Research

# Methodology for description and evaluation of cost profiles and cost structure during transitions period

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## SKI perspective

### Background

A demanding task for our generation is to assure the appropriate financial resources are invested in the Swedish Nuclear Waste Fund. This will enable future generations to execute the decommissioning and dismantling of nuclear power reactors and other nuclear facilities in a prudent manner. The main aim is to fulfil the demands of environmental and health codes in a pan-European context within well defined and reviewed financial boundaries.

By creating prudent cost calculations for future decommissioning cost it is undoubtedly that credence will be given to the long term sustainability of the financing system that underpins the overall management of Sweden’s nuclear waste liabilities.

From this standpoint it is essential to assure that prudent and appropriate levels of financial provisions into Swedish Nuclear Waste Fund will be sufficient to cover all future expected disbursements and withdrawals of funded assets.

SKI conduct on a regularly basis high premium applied studies on endogenous variables, or elements, that might have a major impact on the future assets in the Swedish Nuclear Waste Fund in order to reduce the uncertainties in the estimated financial requirements for decommissioning; Thereby, mitigate the risk of creating a deficit in the Swedish Nuclear Waste Fund.

### Purpose of the project

The main objective of this study has been to describe the different activities that form the transition period in a decommissioning strategy. The phase is middle between the permanent shut-down of the nuclear power plant and the actual start of the decommissioning and dismantling of the nuclear installation in question.

The fact that decommissioning of nuclear power plant and nuclear installations, that has been permanent shut-down, may take between ½ to 2 generations to fulfil motivates a development towards more unified description of all phases in the decommissioning and dismantling process. On of the phases in the process that have a critical impact upon the total length of decommissioning and dismantling of nuclear power plants and nuclear installation is beyond questioning the length of the transition period.

### Results

The study offers a comprehensive presentation of a frame-work for a more uniform definition of the concept of transition period. The presentation shows a way of classification of different activities that will give a good transparency. Hence, the presented format is suitable for classification of input data in such a way that benchmarking processes with comparison and consistency validation can be developed. The ultimate goal is to present clear and consistent cost data so that stakeholders may find confidence in the cost calculation process and funding decisions.

## Continued work

There is an apparent need for further studies in this field. One urgent question is how data can be classified, stored and retrieved so that pan-European, as well as more international, comparisons can be undertaken.

Another actual question is to identify crucial cost-driver in the decommissioning process. This will both broaden and deepen our understanding of the "raison du étre" for finding unified methods for the planning stage of the decommissioning and dismantling process. Here one way is to make a revision of the "*Proposed Standardised List of Items for Costing Purposes, Interim Technical Documentation*" issued in year 1999 by OECD/NEA.

## Effects on SKI work

SKI will be able to use the study as supporting documentation in the review of the estimates given for the decommissioning costs of permanent shut-down nuclear power plant and nuclear installations.

## Project information

At SKI Staffan Lindskog have been responsible to supervise and co-ordinate the project. At DECOM, Slovakia, Frantisek Ondra has carried-out the task with determination and skill. Marek Vasko has contributed to the working processed with ideas and suggestions for improvements.

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**CONTENTS**

# EXECUTIVE SUMMARY

In this paper the transition period is described. The transition period means the period between the permanent shutdown and the issue of the decommissioning license. During the transition period, series of changes, modifications and adaptations of existing technological systems as well as organizational aspects are needed to be performed within the facility. The aim is to meet the new objectives and requirements of the period. The transition period from operation to decommissioning has to include the technical, management and organizational issues to provide a minimization of time-delays and undue costs, requalification of personnel, optimization of resources, and initiation and partial implementation of preparatory activities for decommissioning.

The paper describes the basic goals during the transition period, i.e. to set up the facility to clearly stable conditions ready for decommissioning, to eliminate or mitigate hazards, and to transfer program and financial responsibilities from the operating to the decommissioning organization as appropriate.

Next section describes selected strategic issues for which pre-shutdown planning should be conducted so as to arrive at decisions on courses of action upon shutdown. This includes overall planning for the transition and implementation of the decommissioning strategy, cost reduction, waste management issues, and development of techniques and tools required for decontamination and dismantling.

Main activities of the transition period are described such as: the removal of spent fuel, system cleanout operation, treatment, conditioning, storage and/or disposal of waste during the transition period, decontamination or fixing of contamination, characterization and inventory of radioactive and hazardous materials, consideration of systems, preparation of facility's rooms and buildings, protection from external or internal events, removal of minor components.

Main section presents the general methods for decommissioning costing and application of these methods for activities of the transition period. The chapter presents the classification of activities of the transition period from the point of view of decommissioning costing, identification of main cost drivers for activities which are specific for the period between the shutdown and start of decommissioning and the methods for cost estimation. The structure of main phases of the transition period are analyzed. Procedures for cost estimation typical for these phases are presented.

The European Commission (EC), the International Atomic Energy Agency (IAEA) and the OECD/Nuclear Energy Agency (NEA) made efforts addressing various aspects of decommissioning and decommissioning costs. Based on these activities and on the advantage of having standardized cost items, a common list of cost items and related cost-item definitions for decommissioning project has been established in document "A Proposed Standardised List of Items for Costing Purposes in the Decommissioning of Nuclear Installations" (PSL) in 1999. Member states are encouraged to adopt and use this costing structure system to gain traceability, compatibility and transparency of evaluated cost for individual decommissioning projects.
The PSL of decommissioning activities includes also the activities of the transition period and is presented in Appendix 1. Activities relevant to the transition phase are red colored. Activities partly or possibly relevant to transition period are blue colored. Activities not relevant to transition period are grey colored.
The transition period has been subject of several IAEA publications. A short description of these documents is presented in Appendix 2.

# 1. INTRODUCTION

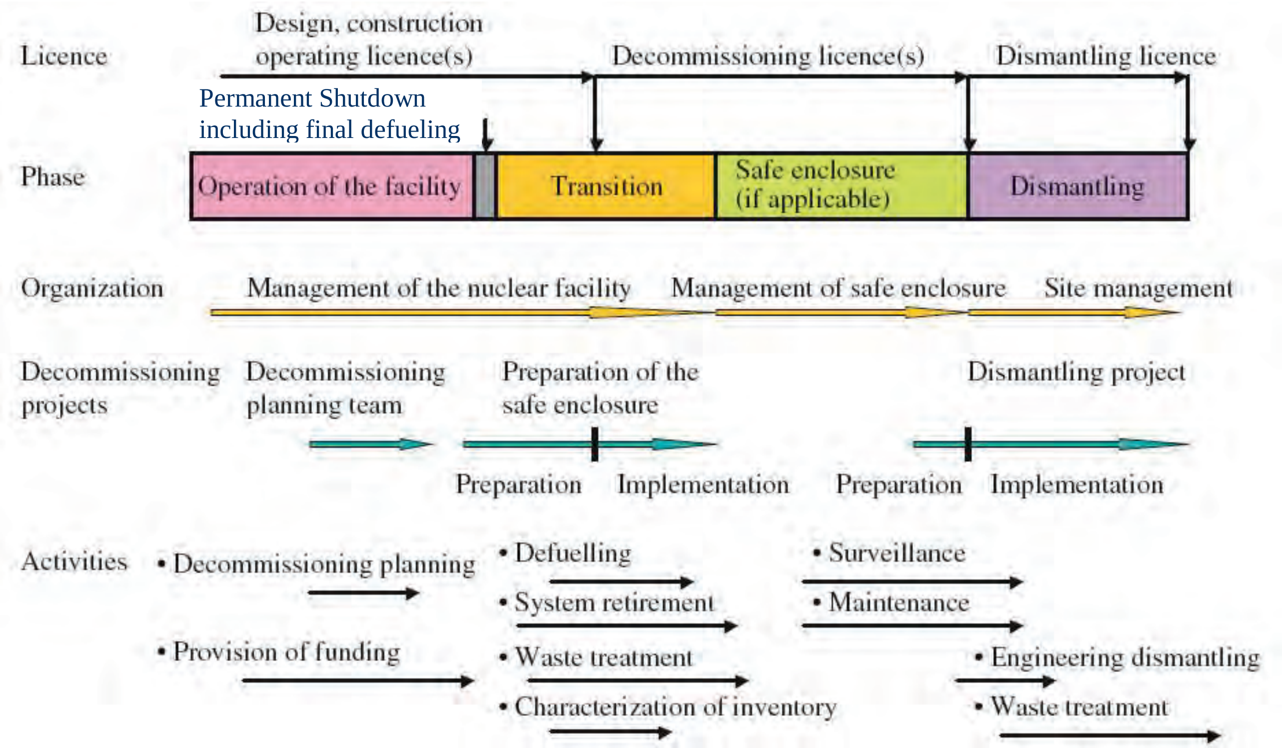
The transition period from installation operation to implementation of a decommissioning strategy is important [1]. During this period a number of plans, and modifications thereof, are made to adapt a facility to new objectives and requirements. Transition activities take place between operation and placement of the facility in a safe and stable condition preparatory to safe enclosure and/or dismantling. Typically these activities include final defueling of reactors, retirement of equipment and systems, radiological and waste characterization, operational waste treatment and removal of minor components.

Generally, removal or dismantling of major components and, where applicable, safe enclosure (SE) are excluded. However, activities carried out during the transition period will depend upon the type of facility and the regulatory regime. The objective of the transition period is to plan and implement these activities in a timely manner. A cultural change is also needed to reflect different management and working practices. It is essential that planning for the transition and decommissioning begin during operation and that activities be implemented as soon as possible after permanent shutdown to ensure a controlled transition and the best use of resources.

A key to the success of the transition period is the training and preparation of facility personnel. This includes, in particular, utilizing operating staff whose knowledge of the facility and its systems is valuable during this transition period. Figure 1-1 provides a possible scheme for decommissioning related activities, projects and organizational aspects covering the period from operation to final dismantling of a nuclear installation.

The subject of the transition period has been dealt with in part by IAEA publications, e.g. Refs [2]-[5], [16] (short description of these documents is published in Appendix 2), but never addressed as a distinct subject. Little publicly available literature exists on this subject.

Figure 1-1 Decommissioning related activities during the life cycle of an NPP



# 2. OBJECTIVES OF THE TRANSITION PERIOD

Planning for the transition should begin during the facility's operating period. Depending on national regulations, an operating license may remain in effect during all or part of the transition period. The goals during the transition period are **to put the facility in a clearly stable condition (e.g. SE), to eliminate or mitigate hazards, and to transfer program and financial responsibilities from the operating to the decommissioning organization as appropriate.** Timely completion of the transitional activities can take advantage of a facility's operational capabilities before they are lost. Certain activities can be completed more efficiently and cost effectively at this time than if they are postponed.

Activities during a facility's transition period continue to incorporate integrated safety management at all levels to provide protection for workers, the public, the environment as well as the plant. An important objective through transition and eventually decommissioning is to maintain an integrated and smooth process with links to the previous operational phases through reduced surveillance and maintenance.

The transition from the operating to the decommissioning organization can take a considerable amount of time, even years. It is important that progress made during the transition supports the decommissioning strategy. Transition planning is a necessary part of overall decommissioning planning and management.

Key objectives during facility transition are to [6]:

(a) Develop the transition and decommissioning plans, including the specification of end points establishing and defining the required conditions;
(b) Make an expeditious start to activities aimed at eliminating or mitigating hazards, beginning with those that clearly should be carried out regardless of the subsequent decommissioning strategy;
(c) Complete the necessary activities to meet the transition end points, with priority being given to the specified end points for mitigation and removal of hazards and materials;
(d) Maximize the utilization and effectiveness of current operating knowledge, personnel and operating systems or programs to reduce hazards at the facility, with emphasis on processes and systems for which the skills and knowledge required are unique;
(e) Establish effective relationships among all involved parties, in particular among the operating and decommissioning organization, contractors and authorities;
(f) Mitigate the social impacts of organizational changes;
(g) Reduce the cost of surveillance and maintenance and other transition activities;
(h) Identify the treatment, storage, transport and disposal requirements for all materials and wastes;
(i) Review the budget and funding for specific decommissioning projects;
(j) Initiate the ongoing process of culture change and implement new work methods and philosophies.

A primary objective during the transition from facility operations through to SE or immediate dismantling is to focus on actions that cost effectively support this process. Experience has shown that a number of general tasks are appropriate during the transition period. These address non-radiological hazards, radiation fields, contamination, waste, isolation and containment, monitoring and control, refurbishment and installation, as well as documenting and labeling of components.

Most, if not all of these, apply to facilities that are currently operating, as well as to facilities that have ceased operations and are essentially locked and/or abandoned. The challenge is to identify those transition actions that are appropriate to a particular nuclear facility prior to implementing the decommissioning strategy.

# 3. PLANNING OF THE TRANSITION PERIOD

It is important to establish a project team to plan for the transition and decommissioning well in advance of the permanent shutdown. This team does not need to be large or employed full time and could also be a unit separate from the operating organization. Its technical and safety expertise should include knowledge of system reconfiguration or retirement, spent fuel and waste management, plant history, licensing and other decommissioning aspects. Standard project expertise such as cost estimation, time and work scheduling are also important.

This team may report to senior management but not be responsible for the day-to-day operations of the plant. It will be responsible for updating the decommissioning plan based on the agreed decommissioning strategy.

Typical objectives of the project team could include:

(a) Project development (time, cost and quality),
(b) Cost estimate verifications,
(c) Project risk evaluation,
(d) Plant system reconfiguration and retirement,
(e) Spent fuel management options,
(f) Waste management plans,
(g) Preparation of safety documentation,
(h) Interaction with stakeholders,
(i) Staffing plans,
(j) Specification of transition end points,
(k) Management of records,
(l) Implementation of the change management strategy.

Establishment of accurate decommissioning costs and risks provides important information for allocating and managing the decommissioning fund. The cost of a smaller project team could be considered as an investment to achieve a better managed decommissioning project.

Next section describes selected strategic issues for which pre-shutdown planning should be conducted so as to arrive at decisions on courses of action upon shutdown. This includes overall planning for the transition and implementation of the decommissioning strategy, cost reduction, waste management issues, and development of techniques and tools required for decontamination and dismantling. An example of the activities required for a specific transition to decommissioning project is given in Ref. [7], which includes licensing, engineering, implementation, staffing levels and overall organization.

## *3.1 ORGANIZATION AND MANAGEMENT DURING THE TRANSITION PERIOD*

At the start of the transition period, the organization will inevitably be that which ended the operational phase. Even in cases where a new operating organization takes over for decommissioning, it is likely that most of the operating staff will be retained and their roles will change to reflect the activities during the transition period, as depicted in Figure 1-1. It is essential that the organizational changes and plant modifications be well defined prior to permanent shutdown. It is important that these changes address roles, responsibilities and reporting lines.

Further guidance about the organizational aspects of the preparation for implementation of the decommissioning strategy can be found in Ref. [5].

## 3.2 COST REDUCTION BY MODIFICATION/RECONFIGURATION OF SYSTEMS

During the transition period, activities are planned and carried out which lead to simplified operation, reduced surveillance and maintenance requirements and lower operating costs. This can be achieved by identifying those plant systems which will become redundant after final shutdown. Further consideration should be given to systems that are needed after shutdown but which are costly to operate and maintain, e.g. the capacity of the ventilation system needed to control contamination in shut down facilities can be greatly reduced. Cost reductions will also take place as a result of changes to technical specifications as the license is amended.

Cost savings can be achieved from reductions in:

(a) Labour (direct and indirect),
(b) Power and fuel consumption,
(c) Consumables,
(d) Surveillance and maintenance,
(e) Regulatory and technical requirements including inspections,
(f) Training (regular operational training for reduced or shutdown systems),
(g) Recycling of material and components,
(h) Nuclear insurance.

Note: This order does not refer to any priority in the likelihood of the possible cost reduction magnitude.

## 3.3 DEVELOPMENT OF TECHNIQUES AND TOOLS

Decontamination and dismantling techniques and tools for nuclear facilities are widely available, as has been demonstrated by the successful completion of a large number of decommissioning projects. Most decommissioning tasks, especially concerning reactors, can be accomplished using existing techniques for which expertise is already available.

However, there may be tasks that will require the development of new techniques or the adaptation of existing techniques to specify decommissioning demands, in particular for the decommissioning of facilities with special design features, experimental and prototype facilities or those with an unusual operating history (e.g. after incidents, extensive reconstruction, etc.).

A related topic is sampling, characterization and location of contaminated materials and areas where decontamination is required in support of decommissioning. It may also be necessary to test decontamination techniques on selected areas of the plant and its components. Similarly it may be possible to measure activated samples from a reactor to validate computer estimates with actual measurements in order to optimize size reduction, waste shipping and disposal. The transition period provides the opportunity for any additional sample collection and plant characterization.

## 3.4 WASTE MANAGEMENT

Activities during the transition period have the potential to increase both the volume and the variety of wastes generated. Planning should ensure that there is sufficient capacity for the treatment of these wastes, their storage or transport and disposal. The issues that may need to be considered include:

(a) The wastes that will arise during the transition period;
(b) Wastes held in interim storage at the facility which need to be recovered for treatment, conditioning and disposal (e.g. sludge, ion exchange resins, spent radiation sources, scrap components);
(c) Long term storage requirements;

(d) Wastes from decontamination and cleanup operations (e.g. additional resins from chemical decontamination, demolition wastes, etc.);
(e) Availability of disposal routes, including transportation;
(f) Materials and equipment left over from experimental and research programs;
(g) Waste retrieval and conditioning methods;
(h) Waste characterization programs and techniques;
(i) Waste minimization programs and techniques;
(j) Clearance levels;
(k) Regulatory authorizations.

## *3.5 MANAGEMENT AND ADMINISTRATIVE ISSUES*

This section mentioning selected management and administrative issues that need to be considered during the transition period such as an inventory of hazardous material (including the radiological inventory), the purchasing and spares policy, record keeping and interaction with all relevant stakeholders in the decommissioning process, training to support the transition. These tasks may take on a high priority when the transition period is being planned.

# 4. TRANSITION PERIOD ACTVITIES

The degree to which objectives (mentioned in chapter 2) can be achieved at a facility will vary greatly depending on its function, current condition, configuration and status. High priority is to be given to actions to eliminate or mitigate hazards such as flushing of process systems, removal of waste and defueling. For other activities, a transition end point development process will ensure that the appropriate activities are identified and completed.

This section deals with actual operations that are normally carried out during the transition period. Typical transition activities are [6]:

(1) Sale, further use, recycling or dismantling of usable fissile/fertile materials.
(2) Removal of spent fuel and other fissile/fertile material from the plant.
(3) Removal of spent fuel and other fissile/fertile material from the site (if applicable).
(4) Stabilization, treatment and/or removal of potentially unstable materials or wastes.
(5) Reduction or elimination of the potential for fire or explosions from violent chemical reactions or nuclear criticality.
(6) Completion of cleanout operations of systems, lines and other equipment not needed in the future that have the potential for significant radioactive and chemical material inventory.
(7) Neutralization and disposal of hazardous chemicals and oil in storage.
(8) Review, using the safety assessment, of changes in the configuration and status of systems and structures as a result of transition activities, e.g. reducing redundancies in systems and structures.
(9) Revision of operating requirements and controls as appropriate to changed conditions; this should also include the number of personnel required to maintain the appropriate safety standards.
(10) Installation and/or verification of sufficient barriers to prevent the spread of contamination.
(11) Verification of appropriate safeguards and security.
(12) Checking and updating of relevant facility drawings and other documents to reflect changes that have been made during the operational period and/or the transition period.
(13) Training and awareness of facility staff for their future work and roles.

It is important to ensure that the above activities are carried out using trained personnel, with appropriate approved procedures and all engineered safety features in place.

## *4.1 REMOVAL OF SPENT FUEL*

Experience has shown that the removal of spent fuel is a crucial step in the decommissioning of reactors. The preferred solution is the early removal of the spent fuel to a storage facility, to a reprocessing plant or to a disposal facility.

Benefits of early defueling include decreased radiological hazards, timely implementation of dismantling, downgrading of the operating license, shutdown of some systems (e.g. cooling water, surveillance), and reduced safeguards requirements. In addition, as long as fuel remains in the fuel storage pools, continuous manning of the unit with shift workers may be required, albeit with a reduced number. If consideration is given to adopting shorter refueling cycles towards the end of the plant’s life, the period required for cooling the fuel in the fuel storage pool is reduced. Thus the pool can be emptied earlier than would otherwise be the case, reducing costs.

As long as all infrastructure and provisions are in place, defueling can be done as during plant operation. However, if removal of the fuel is delayed for a very long time, loss of qualified staff and necessary equipment could become a problem.

In addition to the removal of nuclear fuel it is very desirable to eliminate the possibility of criticality during the transition period. If the spent fuel and other nuclear materials cannot be moved outside the nuclear installation, decommissioning cannot be fully completed.

## *4.2 SYSTEM CLEANOUT OPERATION*

It is essential that process and auxiliary fluids from redundant systems be removed and disposed of while personnel are available who are trained and qualified to operate that equipment. After removal, the systems should be flushed until residual contamination is below predetermined criteria and dried as appropriate.

Experienced personnel are also needed to deal with radioactively or chemically contaminated solids. This is particularly important when the handling equipment is immediately available. Important examples are materials remaining in hot cells that have working manipulators, materials in storage that require such hot cells for handling, items that are in ponds for shielding reasons, and alpha emitting items that require glove-box handling.

It is also important that such operations are not unduly postponed even when handling equipment is not immediately available or not working. In such cases, devising alternate removal means during the transition period is a priority.

Organic fluids or hazardous chemicals used during operation, e.g. lubricants, hydraulic oil, acids, etc. are removed and disposed of during the transition period. Radioactively contaminated organic and flammable fluids, as well as non-radioactive hazardous fluids (e.g. PCB transformer oil) or solids (e.g. asbestos) will require special disposal procedures.

## *4.3 TREATMENT, CONDITIONING, STORAGE AND/OR DISPOSAL OF WASTE DURING THE TRANSITION PERIOD*

Most wastes generated during the transition period are similar in nature to those produced during plant operation and maintenance (spent decontamination solutions, combustible waste – personal protective means, protective clothing etc.) [8]. The amount of work to be undertaken will depend on the operations that were carried out within the facility and the nature of the hazardous inventory associated with the process, that is radiological, toxic or non-hazardous.

Such removal or reduction is important for the transition period although historically this has frequently been delayed until the start of dismantling. Methods for assessing the overall requirements for cleanout, both in terms of the need for and extent of such operations, are given in Ref. [9].

At final plant shutdown, all waste remaining from past activities is commonly removed from the plant for treatment, conditioning, packaging and storage or disposal.

## *4.4 DECONTAMINATION OR FIXING OF CONTAMINATION*

Decontamination after the end of operation will help to reduce occupational exposure during future decommissioning activities. Decontamination will be necessary in the circuits, tanks and containers to remove the activity from inner surfaces, as well as on the surfaces of components and buildings to reduce the potential for airborne contamination. Fixing activity on accessible surfaces may be a viable alternative to its removal. However, implications for eventual dismantling and handling of such material require special consideration and specific recording.

In general, decontamination that is carried out during the transition period is primarily aimed at dose reduction and is not intended for material clearance. Aggressive decontamination methods can often be applied where the systems are no longer needed for operation.

The decision whether to decontaminate a nuclear facility (or parts of it) will in general depend on the type of plant, the radionuclide vector/inventory and other constraints such as:

(a) The decommissioning strategy selected;
(b) The time available;
(c) The availability of funds;
(d) Individual and collective doses to workers;
(e) Liquid and airborne discharges and their radiological impact on the general public and the environment;
(f) Industrial safety requirements;
(g) Available waste management and disposal options;
(h) Workforce availability, including contractors;
(i) Reuse of the buildings for other purposes.

Within established constraints, the optimal decision will in general be based on a multiattribute analysis or cost–benefit analysis [10], [11].

If SE is planned, decontamination will be considered primarily for the areas that will be accessed during the transition period. An alternative in some cases may be to fix contamination in place to reduce airborne resuspension and facilitate access. However, it is important that surface coatings do not overly complicate future decontamination and measurement.

System decontamination may be performed on radioactive systems in order to reduce the general activity level within the systems in preparation for work during the transition period. System decontamination should be carried out while qualified personnel with knowledge of the relevant systems are still available.

Experience with system decontamination has been favourable for both typical BWR and PWR oxides [12]. In addition, more efficient methods with easier to handle final products are constantly being developed.

## *4.5 CHARACTERIZATION AND INVENTORY OF RADIOACTIVE AND HAZARDOUS MATERIALS*

The characterization and establishment of an inventory of radioactive and hazardous materials within the facility involves surveys of existing data, calculations, in situ (at site) measurements and/or sampling and analysis. A database can then be established which will provide significant input into the decommissioning planning process and the development of successful implementation plans.

At the beginning of the transition period, sufficient information should be collected to assess the radiological status of the facility and the nature and extent of any other hazardous materials present.

As work progresses during the transition period, the objectives of characterization move towards developing more detailed data concerning the physical, chemical and radiological conditions of the facility, including contaminated land. This will include activation calculations, taking and analyzing of samples, as well as in situ measurements of dose rates and contamination to fill the gaps in the available information.

Information gathered during these phases serves as the technical basis for work and project decisions, including cost estimates, exposure estimates, risk evaluation, waste management, scheduling and workforce requirements, particularly with respect to radiological exposures.

Since characterization requires time, money, work in an appropriate pace and dose commitment, it should be optimized to meet the above objectives. Further guidance can be found in Ref. [13].

## 4.6 CONSIDERATION OF SYSTEMS

Decisions on which systems must remain functional should be made during the planning of the transition and are based on:

(a) An evaluation to ensure that safety requirements will continue to be met,
(b) Support of human entry or occupancy for surveillance and maintenance,
(c) Possible use during future phases of decommissioning,
(d) Restrictions posed by the current operating license.

Some considerations may require cost–benefit analysis of:

(1) Energy consumption, surveillance and maintenance requirements;
(2) Replacement of complex systems with simpler ones;
(3) The possible need to achieve a safer state;
(4) A diminished need for redundancy;
(5) Operational and structural reliability over the anticipated duration of transition and SE;
(6) Demolition of buildings (after their clearance) that contain systems or components which must be moved elsewhere.

During planning of the transition period, decisions regarding systems and major equipment within a facility may need to consider the following options:

(i) Operable as is: Systems that must remain operable and do not require modification for example, lighting where surveillance and maintenance is to be done.
(ii) Modified: Some systems will need to remain operable but, as a result of the above assessments, modifications are required.
(iii) Preserved for future use: A limited number of systems and equipment may be preserved for the future. For example, installed manipulators and cranes can be of use during dismantling, or radioactive waste treatment systems may be valuable for processing decontamination solutions.
(iv) New: In some cases system functions will be needed, but use of the installed system may not be feasible because it may be overly complex, be over capacity, have high levels of contamination, or entail difficulty of access for operation or maintenance. Installation of a new ventilation system is a typical example.
(v) Permanently shutdown: In many cases, a large number of systems will no longer be needed. In such situations, they are generally left in place and suitably isolated using standard safety practices, especially where there is internal radiological or hazardous chemical contamination or, in the case of electrical systems, the potential for short circuits or high voltage shocks.

## 4.7 PREPARATION OF A FACILITY'S ROOMS AND BUILDINGS

During the transition period, access to rooms and buildings in a facility needs to be defined in at least three ways: routine access, no access and completely isolated.

(a) Routine access: Human access for surveillance and/or maintenance can be as frequent as daily or as infrequent as, say, every three months.
(b) No access anticipated: Access will not be required, or if so the need will be so infrequent that special entry procedures can be established.
(c) Isolated: Entry will not be required until demolition begins.

Decisions as to the type of access needed to specific rooms and buildings are closely tied to an evaluation of the surveillance and maintenance requirements. When the surveillance and maintenance routines are determined and the access requirements are decided on, the results will be important inputs to creating the transition end point specifications. This process may include significant modifications to building access and other infrastructure in preparation for decommissioning. A detailed example is given in Ref. [14].

## 4.8 PROTECTION FROM EXTERNAL OR INTERNAL EVENTS

A number of external or internal events may affect a facility. For example, a fire prevention strategy is intended to eliminate fire hazards to the greatest possible extent. Some likely problem areas may include oils and grease in systems and components which, although emptied and flushed, may still contain residual material. Maintenance of good housekeeping standards and emergency access routes are key features in the implementation of such a strategy.

Flood protection may be a concern after shutdown, depending on the geographical location and the climate, geology and hydrology of the area. Some areas may require sealing or the maintenance of active collection, detection and pumping systems.

## 4.9 REMOVAL OF MINOR COMPONENTS

Generally, no major dismantling of radioactive parts of a plant takes place during the transition period, depending on the licensing regime.

Examples of decommissioning activities which are considered minor are:

(a) Normal maintenance and repair;
(b) Removal of certain, relatively small radioactive components such as control rod drive mechanisms, pumps, piping and valves;
(c) Removal of components similar to those normally removed for maintenance and repair during plant operations other than those defined above as major components;
(d) Removal of non-radioactive components and structures not required for safety. This can entail significant amounts of work and include major non-radioactive components such as cooling towers, transformers and control panels.

During the transition period, removal of readily movable equipment which is no longer needed can be considered. These items are either:

(1) Packaged and disposed of;
(2) Packaged after compaction and disposed of;
(3) Decontaminated e.g. by steam blaster or high pressure water jet;
(4) Directly released without treatment.

# 5. COST OF TRANSITION ACTIVITIES

The chapter presents the short review of general methods for decommissioning costing and application of these methods for activities of the transition period.

## *5.1 REVIEW OF METHODS FOR DECOMMISSIONING COSTING*

### *A) Purpose and principles of current cost estimating methods*

Estimating of costs and other decommissioning parameters is one of the main issues in preparatory phases of decommissioning with the aim to prepare files of qualified data (costs, exposure, amount of waste, manpower, personnel, equipment needed for performing the decommissioning activities, consumption items, etc.).

The decommissioning cost estimation is based on the decommissioning plan which includes all activities, reaching from the planning and transition (from operation to shutdown) phases, performing the decontamination, dismantling and management of resulting waste up to the final remediation of the site. The plan includes also all supporting activities like management of the project, maintenance, surveillance, physical protection, research and development etc. The decommissioning plan should be properly phased. A well elaborated decommissioning plan is an inevitable prerequisite for accurate decommissioning cost estimation.

Practical costing is carried out by identifying all work activities together with their associated material, equipment and service requirements. Subsequently, an estimation is made of the costs arising from each activity, which is subdivided into a series of discrete and measurable elementary work activities. If for some work activities only limited experience is available, preparing the cost estimate includes a phase by phase review of the required data and adequate engineering judgment is needed in order to assess manpower requirements, work efficiencies and time schedules. Following basic steps can be recognised in current decommissioning costs estimation methods:

### *B) Definition of cost categories*

In major decommissioning projects, costs are classified into three categories:

- <u>Activity-dependent costs</u>, which are directly related to the extent of "hands-on" work involved in decommissioning. They include activities such as decontamination, removal of components, packaging, shipping and disposal of wastes, etc. Costs arise from labour, materials, energy, equipment and services.
- <u>Period-dependent costs,</u> which are proportional to the duration of individual activities or to the duration of the entire project. They arise from project management, administration, routine maintenance, radiological, environmental and industrial safety and security activities. These costs are often fairly independent of the exact level of the hands-on activities that are concurrently going on.
- <u>Collateral costs</u> and costs for special items which can neither be assigned to a certain work activity nor to a period-dependent activity. If equipment is used to support many distinct activities, the purchase or the rent of this equipment, as an example, may belong to this category.

### *C) Identification of decommissioning activities and inventories*

In the unit cost factor approach, the decommissioning plan must be developed in terms of discrete basic activities for which unit costs are defined. The list of activities must be completed with a plant buildings and equipment inventory in order to define the extent of each activity. As an example, such an inventory should include the total quantity of piping categorised by size and radiological parameters, the number of pumps, valves and other components, each classified by size and radiological parameters, the amount of concrete classified based on the size and the density of the reinforcing steel, etc. The interaction of the list of decommissioning activities with the list of inventories generates the required extent of calculation structure.

### *D) Definition of Unit Cost Factors*

Unit cost factors are defined in accordance to the detail of the items considered in the plant inventory and in the activity listing of the decommissioning project. As an example, unit cost factors may be defined for cutting a unit length of pipe of a certain size. The approach consists in developing the basic unit cost factors for ideal conditions, e.g., cutting a non-contaminated pipe at a worker's waist height without any risk of radiation exposure. Separately, the various coefficients or correction factors are assessed that reflect the specific working conditions. Basic unit cost factors incorporate the requirement for labour hours per unit activity (under ideal conditions) and the local expenses related to labour per work hour, taking into account the different worker and craft categories.

Various coefficients or correction factors may be considered for, e.g., working height, need for protective equipment (respirators, protective clothing), radiation levels (ALARA principle), work breaks and other productivity losses. In addition, the final value of a unit cost factor may be corrected to include material and equipment costs whenever these are directly proportional to the extent of work. Unit cost factors for waste disposal may be given per unit volume of packaged waste of each type.

### *E) Project Schedule and Staff Requirements*

Based on the plant inventory and unit factors approach, the duration of individual work phases in a decommissioning project may be calculated. The overall project duration is defined by those activities that are on the critical path. An activity is considered to be on the critical path if start-up or continuation of all other remaining tasks depends on completion of this activity. As such, a time schedule may be produced for different phases of the decommissioning project as well as for the entire project. This schedule may be used as a basis for estimating the period-dependent decommissioning costs.

An additional estimate is required to define the size of the staff involved in management, administration and other supporting activities. The relation between period-dependent costs and activity-dependent costs may give rise to a need for optimisation. The project duration may often be reduced by increasing the size of the crew for activities on the critical path. Moreover, if major parts of the decommissioning activities are subdivided into well-defined work packages that may be implemented by subcontractors, the owner's staff requirements may be limited during these decommissioning stages.

### *F) Collateral Costs and Costs for Special Items*

Some costs may be dependent neither on the level of activities, nor on the duration of the project. For this reason, they are considered as a separate cost category, i.e., collateral costs and costs for special items, such as the costs for heavy equipment for site support, small tools, nuclear liabilities insurances, etc.. Although at least a part of the energy requirement is proportional to the duration of some project phases, energy costs such as costs for lighting, heating or cooling may also be included in this cost category. For some parts of the equipment removed, a scrap or salvage value could be considered.

### *G) Total Costs and allocation of contingency*

At the end, the total cost estimate is obtained as a sum of the costs estimated in the three categories. In general, the activity-dependent costs are calculated on the basis of activity lists, plant inventories and unit cost factors. The period-dependent costs are calculated on the basis of estimates, project schedules and staff requirements, while the collateral costs are assessed separately for each item.

Before summing up the cost on the level of each elementary cost items, a contingency is included that reflects the level of uncertainty in the cost estimates. Proper adjusting of contingency is very important. Normally, the general contingency reaches from 30% at the level preliminary plans to 5-10% at the level of detailed decommissioning plans. Contingency for various items may vary significantly. Special contingency items are defined in the standardized cost structure for most uncertain activities, the items in 11.0700 category.

***H) Standardisation in decommissioning costing***

Generally, the decommissioning costs for different decommissioning projects had and still have country specific costs structure. Comparisons of individual cost estimates for specific facilities, in order to ensure whether the calculated costs fit with other comparable plants and decommissioning options, show relatively large variations. Difficulties of understanding of differences can be encountered and invalid conclusions drawn in making cost comparisons without regard to the content of individual cost items and context to cost estimates methods. Well structured and defined general structure of cost items and cost estimation method could facilitate the harmonisation in decommissioning costing. Such a structure was developed by OECD/NEA and was published in 1999 by OECD/NEA, IAEA and EU [15]. The document defines the structure of decommissioning activities, including the activities of the transition period, for which the costs are to be presented. Four cost groups should be presented for each cost item:

- Labour cost
- Investment cost
- Expenses
- Contingency

Such a structure is useful not only for project cost comparisons for various decommissioning projects, but also as a tool for a more effective cost management. This document should be of world wide interests to all decommissioners in order to create a common platform for decommissioning costing.

## *5.2 METHODS FOR COST ESTIMATION OF ACTIVITIES OF THE TRANSITION PERIOD*

The chapter presents the classification of activities of the transition period with general characters and activities which are specific for the period between the shutdown and start of decommissioning (group 2 of the cost standardized structure [15]) and the methods for cost estimation.

The costs for activities within the transition period should be clearly allocated to the operational or decommissioning costs in order to establish an unambiguous boundary between this two sources of funding. The allocation of cost for individual items of the transition period is country or project specific and therefore the application of standardized list of cost items will facilitate the identification of cost items and also cost comparison between various decommissioning projects.

### 5.2.1 General classification of activities of the transition period

**PRINCIPLES OF CALCULATION OF DECOMMISSIONING PARAMETERS**

The general classification of cost categories as defined in chapter 5.1, par. B), refers to types of decommissioning activities from the point of view of methods for calculation of costs and also type of input data needed for calculation of costs and other decommissioning parameters. The methods for calculation of decommissioning parameters for the activities of the two main cost categories are following:

***Activity-dependent cost:***

The calculation formulas for this cost category may differ, but in principle the formulas is following:

$$y = UF * x * CF \qquad (5.1)$$

y - calculated decommissioning parameter

UF - unit factor specific for the calculated item (specific value per specific input variable value)

x - input variable (mass, length, area, number of pc., etc.)

CF - correction factor which defines extended effort for performing the activity under non-ideal conditions

Simple calculation formulas calculate the cost directly, under the assumption that the unit factor UF is the cost unit factor which covers all cost involved in calculated decommissioning activity. The calculated cost do not correspond to the structure of cost groups as defined in chapter 5.1, par. H).

The calculation approach which calculate the cost according cost groups as defined in chapter 5.1, par. H), calculate in the first step the manpower needed for performing the given activity. Based on composition of the working group, the elements of manpower relevant for professions of the working group, are calculated. Finally, based on labor cost per professions, the total labor cost are calculated for the whole working group.

The investment costs, if they are identified for the calculated decommissioning activity, are normally included as a fixed cost item, or they can be calculated proportionally using the formula 5.1 and the unit factor specific for investment cost.

The expenses are calculated for individual consumption items like electricity, water, stem, cement, etc., based on individual consumption unit factors for the given decommissioning activity. Total expenses is the sum of all elementary consumption items.

The contingency for the calculated elementary decommissioning activity is calculated as percentage (chapter 5.1, par. G) from the sum of labour cost, investment cost and expenses for the calculated decommissioning activity. The contingency can be adjusted individually for the calculated item, if there are specific uncertainties.

The input variables are organised in the inventory database. Using this analytical approach, it is possible to calculate the items of cost groups as defined in chap.5.1, par. H per each elementary decommissioning activity.

***Period-dependent cost:***

The calculation formulas for this cost category is in principle following:

$$y = UF * T \qquad (5.2)$$

y - calculated decommissioning parameter

UF - unit factor specific for the calculated item

T - input variable, duration of calculated decommissioning activity

The labour cost is calculated per of each profession of the working group, UF being the specific labour parameters per profession. The investment cost and expenses are calculated in the same manner, using relevant specific unit factors or are included ad foxed cost items. The contingency is calculated like for the activity dependent cost. The input variables are the durations of individual elementary decommissioning activities

**CLASSIFICATION OF ACTIVITIES OF THE TRANSITION PERIOD**

The standardised list of decommissioning activities [15] includes also the activities of the transition period. During development of the document [1], it was discussed which activities from the standardised list of cost items could be allocated to the transition period. The result of the discussion is presented in [1] and in this document it is presented in Appendix 1. According the Appendix 1, following main groups of activities can be identified as relevant for the transition period:

(a) Pre-decommissioning actions, e.g. decommissioning planning;
(b) Facility shutdown activities, e.g. removal of the spent fuel, system reconfiguration and retirement, decontamination and immobilization of residual contamination;
(c) (Limited) procurement of equipment and materials;
(d) (Limited) dismantling activities and characterization of radioactive inventory;
(e) Waste processing, storage and disposal (including hazardous waste);
(f) Site security, surveillance and maintenance;

(g) Transition project management;
(h) Other costs, including asset recovery.

Based on principles of calculation of decommissioning parameters, the activities listed above can be identified mostly as period-dependent types. Only the activities (d) and (e) are of activity-dependent type, for which the physical inventory should be available.

For calculation of cost and other parameters of transition period activities, following main data should be available:

- Parameters of the working groups and parameters of professions in the working groups
- Unit factors specific for elementary decommissioning activities calculated
- Physical inventory data for calculation of activity-dependent cost categories
- Duration of elementary activities for calculation of period-dependent cost categories

It is evident from the above listed principles and classification of decommissioning activities of the transition period, that the work breakdown structure and time schedule of the decommissioning project is needed in order to calculate the parameters of the transition activities.

Most typical and also most expensive activities of the transition period are the activities of group 2 which refers to the period between the shutdown and obtaining the license for decommissioning and activities of the group 5 which refers to management of the operational waste. Mainly these activities contribute to the required final state at the end of the transition period which can be defined as:

- Spent fuel removed from the plant
- Operational waste removed from the plant, treated, conditioned and disposed
- Operational media removed from the plant, treated, conditioned and disposed
- Primary and auxiliary systems used in operation are empty, decontaminated using the procedures from the operational period, and systems are dried

As can be seen in Appendix, the activities in the groups other then the group 2 and 5, can be calculated using the above principles for period dependent cost or activity dependent cost.

For activities of the group 2 and 5 some specific procedures are applied which are described in chapter 5.2.2.

### 5.2.2 Procedure for cost evaluation of specific activities of the transition period

As presented at the end of chapter 5.2.1, the most important activities needed for achieving the required state at the end of the transition period are:

- Cooling down the spent fuel
- Shutdown of operational systems
- Modification of facility systems
- Management of operational waste
- Other activities

**COOLING DOWN THE SPENT FUEL**

Normally, the spent fuel in a nuclear power plant is after the shutdown transported to the spent fuel pond in the vicinity of the reactor, accessible from the reactor hall. In this pond the spent fuel is cooled down in order to reach the parameters (heat generation rate) required for long-term storing. The duration of the cooling down period is dependent of the type of interim spent fuel store. For wet type store, the period of 3 years is sufficient, for dry interim spent fuel store of cask type, the period is five years. During this period the system are in operation comparable to normal operation in order to guarantee the nuclear safety. The number of personnel is also comparable with the normal operation phase.

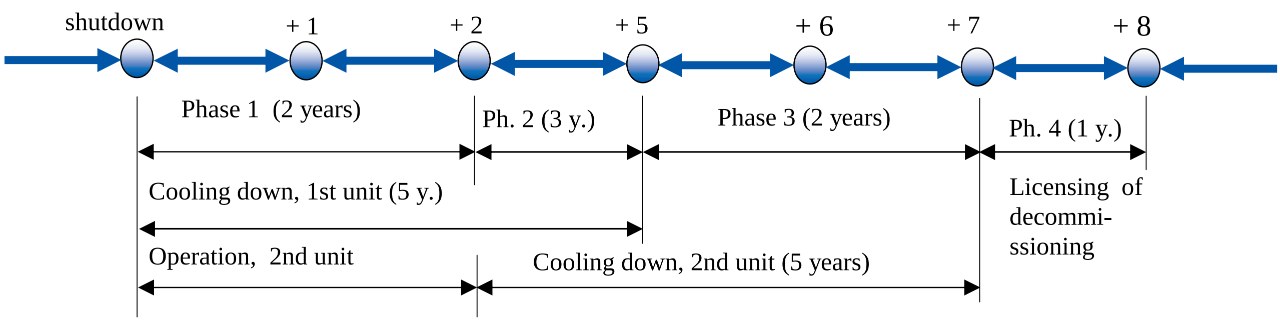
The phase of cooling down the spent fuel can be complex one in the case when the NPP involves two or more reactors within one reactor building and when the reactors are not shutdown at the same date. Example of this are the NPP's of VVER-440 type of Russian provenience. It is twin system with two reactors where the supporting operational system have mutual back-up. Normally the shutdown is organized in a sequence of one or two years and when taking into account the duration of cooling of the spent fuel, the minimal duration of the transition period for twin NPP with sequence of two years is five years for the wet interim spent fuel and seven years for dry store (Figure 5-1).

Cost estimate for the cooling down period has then following steps:

- Identification of phases of cooling down period
- Identification of annual personnel requirements for each phase (number of personnel, professions)
- Identification of annual requirements for operation of systems, maintenance, services, media and other consumables needed for each phase
- Identification of investment cost for each phase

The cost is the sum of annual cost for each year calculated for period-dependent costs according the principles presented in chapter 5.2.1. In the boundaries between the individual phases, the technological systems which are not more used, are reduced or shutdown and isolated. The cost for this activities are calculated separately.

Figure 5-1 Example of phases of transition period for a twin NPP, sequence of shutdown 2 years, spent fuel will be transported to dry interim spent fuel store




**PRIMARY CIRCUIT SYSTEMS AND AUXILIARY OPERATIONAL SYSTEMS**

The primary circuit systems are after shutdown decontaminated u using the procedures like in operation, but using more aggressive media. Normally the decontamination is organised by creating several autonomous circuits for circulating the decontamination solvents in the decontamination circuit and subsequent rinsing of flushing the autonomous circuit with water or surface stabilisation solvents. The procedure for cost estimate is following:

- Identification of number of autonomous circuits
- Identification of duration of preparatory, decontamination and finishing phase for each circuit
- Identification of personnel
- Identification of consumables and investment for processes

The total cost is the sum for individual phases and individual circuits, calculated as period-dependent activities.

After the decontamination the systems are dried or blow-down in order to reach the state dry and decontaminated. Prior to these activities, the systems are drained and the system fluids are treated. At the end, the radiological characterisation of the final state in systems is performed by in situ measurement and by sampling.

The procedure for cost estimate is evaluation of activities system by system, using the approach for evaluating the period dependent activities, i.e. collecting or developing the input data, estimation of duration, calculation of period-dependent cost.

**FACILITY SYSTEMS**

During the operation, there are several groups of supporting systems which are needed for standard operation like:

- Control and information systems
- Ventilation
- Radiation monitoring
- Supply of electricity
- Supply of water
- Transporting devices, lifts,..
- Others

These systems are needed during the transition period in reduced extent dependent on the phases of the transition period. The costs are calculated systems by system for operation in individual phases of the transition period and for reduction or modification of systems in the boundaries between phases. The final state of these systems is the extent needed for the decommissioning phase.

**MANAGEMENT OF OPERATIONAL WASTE**

The operational waste are waste from the operational phase and waste from the transition period. The wastes are treated continuously or in some facilities are only stored. At the end of the transition period, all operational waste should be processed. The procedure for cost estimate for management of operational waste has following steps:

- Identification of all historical non-treated waste at the NPP and the categories of wastes
- Identification of inventory of waste generated during the drainage and decontamination of systems
- Estimation of other wastes generated during the transition period
- Collection of unit factors for processing of types of identified wastes, up to the state of theirs disposal
- Calculation of costs based on inventories of wastes and unit factors for individual types of wastes

# 6. SUMMARY

In this paper, the transition period, i.e. the period between the permanent shutdown and the start of the licensed decommissioning, has been described. During the transition period series of changes, modifications and adaptations of existing technological systems together with organizational aspects are needed to be performed within the facility to meet its new objectives and requirements. The transition phase from operation to decommissioning has to include the technical, management and organizational issues to provide a minimization of time-delays and undue costs, requalification of personnel, optimization of resources, and initiation and partial realization of preparatory activities for decommissioning.

The transition phase may vary due to site specific condition, which e.g. demonstrates that all calculations of expected future costs must also be linked to the specific site concerning the transition phase.

It is envisaged from empirical observations that the process, in total, can take from five – eight years up to tens of years. The phase of cooling down the spent fuel can be complex one in the case when the NPP involves two or more reactors within one reactor building and when the reactors are not shutdown at the same date. Example of this are the NPP's of VVER-440 type of Russian provenience. This is a twin system of two reactors where the supporting operational system have mutual back-up. Normally the shutdown is organized in a sequence of one or two years. Taking into account a duration of cooling of the spent fuel, the minimal duration of the transition period for the twin NPP with sequence of two years is five years for the wet interim spent fuel store and seven years for the dry one. The longer the transition period is, the more local knowledge, experiences and personnel may be lost. The proper definition of specific organization during transition period is considered to be vital.

The most important work to be done is the preparation for the decommissioning where the licensing procedure may be both difficult and time-consuming. Another vital task is to create an effective and thrust worthy communication process with the local citizens as well as other stake-holders. This process must be compliant with the environmental legal frame. The EU companies have to put all environmental liabilities into the annual accounts according to the IAS (International Accounting Standards). Therefore, it seems to be appropriate to adopt accounting system with respect to the Proposed Standardized List structure shown in Appendix 1.

The regular recalculations of the future expected cost for the transition period as well as the whole decommissioning process has to be done. The process is done in five year period basis. This demand comes from the European Commission recommendation dated 26/10/2006. The calculations has to reflect timely and cost effective manner of planned decommissioning process.

# APPENDIX 1 - STANDARDIZED COST ITEMS FOR DECOMMISSIONING PROJECTS [15]

Actions relevant to the transition phase appear in red colors; actions partly or possibly relevant to it are in blue color, and actions not relevant to transition appear in grey color.

**01 PRE-DECOMMISSIONING ACTIONS**

01.0100 Decommissioning planning
01.0200 Authorization
01.0300 Radiological surveys for planning and licensing
01.0400 Hazardous material surveys and analysis
01.0500 Prime contracting selection

**02 FACILITY SHUTDOWN ACTIVITIES**

02.0100 Plant shutdown and inspection
02.0200 Removal of fuel and/or nuclear materials
02.0300 Drainage and drying or blowdown of all systems not in operation
02.0400 Sampling for radiological inventory characterization after plant shutdown, defuelling and drainage and drying or blowdown of systems
02.0500 Removal of system fluids (water, oils, etc.)
02.0600 Removal of special system fluids ($D_2O$, sodium, etc.)
02.0700 Decontamination of systems for dose reduction
02.0800 Removal of waste from decontamination
02.0900 Removal of combustible material
02.1000 Removal of spent resins
02.1100 Removal of other waste from facility operations
02.1200 Isolation of power equipment
02.1300 Asset recovery: resale/transfer of facility equipment and components as well as surplus inventory to other licensed (contaminated) and unlicensed (non-contaminated) facilities

**03 PROCUREMENT OF GENERAL EQUIPMENT AND MATERIAL**

03.0100 General site dismantling equipment
03.0200 General equipment for personnel/tooling decontamination
03.0300 General radiation protection and health physics equipment
03.0400 General security and maintenance equipment for long term storage

**04 DISMANTLING ACTIVITIES**

04.0100 Decontamination of areas and equipment in buildings to facilitate dismantling
04.0200 Drainage of spent fuel pool and decontamination of linings
04.0300 Preparation for dormancy
04.0400 Dismantling and transfer of contaminated equipment and material to the containment structure for long term storage
04.0500 Sampling for radiological inventory characterization in the installations after zoning and in view of dormancy

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| 04.0600 | Site reconfiguration, isolating and securing structures |
| 04.0700 | Facility (controlled area) hardening, isolation or entombment |
| 04.0800 | Radiological inventory characterization for decommissioning and decontamination |
| 04.0900 | Preparation of temporary waste storage area |
| 04.1000 | Removal of fuel handling equipment |
| 04.1100 | Design, procurement and testing of special tooling/equipment for remote dismantling |
| 04.1200 | Dismantling operations on reactor vessel and internals |
| 04.1300 | Removal of primary and auxiliary systems |
| 04.1400 | Removal of biological/thermal shield |
| 04.1500 | Removal of other material/equipment from the containment structure and all other facilities, or removal of entire contaminated facilities |
| 04.1600 | Removal and disposal of asbestos |
| 04.1700 | Removal of pool linings |
| 04.1800 | Building decontamination |
| 04.1900 | Environmental cleanup |
| 04.2000 | Final radioactivity survey |
| 04.2100 | Characterization of radioactive materials |
| 04.2200 | Decontamination for recycling and reuse |
| 04.2300 | Personnel training |
| 04.2400 | Asset recovery: Sale/transfer of metal or materials, and salvaged equipment or components for recycling or reuse |

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| **05** | **WASTE PROCESSING, STORAGE AND DISPOSAL** |
| 05.0100 | Waste processing, storage and disposal safety analysis |
| 05.0200 | Waste transport feasibility studies |
| 05.0300 | Special permits, packaging and transport requirements |
| 05.0400 | Processing of system fluids (water, oils, etc.) from facility operations |
| 05.0500 | Processing of special system fluids ($D_2O$, sodium, etc.) from facility operations |
| 05.0600 | Processing of waste from decontamination during facility operations |
| 05.0700 | Processing of combustible material from facility operations |
| 05.0800 | Processing of spent resins from facility operations |
| 05.0900 | Processing of other nuclear and hazardous materials from facility operations |
| 05.1000 | Storage of waste from facility operations |
| 05.1100 | Disposal of waste from facility operations |
| 05.1200 | Processing of decommissioning waste |
| 05.1300 | Packaging of decommissioning waste |
| 05.1400 | Transport of decommissioning waste |
| 05.1500 | Storage of decommissioning waste |
| 05.1600 | Disposal of decommissioning waste |

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| **06** | **SITE SECURITY, SURVEILLANCE AND MAINTENANCE** |
| 06.0100 | Site security operation and surveillance |
| 06.0200 | Inspection and maintenance of buildings and systems in operation |
| 06.0300 | Site upkeep |
| 06.0400 | Energy and water |
| 06.0500 | Periodic radiation and environmental survey |

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| **07** | **SITE RESTORATION, CLEANUP AND LANDSCAPING** |
| 07.0100 | Demolition or restoration of buildings |
| 07.0200 | Final cleanup and landscaping |
| 07.0300 | Independent compliance verification with cleanup and/or site reuse standards |
| 07.0400 | Perpetual funding/surveillance for limited or restricted release of property |
| **08** | **PROJECT MANAGEMENT, ENGINEERING AND SITE SUPPORT** |
| 08.0100 | Mobilization and preparatory work |
| 08.0200 | Project management and engineering services |
| 08.0300 | Public relations |
| 08.0400 | Support services |
| 08.0500 | Health and safety |
| 08.0600 | Demobilization |
| **09** | **RESEARCH AND DEVELOPMENT** |
| 09.0100 | Research and development of decontamination, radiation measurement and dismantling processes, tools and equipment |
| 09.0200 | Simulation of complicated work on model |
| **10** | **FUEL AND NUCLEAR MATERIAL** |
| 10.0100 | Transfer of fuel or nuclear material from the facility or from temporary storage to intermediate storage |
| 10.0200 | Intermediate storage |
| 10.0300 | Dismantling/disposal of the temporary storage facility |
| 10.0400 | Preparation of transfer of fuel or nuclear material from intermediate storage to final disposition |
| 10.0500 | Dismantling/disposal of intermediate storage facility |
| **11** | **OTHER COSTS** |
| 11.0100 | Owner costs |
| 11.0200 | General, overall (not specific) consulting costs |
| 11.0300 | General, overall (not specific) regulatory fees, inspections, certifications, reviews, etc. |
| 11.0400 | Taxes |
| 11.0500 | Insurance |
| 11.0600 | Overheads and general administration |
| 11.0700 | Contingency |
| 11.0800 | Interest on borrowed money |
| 11.900 | Asset recovery: Resale/transfer of general equipment and material. |

# APPENDIX 2 - RELATED IAEA DOCUMENTS

**DECOMMISSIONING TECHNIQUES FOR RESEARCH REACTORS, TECHNICAL REPORTS SERIES NO. 373, IAEA, VIENNA (1994)**

This is the first report published by the IAEA which provides guidance on the preparation and implementation of the decommissioning of different types of research reactor. Different construction and operational features of research reactors have a major impact on the decommissioning techniques required. This report offers information on the conclusions drawn from a number of completed projects and identifies their similarities and differences. It is complemented by a computerized research reactor databank. Staff requirements, decommissioning costs waste activity are presented graphically according to reactor thermal power and integrated energy.

Contents: 1. Introduction; 2. Classification of research reactors; 3. Responsibilities and stages of decommissioning; 4. Planning and management of decommissioning; 5. Regulatory aspects; 6. Technical aspects applicable to all types of research reactor; 7. Considerations specific to different types of research reactor; 8. Safety aspects; 9. Waste management; 10. Quality assurance; 11. Summary and conclusions; Appendix I: Reported research reactor decommissioning projects; Appendix II: Detailed data from research reactor decommissioning projects; Appendix III: Examples of the lessons learned from research reactor decommissioning projects.

**STATE-OF-THE-ART TECHNOLOGY FOR DECONTAMINATION AND DISMANTLING OF NUCLEAR FACILITIES, TECHNICAL REPORTS SERIES NO. 395, IAEA, VIENNA (1999)**

This publication initially discusses those factors important in the selection of a decommissioning strategy and which have an impact on planning and implementing decommissioning technologies (Section 4). These factors include national policies and regulations, cost estimation and funding, planning and management of a decommissioning project, radioactive waste classification and facilitation techniques for decommissioning. Section 5 discusses the impact that safety and radiation protection requirements have on the planning and implementation of decommissioning technologies. Methods and technologies for decommissioning, including decontamination, dismantling, waste management, robotics and remote operation, long term integrity of buildings and systems and other miscellaneous aspects, are described in detail in Section 6. Also, the reader is given a general orientation on where to find descriptions of techniques matching specific applications. Section 7 describes the general lessons learned from decommissioning experience worldwide. Conclusions are given in Section 8. In the Appendix to the report, case histories and specific lessons learned are provided. The report is complemented with an extensive set of references.

**THE DECOMMISSIONING OF WWER TYPE NUCLEAR POWER PLANTS, IAEA-TECDOC-1133, VIENNA (2000)**

This TECDOC covers all decommissioning activities beginning with the permanent shutdown of a reactor and ending with site release/reuse. Although defuelling and removal of spent fuel from the reactor building/site are not considered in many Member States to be part of decommissioning, these activities have been addressed in this publication taking into account their importance to determine strategy, timing and scheduling of decommissioning. Similar considerations apply to other pre-decommissioning activities such as removal of operational wastes from the site. Preparatory activities such as evaluating social aspects, establishing infrastructures, conducting radiological characterization or decommissioning planning are also important parts of this publication.

Following introductory sections on background and mechanisms of the regional project (Sections 1 and 2), and objectives and scope (Section 3), this TECDOC describes the decommissioning process and provides generic guidance on factors important for the decommissioning of nuclear reactors (Section 4). Section 5 gives guidance on the planning and implementation of decommissioning projects, with a focus on organizational aspects.

Section 6 deals with factors relevant to the selection of a decommissioning strategy for WWERs and gives examples of specific strategies as selected in CEE countries. Section 7 gives an overview of typical radioactive inventories in WWERs, including activation and contamination levels. Section 8 provides information on decontamination, dismantling and waste management technologies for WWERs and related available operating experience. Section 9 draws conclusions and Section 10 gives recommendations for future work. The TECDOC is complemented by appendices giving basic information on WWER design and construction features, decommissioning practices and comprehensive lists of WWER-440 units in CEE. These appendices provide details on national policies and schemes relevant to decommissioning infrastructures, planning and other important factors.

**ORGANIZATION AND MANAGEMENT FOR DECOMMISSIONING OF LARGE NUCLEAR FACILITIES, TECHNICAL REPORTS SERIES NO. 399, IAEA, VIENNA (2000)**

In this report, the term 'decommissioning' refers to those actions that are taken at the end of the useful life of a nuclear facility in withdrawing it from service with adequate regard for the health and safety of workers and members of the public and for the protection of the environment. The term 'large nuclear facilities' involves nuclear power plants, large nuclear research reactors and other fuel cycle facilities such as reprocessing plants, fuel conversion, fabrication and enrichment plants, as well as spent fuel storage and waste management plants.

The report covers organizational aspects of decommissioning and describes factors relevant to the planning and management of a decommissioning project. It identifies the general issues to be addressed and provides an overview of organizational activities necessary to manage a decommissioning project in a safe, timely and cost effective manner. There are a number of facilities that present special cases and include those which have undergone a major accident as well as uranium mines and mills and radioactive waste repositories. These facilities are not dealt with in this report.

**SAFETY CONSIDERATIONS IN THE TRANSITION FROM OPERATION TO DECOMMISSIONING OF NUCLEAR FACILITIES, SAFETY REPORTS SERIES NO. 36, IAEA, VIENNA (2004)**

A growing number of nuclear facilities around the world are being shut down for various reasons. The transition period between operations and implementation of the decommissioning strategy includes some routine operations and others that may be specific to the transition stage. These transitional operations are undertaken following procedures authorized by the regulatory body. In this period, a number of modifications, both technical and organizational, are required to adjust the facility to new objectives and requirements. This Safety Report provides information regarding the safety concerns associated with the transition period and suggests solutions for managing them. It addresses issues that are generically applicable to any nuclear facility and those that are specific to various types of nuclear facility.

## REFERENCES


[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Transition from Operation to Decommissioning of Nuclear Instalations, Technical Reports Series No. 420, IAEA, Vienna (2004).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning Techniques for Research Reactors, Technical Reports Series No. 373, IAEA, Vienna (1994).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, State-of-the-Art Technology for Decontamination and Dismantling of Nuclear Facilities, Technical Reports Series No. 395, IAEA, Vienna (1999).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, The Decommissioning of WWER Type Nuclear Power Plants, IAEA-TECDOC-1133, Vienna (2000).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Organization and Management for Decommissioning of Large Nuclear Facilities, Technical Reports Series No. 399, IAEA, Vienna (2000).

[6] SZILAGYI, A., BRIN, G., “Operations to disposition: The final steps of a facility’s operational phase”, WM’00 (Proc. Conf. Tucson, 2000), WM Symposia, Inc., Tucson, AZ (2000).

[7] KACZMARSKY, M.M., ODELL, W.H., “The successful transition from plant operations to decommissioning of Maine Yankee”, WM’00 (Proc. Conf. Tucson, 2000), WM Symposia, Inc., Tucson, AZ (2000).

[8] BUCK, S., YOUNG, M.P., COLQUHOUN, A., “Decommissioning impacts on waste management”, Decommissioning ’91 (Proc. Symp. Tucson, 1991), WM Symposia, Inc., Tucson, AZ (1991) 163–170.

[9] GANGAHAR, M., PHILLIPS, A., To POCO or not to POCO, that is the question, Nucl. Energy 38 6 (1999) 339–341.

[10] GORDELIER, S.C., PASSANT, F.H., “Decommissioning of Nuclear Electric’s gas-cooled reactors: The development of a new strategy”, Decommissioning Policies for Nuclear Facilities (Proc. Int. Sem. Paris, 1991), OECD, Paris (1992) 337–351.

[11] NUCLEAR REGULATORY COMMISSION, Identification and Evaluation of Facilitation Techniques for Decommissioning Light Water Power Reactors, Rep. NUREG/CR-3587, USNRC, Washington, DC (1986).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Decontamination of Water Cooled Reactors, Technical Reports Series No. 365, IAEA, Vienna (1994).

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiological Characterization of Shut Down Nuclear Reactors for Decommissioning Purposes, Technical Reports Series No. 389, IAEA, Vienna (1998).

[14] HOUGH, N.J., “Decommissioning of the uranium processing ‘amber area’ at Dounreay, Scotland” (Proc. Int. Decommissioning Symp. Knoxville, 2000), USDOE, Washington, DC (2000).

[15] OECD NUCLEAR ENERGY AGENCY, INTERNATIONAL ATOMIC ENERGY AGENCY, EUROPEAN COMMISSION, Nuclear Decommissioning — A Proposed Standardised List of Items for Costing Purposes, Interim Technical Document, OECD, Paris (1999).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Considerations in the Transition from Operation to Decommissioning of Nuclear Facilities, Safety Reports Series No. 36, IAEA, Vienna (2004).

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