level (α- and β/γ activity)(please specify):			
Maximum dose rate at contact of package (please specify):			
Maximum size of the package (please specify):			
Maximum weight of the package (please specify):			
Maximum total capacity (in volume):			
Maximum total capacity (in activity):			
Is geographic location (e.g. distance from the decommissioning site) a limit to use this repository?	**Yes**	**No**	
Are there specific materials, e.g. graphite, toxic materials, asbestos,...which are not accepted at this repository?	**Yes**	**No**	
If yes, please specify in more detail:			

QP10		Are new repositories planned for radioactive waste arising from decommissioning?
Yes	**No**	
If yes, please provide the following information for each planned repository/entity.		
Please copy and fill in for each available repository/entity		

Location/entity:	
Opening date:	
Anticipated closing date:	
Characteristics of the acceptability limits for waste (LLW, HLW, heat-generating waste, α- and β/γ waste,…):	
Maximum activitiy level (α- and β/γ activity)(please specify):	
Maximum dose rate at contact of package (please specify):	
Maximum size of the package (please specify):	
Maximum weight of the package (please specify):	
Maximum total capacity (in volume):	
Maximum total capacity (in activity):	
Is geographic location (e.g. distance from the decommissioning site) a limit to use this repository?	**Yes** / **No**
Are there specific materials, e.g. graphite, toxic materials, asbestos,...which are not accepted at this repository?	**Yes** / **No**
If yes, please specify in more detail:	

QP11		What is the national policy regarding:
1) Hazardous non-radioactive waste from decommissioning?		
Answer and/or comments:		
2) Mixed waste (i.e. radioactive waste co-disposed with hazardous non-radioactive materials)?		
Answer and/or comments:		
Remarks:		

QP12	**Are there specific clearance levels and/or procedures for categorizing decommissioning waste as non-radioactive material or for enabling such materials to be released from the regulatory system?**	
Yes	**No**	
If yes, please describe in more detail		
Answer and/or comments:		
Remarks:		

QP13		Are criteria available for unconditional or authorized recycling (re-use) of materials?
Yes	**No**	
If yes, please provide the definition		
Answer and/or comments:		
Remarks:		

QP14		Is a specific license, different from the operating license, required for the transition period between final shutdown and the start of decommissioning?
Yes	No	
Answer and/or comments:		
Remarks:		

QP15		Is a specific license, different from the operating license, required for the actual decommissioning of a nuclear facility?
Yes	No	
If yes, please provide some more details		
Answer and/or comments:		
Remarks:		

QP16		**What kind of documents must be submitted to obtain the consent to proceed with decommissioning (e.g. safety case, requirements/guarantee of funding, environmental assessment, etc)?**
Answer and/or comments:		
Remarks:		

QP17		Who is responsible (liable) for the decommissioning costs?		
Government:		Yes	No	
Utility/operator:		Yes	No	
Other (please specify):		Yes	No	
Remarks:				

QP18	Who is empowered to manage the decommissioning activities after shut down of the facility?		
Management of the plant during the operational phase	**Yes**	**No**	
Newly assigned organization with full responsibility for decommissioning	**Yes**	**No**	
Other configuration (please specify)	**Yes**	**No**	
Remarks:			

QP19		**What are the consequences of a possible/eventual decision on nuclear energy phase-out for the decommissioning of the nuclear facility?**
(e.g. limited operational period of facilities, earlier shutdown, decommissioning of specific facilities,…)		
Answer and/or comments:		
Remarks:		

QP20		What is the situation relating to trans-boundary material movements?
(e.g. import/export of redundant (low-level) radioactive material in view of recycling, re-use or release, disposal)		
Answer and/or comments:		
Remarks:		

QP21	What is the situation related to the acceptance of foreign waste for processing, storage, disposal?
Please describe in more detail	
Answer and/or comments:	
Remarks:	

Questions relating to Decommissioning Funds

DECOMMISSIONING FUNDS

The objective of this section of the project is to provide the available information relating to the practices for the funding of decommissioning activities.

The purpose of the information to be collected is to provide an understandable overview of the current situation and to provide a guideline for the selection of a decommissioning strategy that will be validated through appropriate, representative and real decommissioning projects within the EU Member States
An overview of the analyses and conclusions as well as recommendations will be drawn from the study which will be taken from the most updated and reliable data, obtained from public sources and experts from relevant countries. This information may be used as an input for preparing a model annual report from the European Commission to be submitted to the European Parliament and the Council on the status and use of the decommissioning and waste management funds.

QF1		What is the legislative background that obliges the utilities or institutions or organizations to create and manage a decommissioning fund?
(e.g. legislation, recommendations, …)		
Answer and/or comments:		
Remarks:		

QF2	Coverage of the decommissioning fund – terminology		
Are the following items covered by the fund concerned?			According to your estimate, what is the share ir represents in the overall budget?
Total Decommissioning Costs	**Yes**	**No**	
In case of deferred decommissioning:			
Are preliminary decommissioning costs covered?	**Yes**	**No**	
Are safe enclosure costs covered?	**Yes**	**No**	
Are final decommissioning costs covered?	**Yes**	**No**	
Total Waste Management Cost	**Yes**	**No**	
Cost for management of waste from decommissioning	**Yes**	**No**	
Cost for interim storage of spent fuel	**Yes**	**No**	
Cost for long-term/final disposal of spent fuel	**Yes**	**No**	
Other costs (please specify)	**Yes**	**No**	
Cost for Social Measures	**Yes**	**No**	
Cost for supporting programmes for employees	**Yes**	**No**	
Cost for regional development	**Yes**	**No**	
Other cost relating to social aspects of decommissioning (please specify)	**Yes**	**No**	
Other cost not mentioned above (please specify)	**Yes**	**No**	
Is there any regulation that stipulates how often the decommissioning cost should be revised/updated?	**Yes**	**No**	
If so, how often are decommissioning cost revised/updated?			

QF2	Coverage of the decommissioning fund – terminology		
Are the following items covered by the fund concerned?			According to your estimate, what is the share ir represents in the overall budget?
What are the assumptions used for estimating decommissioning cost?			
Should decommissioning cost be approved by the regulatory authority or governmental agency?	**Yes**	**No**	
If yes, by whom?			
Are the decommissioning cost estimated using deterministic or probabilistic methods?	**Yes**	**No**	
If deterministic methods are used, are there any plans to use probabilistic methods in the near future?	**Yes**	**No**	

QF3		**Is collection of all financial means for decommissioning activities defined at start-up of facility operation?**
Yes	**No**	

If yes, please provide more detailed information

Answer and/or comments:

Remarks:

QF4		Is continued collection of funds during the operational period of the facility carried out?
Yes	**No**	
If yes, please specify how it is done		
Answer and/or comments:		
Remarks:		

QF5		How are decommissioning funds required to be collected?		
By a specific charge included in the electricity price		**Yes**	**No**	
By a tax (please specify the kind of tax)		**Yes**	**No**	
By Governmental / compulsory fees (please specify these fees)		**Yes**	**No**	
By other means (please specify)		**Yes**	**No**	
Who are liable to contribute to the decommissioning fund?				
No specific requirements		**Yes**	**No**	
Remarks:				

QF6		When should the total amount of decommissioning funds be available? (Within what period should the total amount of decommissioning funds be collected?)		
Within ….. years from commercial operation		**Yes**	**No**	
At the time of shutdown of the plant/facility		**Yes**	**No**	
Within ….. years of the start of the decommissioning of the plant		**Yes**	**No**	
Within …. Years from the shutdown of the plant/facility		**Yes**	**No**	
Others (please specify)		**Yes**	**No**	
Remarks:				

QF7		By whom are decommissioning funds managed?		
As a segregated fund		Yes	No	
By the utility / operator within the own assets		Yes	No	
By the utility / operator within a separated account		Yes	No	
By the utility / operator as a segregated fund (collected money)		Yes	No	
By other means (please specify)		Yes	No	
No specific requirements		Yes	No	
Remarks:				

QF8	How are decommissioning funds required to be held?		
By the Government	**Yes**	**No**	
By the utility/operator of the facility	**Yes**	**No**	
By another body (please specify)	**Yes**	**No**	
No specific requirements	**Yes**	**No**	
Remarks:			

QF9		Are decommissioning funds required to be based on:			
Overnight / undiscounted decommissioning costs?			**Yes**	**No**	
Net present value / discounted decommissioning costs?			**Yes**	**No**	
If yes, please specify the discount rate and reference date of discounting					
If the fund is managed independently, how is the money transferred to the fund? (quarterly, annually)					
If the fund is managed independently, are there any requirements for financial audits?			**Yes**	**No**	
Should the fund pay taxes?			**Yes**	**No**	
Others (please specify)			**Yes**	**No**	
Remarks:					

QF10		Are decommissioning funds subject to periodical review?		
Yes	**No**			
What is the review period?				
Is the review carried out by the utility or operator of the facility?		**Yes**	**No**	
Is the review carried out by a governmental organization?		**Yes**	**No**	
Is the review carried out by other organizations?		**Yes**	**No**	
Does the review include an evaluation whether sufficient means will be available to cover the decommissioning programme?		**Yes**	**No**	
Does the review include an investigation of the accuracy of the collection of financial means?		**Yes**	**No**	
No specific requirements		**Yes**	**No**	
Remarks:				

QF11		What is the expected accuracy of estimations of the financial needs for decommissioning?
Please provide more details		
Answer and/or comments:		
Remarks:		

QF12		Are nuclear installations other than nuclear power plants (research reactors, hot cells, etc) treated in the same way as private utilities with regard to funding?
Yes	**No**	

Answer and/or comments:

Remarks:

QF13		How are the security and/or uniqueness of the destination of the funds guaranteed?		
Can the available funding be used for other purposes in a specific period before the start of decommissioning?		**Yes**	**No**	
If yes, please specify in more detail				
If the plant should be shutdown for economic/technical/political reasons before its useful life, and he contribution to the decommissioning fund is not completed, is there any mechanism to cover the cost of decommissioning ?		**Yes**	**No**	
Remarks:				

QF14		Are insurances available to cover financial risks?
Yes	**No**	
If yes, please provide some more information		
Answer and/or comments:		
Remarks:		

QF15		Can the progress of a current or related programme be financed by means of current benefits from the operation of other plants and/or facilities?
Yes	**No**	
If yes, please provide the definition		
Answer and/or comments:		
Remarks:		

QF16		Are any annual or pluri-annual public endowments considered?
Yes	**No**	
If yes, please describe in more detail		
Answer and/or comments:		
Remarks:		

QF17		Is there any alternative for the internal management of funds (e.g. internal investments,…)
Yes	No	

If yes, please explain

Answer and/or comments:

Remarks:

QF18		Is there any alternative for the external management of funds (e.g. bank, financial subsidiary, etc,…)
Yes	**No**	
If yes, please explain		
Answer and/or comments:		
Remarks:		

QF19		May funds be transferred to authorities or an agency?
Yes	No	
If yes, please explain		
Answer and/or comments:		
Remarks:		

QF20		In case funding is arranged by several "sub-funds" from different donors, is there one single co-ordinator for all sub-funds?
Yes	**No**	

If yes, please provide the definition

Answer and/or comments:

Remarks:

QF21		Are effects considered that might have an impact on the decommissioning fund?
Yes	**No**	
If yes, please describe in detail		
Answer and/or comments:		
Remarks:		

QF22		Management of funds		
Some sources indicate that a secure, segregated fund in independent, trustworthy hands is the most favourable solution.				
How do you see your situation with regard to this statement? Do you agree, disagree; what is your opinion….)?	**Yes**	**No**		
Do you find it necessary to investigate a possible modification of the national system?	**Yes**	**No**		
Do you see any needs for European level harmonization, especially in the light of the opening of the international electricity market?	**Yes**	**No**		
Remarks:				

QF23		What was the growth of the provisions for decommissioning in the last years, i.e. indicate the amount of financial means that were accumulated from all possible sources in the decommissioning fund in the year 2000, 2001, 2002, 2003 and 2004
Answer and/or comments:		
Year 2000: Year 2001: Year 2002: Year 2003: Year 2004:		
Remarks:		

Questions relating to Decommissioning Strategy

DECOMMISSIONING STRATEGY

Decommissioning strategy, in the context of this project, is intended to include all technical, logistic and scheduling aspects proposed by the operators to their national regulatory authorities when requesting the authorization to proceed with the decommissioning project. Topics to be covered include: permitted or expected re-use of the site; socio-economic context of the site/region; public acceptance issues; specific factors affecting the company strategy regarding decommissioning; possibilities for recycling materials; possibility of one piece removal of a reactor pressure vessel; driving factors and priorities, e.g. minimization of doses to workers, minimization of costs, minimization of wastes.

The figure below shows in principle the parties involved and being able to influence a decommissioning project, often labeled as stakeholders.

The various stakeholders may have their own interest for interacting on the selection of a decommissioning strategy, as may be expressed by considering a number of key factors.

The questions are grouped around such key factors according to the impact on the process to define the most widely acceptable decommissioning strategy which will be specific for each nuclear facility, depending on the weight of each key factor. The groups of key factors are:

Legal, Ownership and Regulatory Factors
- Legal background anchoring a decommissioning strategy
- Regulatory requirements, radiological protection and industrial safety of workers, clearance levels
- Political decisions or directives
- Plant ownership during decommissioning
- Identification of the involvement of other stakeholders

Socio-economics, Public Stakeholder Acceptance
- Socio-ethic impact and impact on the environment
- Public acceptance
- Communication policy
- Reuse of site

Availability of Human, Financial and Information Sources
- Availability of skilled decommissioning crews
- Availability of funding
- Availability of plant knowledge, plant history and hidden problems
- Availability of on site waste management facilities
- Availability of dismantling technologies
- Need for research and development of decommissioning technologies

Decommissioning Strategy Selection and Optimization Process
- Comprehension of pros and contras of different strategies, considering the steps, phases and endpoints
- Optimization process for waste materials, expected dose rates, costs
- Project risk evaluation
- Tools for optimization

Site, Facility Type and Process Relevant Parameters
- Expected amount of waste types

- Treatment and fractionizing of large components
- Required radiation protection technologies

In order to cover the main issues, please answer questions QSI-1 to QSV-4 below. If you wish to provide additional information, please insert the corresponding text at the end of your answer under the heading "Decommissioning strategy"

The questions are mostly written in the past tense as if a decommissioner is asked to reply, who has just terminated his project.

If the addressee participates in an ongoing project, he is asked to read the questions and respond in the present tense.

If the addressee is launching the decommissioning project he is asked to respond in the future tense.

Questions Group I: Legal, ownership and regulatory factors

QSI-1	Plant or facility details
Name:	
Location	
Category (e.g. commercial, prototype, research facility, other nuclear installation):	
Type (e.g. PWR, BWR, LMR, Fuel Cycle Facility, Hot-lab, Conditioning Facility, etc):	
Type of reactor pressure vessel (e.g. steel, concrete, pressure tube, etc):	
Type of process systems to be decommissioned (dissolver, evaporator, furnace systems, etc):	
Number of units on the site:	
Capacity on the site (MWe net, heat production capacity, throughput, volume, number of buildings of research reactor ,...if applicable)	
Number of units for which decommissioning cost data are provided:	
Number of employees during operation:	
Date of commissioning:	
Date of shutdown (specify whether the date is actual, expected, assumed for costing purposes):	
Expected date of decommissioning strategy end point:	

QSI-2	Who selected the decommissioning strategy?		
Utility/operator/licensee:	**Yes**	**No**	
Regulator:	**Yes**	**No**	
National Government:	**Yes**	**No**	
Regional Government:	**Yes**	**No**	
Joint decision:	**Yes**	**No**	
If yes, please name the parties involved:			
Others (please specify)	**Yes**	**No**	
Remarks:			

QSI-3		Change of owner			
Is the responsibility for decommissioning transferred from the utility/operator to another body?			**Yes**	**No**	
If yes, please specify					
Remarks:					

QSI-4	**Identification and completeness of stakeholders**
Which stakeholders were consulted during the process? (e.g. Government, regulators, public,…)	
Based on your experience, whom do you consider to be/become a stakeholder who was not/not yet considered?	
Remarks:	

QSI-5		Legal background			
How is the process of selecting a decommissioning strategy anchored in the legislation of your country? (please specify the most important laws and ordinances)					
Are internationally accepted definitions for strategy of decommissioning introduced and binding in your country?			**Yes**	**No**	
Remarks:					

QSI-6	Regulatory requirements		
1. Do regulatory requirements include:			
Selection of a decommissioning strategy:	Yes	No	
Please comment in more detail			
Radiological protection and industrial safety of workers:	Yes	No	
Please comment in more detail			
Clearance levels for release of materials:	Yes	No	
Please comment in more detail			
Clearance levels for release of sites:	Yes	No	
Please comment in more detail			
2. Which were the main points of discussion from the regulatory side at the time when the project was started?			
Please comment in more detail			
3. Are EU Directives for decommissioning requirements correspondingly incorporated into the legislation of your country?			
	Yes	No	
Remarks:			

Questions Group II: Social economics and public stakeholder acceptance

QSII-1	General impact on the environment

Was an Environmental Impact Assessment (EIA) implemented from the very beginning of the project?	**Yes**	**No**	
If No, how was it introduced and by which legislative background			
Legislation of your country:	**Yes**	**No**	
By a Directive of the EU:	**Yes**	**No**	
Voluntarily by the plant owner:	**Yes**	**No**	
Remarks:			

QSII-2	Public acceptance and participation		
Were public hearings foreseen from the very beginning of the project?	**Yes**	**No**	
Did the plant owner establish communication channels with the neighbouring communities on a professional basis?	**Yes**	**No**	
Has the public been informed by a continuous dialog?	**Yes**	**No**	
Remarks:			

QSII-3	Social impact		
1. In order to mitigate and smooth social impacts on the surrounding communities, did the plant owner develop countermeasures against unemployment and plans for creating new jobs?	**Yes**	**No**	
2. Was reuse of the site intended to be such a countermeasure			
From the very beginning	**Yes**	**No**	
After a certain milestone was reached	**Yes**	**No**	
Never	**Yes**	**No**	
3. When deciding about the decommissioning strategy, has it been considered that early decommissioning might introduce dramatic changes of employment after plant shutdown?	**Yes**	**No**	
4. When deciding about the decommissioning strategy, has it been considered that early decommissioning might smooth social impacts on former staff member families?	**Yes**	**No**	
Remarks:			

QSII-4	Ethical aspects		
Have ethical aspects, such as the responsibilities to the later generations, been considered when developing the decommissioning strategy?	**Yes**	**No**	
Remarks:			

Questions Group III: Availability of information, human, financial and technology sources

QSIII-1	**History of the plant relevant for decommissioning cost purposes**	
Please provide information on the history of the plant relevant for decommissioning cost purpose, e.g. extended shutdown, incidents, accidents, and major refurbishments and other (hidden) items		
1. Extended shutdown		
What are the reasons for shutdown?		
What is (expected to be) the amount of waste resulting from the shutdown or clean-up of the facility, that will have to be managed during decommissioning?		
2. Incidents		
Have there been major incidents that might have an impact on the decommissioning activities?	**Yes** | **No**	
How long did it take to remediate the consequences of the incidents?		
Are remainings of incidents still available in the facility that might have an impact on the decommissioning activities?	**Yes** | **No**	
3. Accidents		
Have there been major accidents that might have an impact on the decommissioning activities?	**Yes** | **No**	
How long did it take to remediate the consequences of the accidents?		
Are remainings of accidents still available in the facility that might have an impact on the decommissioning activities?	**Yes** | **No**	
4. Major refurbishments		
Were parts refurbished?	**Yes** | **No**	

QSIII-1	History of the plant relevant for decommissioning cost purposes		
Which ones and when?			
Have new infrastructures (e.g. material, systems, components, etc) been brought into the facility during operation? Which ones and when?	**Yes**	**No**	
5. Have specific items to be analysed and/or other problems to be solved before practical decommissioning activities could start? Which ones and when?	**Yes**	**No**	
6. Was during the selection of the decommissioning strategy any programme foreseen in order to obtain comprehensive knowledge about the facility's status and the operating history? ("site characterization plan")	**Yes**	**No**	
Remarks:			

QSIII-2	Availability of skilled decommissioning crews		
1. Could the project rely on sufficient professional decommissioners available on the market?	**Yes**	**No**	
2. Did the project rely on own operating crew?	**Yes**	**No**	
3. Was the project obliged to train its staff:			
"on the job"?	**Yes**	**No**	
on special mock-up	**Yes**	**No**	
Remarks:			

QSIII-3	Availability of funding		
Are required financial means for decommissioning provided in specific funds?	**Yes**	**No**	
Is the totally required money available?	**Yes**	**No**	
How is it ensured that the required financial means will be available?			
Remarks:			

QSIII-4	**Availability of on site Waste Management facilities**		
1. If waste treatment and storage facilities are available on site, can they be used to treat and store the decommissioning waste?	**Yes**	**No**	
2. Do the available waste management facilities require technical adaptations to treat the dismantling wastes?	**Yes**	**No**	
3. If the required waste management facilities are not available, which solution will be incorporated in the cost optimizing process?			
Remarks:			

QSIII-5	**Availability of dismantling technologies**		
Are well proven dismantling technologies available for all the materials to be segmented or fractionized and pre-sorted in situ during dismantling?	**Yes**	**No**	
Are well proven decommissioning technologies available for decontamination of components/materials, building structures?	**Yes**	**No**	
Are well proven technologies available for the monitoring in view of unconditional or conditional release for materials after or without decontamination?	**Yes**	**No**	
Remarks:			

QSIII-6	**Necessity for development of new (other) technologies**
If the answer to questions in QSIII-5 is "no", which technologies are foreseen to be developed?	
Answer/Comments/Remarks:	

Questions Group IV: Decommissioning strategy selection and optimization process as a basis for the Decommissioning Plan

QSIV-1	**Comprehension of pros and contras of different decommissioning strategies, stages, phases and endpoints**		
1. Have the different decommissioning strategies, the pros and contras, the stages and phases been adequately addressed when developing a decommissioning plan in order to prepare the selection process and implement it?	**Yes**	**No**	
2. How was this implementation proved and verified?			
3. Is there a clear end point in the strategy selected relating to re-use of the site, including the corresponding clearance levels?	**Yes**	**No**	
Remarks:			

QSIV-2	Strategy selection		
Does the decision making process for strategy selection includes:			
Assessment of regulatory constraints?	Yes	No	
Characterization of the facility after shut-down?	Yes	No	
Identification of influential key factors?	Yes	No	
Evaluation of alternatives?	Yes	No	
Which decommissioning strategies were considered?			
1. Immediate decommissioning?	Yes	No	
2. Deferred decommissioning?	Yes	No	
What were the main reasons for the selection of deferred decommissioning?			
Was the reason the lack of remote handling experience?	Yes	No	
Other reasons? Please specify	Yes	No	
Please indicate the deferral period …….. years			
Define how the clearance levels will be met when the correlation between short lived nuclides and other isotopes will have been lost			
Remarks:			

QSIV-3	**Tools for optimization**		
1. What process was used to determine and select the decommissioning strategy? (e.g. cost-benefit analysis, multi-attribute decision analysis)	**Yes**	**No**	
2. Have different evaluation tools or methods, such as proposed by the OECD/NEA been used?	**Yes**	**No**	
Remarks:			

QSIV-4	Optimization process in view of radioactive waste minimization, expected dose rates, costs		
What was included in the assumed scope of decommissioning when the strategy was developed?			
On-site storage of fuel	**Yes**	**No**	
Decontamination for unconditional recycle, re-use or release (Indicate the expected % of material released relating to the total material inventory)	**Yes**	**No**	
Decontamination for conditional recycle, re-use or release (Indicate the expected % of material released relating to the total material inventory)	**Yes**	**No**	
Volume reduction (e.g. compaction) for radioactive waste materials	**Yes**	**No**	
Packaging of historic/operational waste, e.g. sludge, ion-exchange resins	**Yes**	**No**	
Removal of reactor building	**Yes**	**No**	
Removal of conventional plant buildings, e.g. turbine hall	**Yes**	**No**	
Removal of conventional ground	**Yes**	**No**	
Disposal of radioactive waste	**Yes**	**No**	
Disposal or recycling of non-radioactive waste material	**Yes**	**No**	
Final site surveys	**Yes**	**No**	
De-licensing of the site	**Yes**	**No**	
Is waste minimization "a requirement" in your country?	**Yes**	**No**	
Remarks:			

QSIV-5	Waste management	
What are the plans for radioactive wastes resulting from decommissioning?		
To be disposed of directly to a waste repository	**Yes**	**No**
To be stored on-site pending the availability of a waste repository	**Yes**	**No**
To be stored off-site pending the availability of a waste repository	**Yes**	**No**
Other	**Yes**	**No**
If yes, please specify in more detail		
Remarks:		

QSIV-6	**Project risk evaluation**		
1. Which project risks were identified and how were these evaluated and assessed			
2. Is loss of funding considered to be a project risk?	**Yes**	**No**	
If yes, please explain how to deal with loss of funding:			
3. Is the handling of historic liabilities of the site and corresponding funding defined?	**Yes**	**No**	
If yes, please specify briefly			
Remarks:			

QSIV-7	**Selected decommissioning strategy**		
Which decommissioning strategy has been considered for calculating the cost data provided?			
(please refer to strategy numbers given in QSIV-2 and indicate the key stages of the assumed strategy, the main activities undertaken at each stage and the duration (years) for each stage)			
Have other strategies been analysed for comparing decommissioning costs?	**Yes**	**No**	
Which were the results of these analyses and how did they influence the decision taking relating to the adopted decommissioning strategy?			
Remarks:			

QSIV-8	**Optimization for deferred strategy**		
Is there a dormancy or deferral period considered before decommissioning?	**Yes**	**No**	
What will be the conditions?			
What will be the required operations?			
What will be the required maintenance measures?			
What will be the required monitoring measures?			
What will be the required safety measures?			
What will be the required security measures?			
Remarks:			

Questions Group V: Site, facility type and process relevant parameters

QSV-1	**Expected amount of waste types**		
Expected amounts of materials, weight of residual materials (free release or restricted re-use) and radioactive waste from decommissioning			
	Materials	**Radwaste**	
	(tons)	(tons)	
Solids, non-combustible			
Reactor and biological shield			
Metals			
Other primary circuit components (e.g. steam generator, pipes)			
Other contaminated components and materials (e.g. fuel handling, effluent treatment)			
Concrete			
Materials from conventional buildings included in the scope of decommissioning			
Solids, combustible			
Solid combustible materials			
Graphite			
Other materials			
Liquid radioactive wastes (m^3)			
Total			
Remarks:			

QSV-2	**Estimated dose rate inside the reactor pressure vessel and estimated activation outside (only for nuclear power plants)**
1. What is the expected dose rate inside the reactor pressure vessel at	

shutdown?	
2. Which is the spectrum of nuclides causing this dose rate?	
3. What is the depth of activation in the biological shield?	
Remarks:	

QSV-3	Radiological protection technologies to be applied		
How is reactor dismantling to be performed?			
Fully remotely (with no direct worker access or contact with reactor components	**Yes**	**No**	
Semi remotely (with restricted access or contact with reactor components)	**Yes**	**No**	
Working in contact (no significant restrictions on worker access or contact)	**Yes**	**No**	
Other	**Yes**	**No**	
If yes, please specify in more detail			
Remarks:			

QSV-4	Segmenting of large items		
How is dismantling of the reactor pressure vessel and the primary circuit components done?			
Removal as a large piece without segmenting and disposal?	**Yes**	**No**	
Segmenting into small pieces, removal, packaging and disposal	**Yes**	**No**	
In the last case, please indicate the maximum size of pieces:			
Remarks:			