European Commission

International Atomic Energy Agency

OECD/Nuclear Energy Agency

A PROPOSED STANDARDISED LIST of ITEMS FOR COSTING PURPOSES in the DECOMMISSIONING OF NUCLEAR INSTALLATIONS

Interim Technical Document

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AD DEVELOPMENT

FOREWORD

Experience over the last decade has demonstrated that, in general, the process of decommissioning has reached industrial maturity, although specific techniques continue to evolve. The use of these techniques in the decommissioning of nuclear facilities continues to increase this experience.

Various international studies of decommissioning project costs have shown that there are substantial variations in cost estimates for individual installations. Studies attempting to understand the reasons for these differences have been somewhat hampered by the fact that different types of costing methods are used, having different data requirements. Although some uncertainty is inevitable in any costing method, an understanding of the costing methods used in particular projects is useful to avoid key uncertainties. Difficulties of understanding can be encountered and invalid conclusions drawn in making cost comparisons without regard to the context in which the various cost estimates were made.

The European Commission (EC), the International Atomic Energy Agency (IAEA), and the OECD/Nuclear Energy Agency (NEA) have ongoing activities addressing various aspects of decommissioning and decommissioning costs. Based on these activities and common objectives, and on the advantage of having standardised cost items, they agreed to prepare a common list of cost items and related cost-item definitions for decommissioning projects.

Developed and reviewed by experts of the three organisations and their supporting groups, input has included information and experience concerning decommissioning cost items and cost-item definitions. The resulting list represents a new, uniform and more complete approach to decommissioning costs. It is hoped that the standardised list will be widely accepted and used. It is recognised that at this stage the list has achieved approval in theory but should be further evaluated in practice. Therefore, this report should be viewed as an interim document, to be broadly distributed, discussed and used, and to be finalised, most effectively in a workshop format, after approximately three years. Thereafter, a more definitive and more broadly tested and supported report will be issued.

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ACKNOWLEDGEMENTS

The representatives of the three co-operating organisations (EC, IAEA and OECD/NEA) wish to stress that this project was very successful, thanks to the high effectiveness and qualification of its co-ordinator, Lucien Teunckens from Belgoprocess (Belgium).

EDITORIAL NOTE

This document has been developed jointly by work of the EC, the IAEA and the OECD/NEA. The views expressed do not necessarily reflect those of the governments of the nominating Member States or of the nominating organisations.

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1. INTRODUCTION

1.1 Background

For nuclear facilities, decommissioning is the final phase in the life cycle after siting, design, construction, commissioning and operation. It is a process involving operations such as decontamination, dismantling of plant equipment, demolition of buildings and structures and management of resulting materials. All these activities take into account health and safety requirements for operating personnel and the general public, and any implications for the environment.

In several projects to decommission various types of nuclear facilities, it has been shown that technical methods and equipment are available today to dismantle safely nuclear facilities, of whatever type or size. Much experience in the use of these techniques has resulted from maintenance and repair work, and from the decommissioning of prototype, demonstration, and small power reactors or other nuclear facilities.

Decommissioning projects for various types of nuclear facilities have also demonstrated that decommissioning costs can be managed. However, comparisons of individual cost estimates for specific facilities may show relatively large variations, and several studies have attempted to identify the reasons for these variations.

In the past, the basis of the cost estimates for decommissioning projects lay in the world-wide experience obtained either in decommissioning projects or in maintenance and repair work at operating nuclear facilities where conditions are similar to some extent. This experience was utilised directly or as an analogue for estimating the costs of similar tasks in decommissioning projects, or indirectly for the assessment of unit costs for basic decontamination and dismantling activities.

Different costing methods have different data requirements, however, and consequently, their reliability depends on the extent to which various data are available and applicable to the specific case being considered. Independent of the assessment method, some uncertainty is inevitable in all estimates of future costs, and no costing method is generally superior to others in this respect. However, analysis of the costing method may be useful in order to locate the key uncertainties in each specific estimate. It has been shown, indeed, that there is a potential for making errors, and that difficulties can be encountered in performing quick international cost comparisons. Numbers taken at face value, without regard to their context, are easily misunderstood and misinterpreted. This is due, among other things, to the fact that there has been no standardised listing of cost items established specifically for decommissioning projects. Such a standardisation would be useful not only for making cost comparisons more straightforward and meaningful, but should also provide a good tool for cost-effective project management.

1.2 Objectives

In the past, a Task Group on Decommissioning Costs within the Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects of the Nuclear Energy Agency of the Organisation for the Economic Co-operation and Development (OECD/NEA) had considered and evaluated the reasons for the large variations in reported cost estimates from decommissioning projects [1]. In November 1994, a new Task Group on

Decommissioning Costs was set up with similar objectives, looking this time (specifically and separately) at power reactors and fuel facilities.

Similarly, in 1995, the International Atomic Energy Agency (IAEA) began developing a technical document on cost of radioactive waste management and decommissioning of nuclear facilities, and called international experts to form a Consultants Group on Decommissioning and Waste Management Costs.

In its 1994-1998 Nuclear Fission Safety Programme, the European Commission (EC) decided to continue activities in view of setting up a database for decommissioning costs.

Based on these concurrent activities and their similar aims, the three organisations agreed to start a co-ordinated action in order to produce a standardised or uniform listing of cost items and related cost-item definitions for decommissioning projects. Such a standardised list as described previously, would facilitate communication, promote uniformity, and avoid inconsistency or contradiction of results or conclusions of cost evaluations for decommissioning projects carried out for specific purposes by different groups.

1.3 Scope and structure

Achieving the objectives required identification, definition, harmonisation and verification of general and specific decommissioning activities and relating cost items to be included in a standardised list of cost items for decommissioning projects.

The proposed list as well as the underlying principles of the cost items involved, were discussed with representatives of the three organisations in view of general harmonisation and completeness in order to obtain a standard for a decommissioning cost structure that could be acceptable to the organisations and their Members. In addition, the principles had to be clarified to the reader and the possible user in a final report including:

- A description of the methodology and the terminology used;
- A description of the methodology for handling decommissioning projects and describing different decommissioning stages;
- A glossary of terms used in the decommissioning and waste management sector.

Section 2 of this report gives a historical overview of this co-ordinated action and describes how it was organised. Section 3 describes how the methodology was implemented in the process of identification, definition, harmonisation and verification of general and specific activities and relating cost items in order to create a standardised list of cost items for decommissioning projects.

In Annexes 1 and 2, the standardised lists of cost items and cost groups for decommissioning projects are given, while Annexes 3 and 4 comprise the corresponding definitions to these standardised cost items and cost groups. In addition, Annex 5 includes a related glossary.

2. CO-ORDINATED ACTION TOWARDS A STANDARD INTERNATIONAL STRUCTURE FOR DECOMMISSIONING COSTS

In the following sections, an overview is given of the historical steps that contributed to the decision taken to start the co-ordinated action with the EC, the IAEA and the OECD/NEA, in order to adopt a standardised list of cost items and related cost-item definitions for decommissioning projects. In addition, a description of how the tasks were organised is provided.

2.1 OECD Nuclear Energy Agency

In 1989, the OECD/NEA Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects, set up a Task Group on Decommissioning Costs in order to identify reasons for the large variations in reported cost estimates of decommissioning projects. The Task Group gathered cost data from 12 projects in the Co-operative Programme, established a basis for comparison of decommissioning tasks adopted in all projects, prepared a matrix of cost groups and cost items with a cost breakdown in "labour costs", "capital equipment and material" and "expenses", and incorporated the project cost data into this matrix.

Cost data was progressively refined by discussions between Task Group and project managers to improve the basis of comparison and to make the data more uniform. The projects were divided into groups with similar characteristics (models) to facilitate the analysis of the cost distribution. Real project-specific discrepancies were identified and analysed without bias resulting from inconsistent or inappropriate data.

In addition, the Task Group reviewed some general factors identifying issues dealing with political/geographical, technical and economic/financial aspects causing variations in estimated costs. These factors were only treated qualitatively, since data could not be separated to analyse their quantitative effects.

One of the lessons learnt by the Task Group was the potential for making errors and the difficulties encountered in performing quick international cost comparisons. It was evident that the answers to any cost questionnaire must be analysed and refined by follow-up questionnaires to understand the real contents. Numbers taken at face value, without regard to their context, are easily misunderstood and misinterpreted.

Another important observation the Task Group made was that there was no standardised listing of cost items or estimating methodology established for decommissioning projects. Such a standardisation would be useful not only for making cost comparisons more straightforward and meaningful, but should also provide a good tool for cost-effective project management. In their report, the Task Group made a proposal for a listing of cost items and cost groups that could be the framework for such a standardisation [Ref. 1].

In 1994, the Liaison Committee of the Co-operative Programme decided to re-start the work of the Task Group on Decommissioning Costs. The terms of reference/programme of work for the new study were decided as follows:

- Structure/break down the costs in cost groups/cost items/cost factors; clearly define the scope of each of these, compare the results with other lists (from current studies), and prepare a new "standardised" list;
- Compare/contrast/explain differences in results presented in various countries/projects, looking specifically to commercial nuclear facilities/projects in or related to the Co-operative Programme, separating reactors and fuel facilities in two groups;
- Prepare a questionnaire, and ask participating organisations to provide their relevant cost figures in the standardised list, producing a new inventory of cost estimates (at least six reprocessing plants and over a dozen reactors of various sizes and types, including commercially operated plants, are involved, and also other organisations have shown interest in a co-operation);
- Analyse and scrutinise the cost inventory in order to identify aspects of discrepancy and the reasons for these.

"Customers" for the results of the work of the Task Group would include organisations planning to decommission, and organisations estimating how much to put aside for decommissioning in the future.

In its early meetings, the Task Group reviewed the list of cost items proposed by the former Task Group. In a later phase, this list was adapted and was made completely similar to the list of cost items proposed by the IAEA Consultants Group on Decommissioning and Waste Management Costs (see next paragraph). Definitions (a library) at cost item and/or sub-item level were prepared, including a description of the technical activities considered in each cost item. The content of a questionnaire was discussed.

The initial planning aimed to produce a final report somewhere near the end of 1996. As a result of the decision to start the co-ordinated action with EC, IAEA, and OECD/NEA, the Task Group decided that the questionnaire and related documents should be sent out to participants after preliminary approval on the list of cost items and cost-item definitions within the international co-operation.

2.2 International Atomic Energy Agency

In its 1995-1996 programme, the IAEA initiated a task to develop the fundamental points of, the objectives of, and a strategy for a technical document on the costs of radioactive waste management and decommissioning of nuclear facilities.

The emphasis of the task was to create a comprehensive list of cost groups, cost elements and cost factors (factors that influence costs) related to waste management and decommissioning from a waste generator/owner point of view.

Members of a Consultants Group thought it would be beneficial to establish a "standard" glossary, providing definitions of technical and cost terms and cost items. It was expected that such a list would facilitate communication, and possibly, encourage common usage among Member States. Reference should be made to previous studies related to technical descriptions of cost items for decommissioning and waste management activities.

The target audience of the document was expected to be decision-makers developing waste management systems and the cost of decommissioning, *i.e.*, cost provided for and from the waste generator (owner) point of view.

The Consultants Group agreed on the definitions of "cost group", "group of tasks", "cost element", "cost factor", and "cost breakdown unit" as "labour cost", "plant and capital equipment" and "expenses". In addition, a list of cost groups and cost items (defined by activities/steps) has been defined for both radioactive waste management and decommissioning, being very similar to the list prepared by the Task Group on Decommissioning Costs of the OECD/NEA Co-operative Programme [Ref. 2].

Within a time schedule of 2.5 to 3 years, the following activities were planned:

- To prepare definitions of the technical cost groups, cost elements, and cost factors;
- To prepare a questionnaire, send it out to volunteer organisations from Member States, review responses, review and analyse data for consistency and determine if additional clarification is required;
- To prepare a final report, including an introduction, analysis of collected data, and case studies.

2.3 European Commission

In its 1994-1998 Nuclear Fission Safety Programme, Area C.4, "Decommissioning of Nuclear Installations", the European Commission continued activities in the field of the dismantling of nuclear installations, particularly relating to issues of environmentally compatible disposal of radioactive dismantling wastes, the minimisation of radiological impact and the reduction of costs, *i.e.*, by the application of innovative techniques [Ref. 3, 4].

The objectives of this part of the programme were to collect and analyse relevant decommissioning data as well as to test and evaluate decommissioning strategies and techniques. It also aimed at stimulating the exchange of experience from the decommissioning of nuclear facilities.

Under Section C.4.3, "Collection of data on specific waste arisings, doses and associated costs", the aim was to continue maintenance and further development of the already existing EC DB COST database. The inclusion of data from current and future decommissioning projects is considered of interest to the Community as a whole.

EC DB COST was set up with the co-operation of eight partners from the European Union. In its early form, the system was implemented in an Oracle 6 database, and contained a number of work packages describing decommissioning tasks and related costs.

As part of the 1994-1998 Nuclear Fission Safety Programme, the EC reviewed the database concept to have it applied in an Oracle 7 environment, *i.e.*, a more "Windows" like concept, which was easier to apply by common PC-users. This revision has taken into account the discussions between the three organisations in order to identify internationally harmonised cost items.

Besides, a concerted action of European decommissioning operators and experts was launched in order to evaluate decommissioning techniques and strategies as well as to assist in the data supply and their qualification for the database.

2.4 Initiation of the co-ordinated action

Based on the concurrent activities mentioned in the foregoing sections, a co-ordinated action was started to have the three organisations (EC, IAEA, OECD/NEA) develop a standardised list of decommissioning cost items. Such a standardised list would facilitate communication, promote uniformity, and avoid inconsistency or contradiction of results or conclusions of cost evaluations carried out for specific purposes by different groups.

During internal discussions within the three organisations, initiated by their related representatives, it came out that the work carried out by the OECD/NEA Task Group was, as to the structure, very close to the work achieved in the IAEA Consultants Group. It was suggested that the work of the OECD/NEA Task Group be used as the basis for further discussions.

Finally, the participants agreed that the three organisations had the same objectives in this proposal for a co-ordinated action, *i.e.*, to produce a common list of cost items for decommissioning operations, including related cost-item definitions, in order:

- To facilitate communication;
- To promote uniformity;
- To encourage common usage;
- To avoid inconsistency or contradiction of results/conclusions of cost evaluations;
- To be of world-wide interest to all decommissioners.

2.5 Implementation of the co-ordinated action

Based on letters of intent of the three organisations, representatives of the EC, the IAEA, and the OECD/NEA met in order to prepare the practical aspects of the co-ordination activities. General principles on co-operation were developed, and it was suggested that the co-operation should be carried out on two levels:

- A technical level, including the work carried out by experts in working sessions;
- A higher level, including follow-up of the co-ordinated action which should be done in a project committee; the director level of the three organisations could join the working party at topical meetings.

It was noted that the contribution of the EC could be incorporated within the EC 1994-1998 Nuclear Fission Safety Programme in the form of a cost-shared contract with Belgoprocess. As per EC formalities, the IAEA as well as the OECD/NEA would be listed as associated partners, having no financial support from the EC, and being in charge of their own technical secretaries and experts.

A common final document, including the standardised list of cost items and cost-item definitions, should be published.

The representatives also agreed that co-operation could be concluded by organising a joint seminar or workshop, where the results of the work could be presented, discussed and demonstrated.

Based on these considerations, the activities to be incorporated in the co-ordinated action were discussed. A detailed review of a working document was made, including proposed objectives, work content, project milestones and deliverables, benefits, economic and social impacts, project management structure and partnership. After evaluation, the representatives of the three organisations agreed on the contents of the work programme, and appointed Mr. L. Teunckens from Belgoprocess (Belgium) as the project co-ordinator.

It was concluded that the co-ordinated action to produce a standardised listing of cost items for decommissioning projects with related cost-item definitions could start officially on 1 January 1997.

3. DEVELOPMENT OF A STANDARDISED LIST OF COST ITEMS AND COST-ITEM DEFINITIONS FOR DECOMMISSIONING PROJECTS

3.1 Introduction

Achieving the objectives required identification, definition, harmonisation and verification of the general and specific activities carried out during the decommissioning of nuclear facilities, as well as their relating cost items, for inclusion in a standardised list of cost items for decommissioning projects. The tasks were subdivided into seven areas:

- Identification of decommissioning activities and related cost items,
- Harmonisation of decommissioning cost items,
- Grouping of decommissioning cost items,
- Identification of definitions of decommissioning cost items,
- Harmonisation of decommissioning cost-item definitions,
- Identification, definition and harmonisation of cost categories for decommissioning activities,
- Final report on standard structure and list of decommissioning cost items.

3.2 Identification of activities and related cost items

The general and specific decommissioning activities and relating cost items considered in the evaluations or specific projects carried out by the individual participating organisations were identified and listed.

The OECD/NEA Task Group provided its list of cost items for decommissioning projects.

Similarly, the IAEA provided the list of cost groups and cost elements for radioactive waste management and decommissioning defined at the IAEA consultants meeting of June 1995 in Vienna. When considering the structure, this list proved to be very similar to the list prepared by the OECD/NEA Task Group. It was assumed, therefore, that this list could be used as the basis for further discussions.

Preliminary comments on the list of cost items from the OECD/NEA Task Group and the IAEA Consultants Group were obtained from the EC DB COST co-ordinator, as well as two documents describing the structure of EC DB COST.

The representatives of the organisations considered that the information provided was to be used and extended to prepare a common document containing a single and standardised list of cost items, cost groups and cost-item definitions for decommissioning activities.

3.3 Harmonisation of cost items

Specific meetings were organised, and extended information was exchanged by letters in order to discuss this list with representatives of the three organisations with a view to achieving harmonisation and completeness. Finally, it was considered that the resulting list was the basis for a single, uniform and agreed reference list of decommissioning cost items for which specific definitions had to be prepared.

3.4 Grouping of cost items

After harmonisation of the information received about decommissioning cost items discussed in the individual organisations, an overall concept was provided to concentrate the decommissioning cost items of the reference list into groups.

The concept is based on the approaches adopted within the OECD/NEA Task Group and the IAEA Consultants Group, in which cost items are grouped that are related to activities carried out with a similar emphasis, whether or not tied to a similar time schedule for decommissioning, or that are based on overall activities that cannot be categorised in a specific time period.

It is considered that these principles are not in contradiction to the approach adopted in the EC DB COST, in which a number of work packages are defined with a description of decommissioning tasks and related costs. A work package is considered to be a coherent set of selected decommissioning activities or tasks carried out as a part of a decommissioning project or as a decommissioning project itself. It seemed easy to bring EC DB COST in line with the requirements discussed in order to achieve internationally harmonised cost items.

Based on these considerations, eleven cost groups were identified:

- Pre-decommissioning actions,
- Facility shutdown activities,
- Procurement of general equipment and material,
- Dismantling activities,

- Waste treatment and disposal,
- Security, surveillance and maintenance,
- Site cleanup and landscaping,
- Project management, engineering and site support,
- Research and development,
- Fuel,
- Other costs.

This list of cost groups was discussed and adopted by the representatives of the three co-operating organisations.

3.5 Definitions of cost items

The OECD/NEA Task Group provided definitions for the decommissioning activities considered in their evaluations. These definitions were elaborated at cost item and/or sub-item level.

Together with the list of cost groups, cost elements and cost factors for radioactive waste management and decommissioning defined at the IAEA consultants meeting in June 1995 in Vienna, the IAEA also provided a publication entitled *IAEA Waste Management Glossary*, as well as glossaries in Safety Series Nos. 111-F, *The Principles of Radioactive Waste Management*, and 111-S-1, *Establishing a National System for Radioactive Waste Management*, in order to be used when preparing a draft of decommissioning cost-item definitions based on the proposed standard terminology.

Similarly, the EC provided an overview of the working groups (elements of cost-item definitions) considered in EC DB COST as well as a description of the structure of the EC DB COST and an overview of the related work packages (cost items).

This information was considered to be the basis for developing the definitions for the proposed single and standardised list of cost items for decommissioning activities.

3.6 Harmonisation of cost-item definitions (Annexes 1 and 3)

The information received about definitions of decommissioning cost items discussed in the individual organisations was evaluated, compared and compiled into one document in order to present a draft for a single and standardised list of cost items, cost groups and cost item definitions for decommissioning activities.

It should be re-emphasised that, as indicated in Section 3, the concept is based on the approaches adopted within the OECD/NEA Task Group and the IAEA Consultants Group, and that the principles are not in contradiction with the approach adopted in EC DB COST.

As a result, definitions for the cost items in the standardised list were prepared considering that:

- Decommissioning activities include an inventory of a coherent set of tasks, that cover the specific aspects that may have to be dealt with during the decommissioning of a nuclear facility, whether or not a specific task will be executed in a specific decommissioning project;
- Processes or work packages comprise a selection of a coherent set of decommissioning activities or tasks that must be carried out as a part of a decommissioning project or as a decommissioning project itself;
- A global decommissioning project with a specific cost comprises a selection of processes or work packages, being as such a collection of dedicated decommissioning activities grouped in specific processes/work packages, that may be universally and independently

selected from the standardised list of decommissioning cost items based on the specific application defined in the project itself.

A fair agreement was obtained with the OECD/NEA. Written comments were also received from representatives of the NEA Nuclear Development Committee (NDC) and the IAEA.

Further discussions were held with the EC DB COST co-ordinator regarding the subdivision of cost item definitions into sub-items in order to allow for more specific identification and comparison of the available information.

Based on the comments and the additional considerations received, a new version of the proposed standardised list of decommissioning cost items and related cost item definitions was prepared.

3.7 Identification, definition and harmonisation of cost groups (Annexes 2 and 4)

In the evaluations or specific projects carried out by the individual participating organisations, the cost resources for the general and specific decommissioning activities and relating cost items are mostly divided into cost categories. A cost category specifies the nature of the cost (*e.g.*, depreciation costs, salary costs, building rent, etc.), and related cost categories may be grouped. The identification and listing of these cost categories and their specific definitions was completed.

Based on the information received about the costs, categories were compared and compiled into one list, presenting a draft for a single and standardised list of cost categories and related definitions, similarly to what was done for the decommissioning cost-item definitions.

4. CONCLUSIONS

The European Commission (EC), the International Atomic Energy Agency (IAEA) and the OECD/Nuclear Energy Agency (NEA) have ongoing activities addressing various aspects of decommissioning and decommissioning costs. Based on these concurrent activities and common objectives, and acknowledging the advantages of standardised cost-item definitions, the three organisations agreed to carry out a co-ordinated action to establish a standardised list of decommissioning cost items and related definitions. Such a standardised list should mainly facilitate communication, promote uniformity, and avoid inconsistency or contradiction of results or conclusions of cost evaluations for decommissioning projects.

In the course of this joint project, identification, definition and verification of general and specific decommissioning activities and relating cost items have been successfully achieved thanks to a very co-operative spirit from all partners. Harmonisation of the definitions was carried out particularly thanks to the highly qualified project co-ordinator, Belgoprocess.

The three organisations agreed to produce and publish a common interim document describing the aims, scope and content of the co-ordinated action, and containing a commonly agreed upon list of decommissioning cost items, including their respective definitions (Annexes 1 to 4), to inform interested bodies in the respective Member States.

This interim document and its annexes are a first attempt at putting forth a common list to eliminate decommissioning cost evaluation discrepancies and to allow in the future a better information exchange in this area. Although it is hoped that the list will be widely accepted and used, it is recognised that at this stage it has achieved approval in theory only and should be further evaluated in practice. The wish is therefore that the enclosed list be broadly distributed, discussed, used and regularly updated in the future.

During the co-ordinated action, links have been established with other relevant projects and organisations interested in contributing to the general objective of the project. The co-ordinated action

also obtained a growing interest from a lot of other organisations and companies involved in decommissioning all over the world.

The first benefit from the co-ordinated action is seen in the fact that experts from the co-operative partners have regularly been in contact, exchanged qualified information and learnt from each other's experience. The list could serve as a basis for existing and future databases to evaluate decommissioning costs in the three co-operating organisations, with the potential benefit of fast and a comprehensive exchange of decommissioning data, thus improving international co-operation.

5. REFERENCES

[1] OECD NUCLEAR ENERGY AGENCY, "Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects", Report from the Task Group on Decommissioning Costs, CPD/DOC(91), June 1991.

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, "Summary Record of the Consultants Meeting of 26-29 June 1995 on Radioactive Waste Management and Decommissioning Costs", CT2506, Vienna, July 1995.

[3] EUROPEAN COMMISSION, 1994-1998 Nuclear Fission Safety Programme, "Synopsis of the Research Projects", EUR 16980, 1996.

[4] EUROPEAN COMMISSION, 1994-1998 Nuclear Fission Safety Programme, "Progress Report 1997", EUR 18322/2, 1998.

Annex 1

STANDARDISED COST ITEMS FOR DECOMMISSIONING PROJECTS

01 PRE-DECOMMISSIONING ACTIONS

01.0100 Decommissioning planning

- 01.0101 Strategic studies
- 01.0102 Conceptual planning
- 01.0103 Detailed planning
- 01.0104 Safety and environmental studies

01.0200 Authorisation

- 01.0201 License applications and license approvals
- 01.0202 Public consultation and public inquiry

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

- 02.0101 Termination of operation, plant stabilisation, isolation and inspection
- 02.0102 Facility reuse

02.0200 Removal of fuel and/or nuclear-fuel materials

- 02.0201 Defuelling and transfer of fuel to temporary spent-fuel storage
- 02.0202 Nuclear-fuel material inventory recovery

02.0300 Drainage and drying or blowdown of all systems not in operation

02.0400 Sampling for radiological inventory characterisation after plant shutdown, defuelling and drainage and drying or blowdown of systems

- 02.0401 Sampling for radiological inventory characterisation in the installations after plant shutdown, defuelling and drainage and drying or blowdown of systems
- 02.0402 Subgrade soil sampling and monitoring wells to map contamination plumes

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

- 04.0301 Zoning for long-term storage
- 04.0302 Removal/disposition of inventory not suitable for long-term storage

04.0400 Dismantling and transfer of contaminated equipment and material to containment structure for long-term storage

04.0500 Sampling for radiological inventory characterisation in the installations after zoning and in view of dormancy

04.0600 Site reconfiguration, isolating and securing structures

- 04.0601 Reconfiguration and maintenance of essential services and facilities to support long-term storage and/or decommissioning operations
- 04.0602 Site boundary reconfiguration
- 04.0603 Construction of temporary enclosures, storing, structural enhancements, etc. to support site remediation
- 04.0604 Stabilisation of radioactive and hazardous waste pending remediation

04.0700 Facility (controlled area) hardening, isolation or entombment

04.0800 Radiological inventory characterisation 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

- 04.1101 Design and procurement of special tools for dismantling the reactor vessel and internals
- 04.1102 Design and procurement of special tools for dismantling other components or structures

04.1200 Dismantling operations on reactor vessel and internals

04.1300 Removal of primary and auxiliary systems

- 04.1301 Removal of primary and auxiliary systems in reactor facilities
- 04.1302 Dismantling and removal of contaminated equipment, piping, liners and internal systems in non-reactor nuclear facilities

04.1400 Removal of biological/thermal shield

04.1500 Removal of other material/equipment from 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

- 04.1801 Removal of contamination from areas and structures in all buildings and stacks
- 04.1802 Removal of embedded pipes in buildings
- 04.1803 Removal of structures/facilities to gain access to radionuclides that may have breached design boundaries

04.1900 Environmental cleanup

- 04.1901 Removal of embedded pipes outside buildings
- 04.1902 Removal of structures/facilities to gain access to radionuclides that may have breached design boundaries
- 04.1903 Removal of contamination from areas and structures outside all buildings and stacks

04.2000 Final radioactivity survey

04.2100 Characterisation of radioactive materials

- 04.2101 Characterisation of radioactive materials for recycling and reuse
- 04.2102 Characterisation of radioactive materials for final disposal

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

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

- 05.0401 Processing
- 05.0402 Packaging
- 05.0403 Transport

05.0500 Processing of special system fluids (D_2O, sodium, etc.) from facility operations

- 05.0501 Processing
- 05.0502 Packaging
- 05.0503 Transport

05.0600 Processing of waste from decontamination during facility operations

- 05.0601 Processing
- 05.0602 Packaging
- 05.0603 Transport

05.0700 Processing of combustible material from facility operations

- 05.0701 Processing
- 05.0702 Packaging
- 05.0703 Transport

05.0800 Processing of spent resins from facility operations

- 05.0801 Processing
- 05.0802 Packaging
- 05.0803 Transport

05.0900 Processing of other nuclear and hazardous materials from facility operations

- 05.0901 Processing
- 05.0902 Packaging
- 05.0903 Transport

05.1000 Storage of waste from facility operations

- 05.1001 Preparation of storage facility
- 05.1002 Waste storage
- 05.1003 Storage of radioactive waste from facility operations
- 05.1004 Decontamination of storage facility
- 05.1005 Dismantling/disposal of storage facility

05.1100 Disposal of waste from facility operations

05.1101 Preparation of disposal site

05.1102 Waste disposal

05.1103 Disposal of radioactive waste from facility operations

05.1104 Disposal of non-radioactive waste from facility operations

05.1200 Processing of decommissioning waste

05.1201 Processing of radioactive decommissioning waste

05.1202 Processing of non-radioactive decommissioning waste

05.1203 Waste containers

05.1300 Packaging of decommissioning waste

05.1301 Packaging of radioactive decommissioning waste

05.1302 Packaging of non-radioactive decommissioning waste

05.1400 Transport of decommissioning waste

05.1401 Transport of radioactive decommissioning waste

05.1402 Transport of non-radioactive decommissioning waste

05.1500 Storage of decommissioning waste

05.1501 Preparation of storage facility

05.1502 Waste storage

05.1503 Storage of radioactive decommissioning waste.

05.1504 Decontamination of storage facility

05.1505 Dismantling/disposal of storage facility

05.1600 Disposal of decommissioning waste

05.1601 Preparation of disposal site

05.1602 Decommissioning waste disposal

05.1603 Disposal of radioactive decommissioning waste on disposal site

05.1604 Disposal of non-radioactive decommissioning waste

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

07 SITE RESTORATION, CLEANUP AND LANDSCAPING

07.0100 Demolition or restoration of buildings

07.0101 Dismantling of “balance-of-plant” systems and building components

07.0102 Dismantling of the structure

07.0103 Dismantling of the stack

07.0200 Final cleanup and landscaping

07.0300 Independent compliance verification with cleanup and/or site-reuse standards

07.0400 Perpetuity funding/surveillance for limited or restricted release of property

08 PROJECT MANAGEMENT, ENGINEERING AND SITE SUPPORT

08.0100 Mobilisation and preparatory work

08.0101 Mobilisation of construction equipment and facilities
08.0102 Mobilisation of personnel
08.0103 Set-up/construction of temporary facilities
08.0104 Construction of temporary utilities
08.0105 Temporary relocations

08.0200 Project management and engineering services

08.0201 Project manager and his staff
08.0202 Planning and cost control
08.0203 Quality assurance and quality surveillance
08.0204 Procurement, warehousing, and materials handling
08.0205 General/subcontractor administration
08.0206 Documentation and records control
08.0207 Engineering support

08.0300 Public relations

08.0400 Support services

08.0401 Housing, office equipment, site services
08.0402 Computer support
08.0403 Decommissioning support including chemistry, decontamination and field supervision
08.0404 Waste-management support

08.0500 Health and safety

08.0501 Health physics
08.0502 Radiation protection and monitoring
08.0503 Industrial safety

08.0600 Demobilisation

08.0601 Removal of temporary facilities
08.0602 Removal of temporary utilities
08.0603 Demobilisation of construction equipment and facilities
08.0604 Demobilisation of personnel

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 facility or from temporary storage to intermediate storage

10.0200 Intermediate storage

- 10.0201 Wet intermediate storage
- 10.0202 Dry intermediate storage and containers

10.0300 Dismantling/disposal of temporary storage facility

- 10.0301 Decontamination of temporary storage facility
- 10.0302 Dismantling/disposal of 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

- 10.0501 Decontamination of intermediate storage facility
- 10.0502 Dismantling/disposal of intermediate storage facility

11 OTHER COSTS

11.0100 Owner costs

- 11.0101 Implementation of transition plan
- 11.0102 Capital expenditures

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 Insurances

11.0600 Overheads and general administration

11.0700 Contingency

- 11.0701 Risk, financial assurance versus inherent uncertainties
- 11.0702 Escalation of high-risk cost elements

11.0800 Interest on borrowed money

11.0900 Asset recovery: Resale/transfer of general equipment and material

Annex 2

STANDARDISED COST GROUPS FOR DECOMMISSIONING PROJECTS

12 COST GROUPS

12.0100 Labour costs

12.0200 Capital, equipment and material costs

12.0300 Expenses

12.0400 Contingency

Annex 3

STANDARDISED DEFINITIONS FOR COST ITEMS

01 PRE-DECOMMISSIONING ACTIONS

Section 1 covers all activities carried out in preparation of the actual decommissioning. It is subdivided into 5 groups:

- Decommissioning planning
- Authorisation
- Radiological surveys for planning and licensing
- Hazardous-material surveys and analysis
- Prime contracting selection

01.0100 Decommissioning planning

01.0101 *Strategic studies*

- Evaluation and approval of decommissioning options:
  - Consideration and evaluation of available internal/external facilities
  - Consideration of the risk inherent in acceleration or deferral in proposed alternative
  - Consideration of cost, time and personnel capacity
  - Consideration of available funding
- Evaluation and approval of reuse of facilities
- Consideration of the cost to isolate, protect and maintain such facilities throughout the decommissioning process

01.0102 *Conceptual planning*

- Preparation of preliminary decommissioning plan
- Facility characterisation including:
  - Collection of existing documentation on the facility
  - Inventory of the active and non-active equipment to be dismantled
  - Documentation of the current or expected radiological state by dose-rate measurements, contamination measurements, sampling, radiological calculations, etc., or by dose-rate and contamination estimates in case of a new facility that has not been in operation yet
- Proposal for a decommissioning strategy and a scenario including:
  - Inventory of dismantling activities
  - Inventory of active and non-active waste production and waste routing

- Preliminary estimate of decommissioning work to be carried out including:
  - Estimation of personnel requirements
  - Estimation of occupational dose
  - Scheduling of activities
  - First estimate of decommissioning costs

01.0103 ***Detailed planning***

- Preparation of final decommissioning plan
- Detailed facility characterisation including:
  - Centralisation of existing documentation
  - Structural characterisation
  - Detailed inventory of the active and non-active equipment to be dismantled
  - Documentation of the current radiological state by detailed dose-rate measurements, contamination measurements, sampling, radiological calculations, etc.
- Review of final decommissioning scenario including:
  - Detailed inventory of dismantling activities
  - Detailed inventory of active and non-active waste production
  - Consideration of available funding
  - Consideration of the risk inherent in acceleration or deferral in proposed alternative
- Detailed estimate of decommissioning work to be carried out, including:
  - Personnel requirements
  - Required equipment, tooling, waste management facilities
  - Occupational dose
  - Planning of activities
  - Final cost estimate for decommissioning operations
- Preparation of transition plan with an orderly progression from operations to shutdown including:
  - Staff reduction
  - Re-assignment/training
  - Key employee retention/incentive programmes, etc.

01.0104 ***Safety and environmental studies***

- Nuclear safety analysis, involving:
  - Shutdown of the facility
  - Decommissioning activities, including planning and specification of special decommissioning tooling/equipment
  - Final situation (mainly in case of Stage-3 decommissioning without demolition of buildings)
  - Any safe storage situations (in case of Stage-1 or Stage-2 decommissioning)
- Environmental effect analysis

- Industrial safety and security plan for site operations relating to conventional hazards and quality/safety plans for both:
  - Operation of the facility
  - Organisation of the decommissioning work

01.0200 Authorisation

01.0201 ***License applications and license approvals***

- Regulatory assessment/compliance and permits
- Preparation and revision of technical and operating specifications as to gain regulatory and financial relief effective upon facility shutdown, such as approval(s) to reduce or eliminate:
  - Operating fees
  - Insurance premiums
  - Testing and maintenance requirements
  - Staff positions
  - Training programmes
  - Security provisions
  - Safety systems reconfiguration
  - Non-essential system disposition, etc.
- License applications, license documentation, environmental compatibility assessment
- Appraisal of the documentation provided by the applicant through an expert consultant appointed by the authority
- Discussions with legal authorities
- Expenditures incurred by the authority in processing the licence
- Operation and maintenance procedures

01.0202 ***Public consultation and public inquiry***

- Public information
- Public inquiries
- Public consultations
- Public hearings
- Consideration of the results of public consultations/hearings

01.0300 Radiological surveys for planning and licensing

- Radiological surveys in the installations
- Determination of release criteria and its impact on decontamination methods and decommissioning options

01.0400 Hazardous-material surveys and analyses

- Chemical, explosive, combustible material surveys and analysis, to be carried out for the nuclear and the conventional parts of the buildings

01.0500 Prime contracting selection

- Management options, including:
  - Evaluation of approaches from licensee self-management to turnkey contracting
  - Consideration of available resources and options
- Identification of companies interested in making a tender for decommissioning operations
- Drafting of tender specifications
- Qualification of companies interested in making a tender by auditing their:
  - Quality systems
  - Technical capability
- Technical and financial analysis of tenders of candidate prime contractors
- Examination of capability and acceptance of subcontractors
- Final selection of prime contractor and signing of contract

02 FACILITY SHUTDOWN ACTIVITIES

Section 2 covers all activities relating to shutdown operations of the facility. It has 13 groups:

- Plant shutdown and inspection
- Removal of fuel and/or nuclear-fuel materials
- Drainage and drying or blowdown of all systems not in operation
- Sampling for radiological inventory characterisation after plant shutdown, defuelling and drainage and drying or blowdown of systems
- Removal of system fluids (water, oils, etc.)
- Removal of special system fluids (D_2O, sodium, etc.)
- Decontamination of systems for dose reduction
- Removal of waste from decontamination
- Removal of combustible material
- Removal of spent resins
- Removal of other waste from facility operations
- Isolation of power equipment
- Asset recovery: Resale/transfer of facility equipment and components as well as surplus inventory to other licensed (contaminated) and unlicensed (non-contaminated) facilities

02.0100 Plant shutdown and inspection

02.0101 ***Termination of operation, plant stabilisation, isolation and inspection***

- General operations involved in:
  - Shutdown
  - Preservation and surveillance measures to ensure nuclear safety

02.0102 ***Facility reuse***

- Identification, isolation and conservation of systems to be reused
- Systems to be excluded from the decommissioning scope due to "value" in the reuse or future use of the site, such as:
  - Site general services
  - Road and utility network infrastructure
  - Facilities, etc.

02.0200 Removal of fuel and/or nuclear-fuel materials

02.0201 ***Defuelling and transfer of fuel to temporary spent-fuel storage***

- Complete unloading of spent fuel
- Transfer of spent fuel to its temporary storage facility, using equipment available during normal reactor operations
- Management of unused fuel

02.0202 ***Nuclear fuel material inventory recovery***

- Recovery of nuclear materials to balance the nuclear material inventory
- Application of normal operating procedures of the facility, as long as the cost of the operations is financially advantageous in terms of the quantity of material recovered
- Use of specific procedures or techniques with the possible addition of special reagents, if required
- On completion of these operations, a decontamination phase may be entered, as indicated in item 02.0700

02.0300 Drainage and drying or blowdown of all systems not in operation

- Draining and drying or blowdown of all systems no longer in operation:
  - To simplify shutdown
  - To reduce costs
  - To increase safety
- Not including processing of liquids and waste

02.0400 Sampling for radiological inventory characterisation after plant shutdown, defuelling and drainage and drying or blowdown of systems

02.0401 ***Sampling for radiological inventory characterisation in the installations after plant shutdown, defuelling and drainage and drying or blowdown of systems***

- Non-destructive and destructive sampling for radiological characterisation of equipment and surfaces in the facilities
- In-situ measurements of samples
- Modelling, using design codes, according to reactor operating parameters (flux curves, operating time, etc.)

02.0402 ***Subgrade soil sampling and monitoring wells to map contamination plumes***

- Soil sampling and characterisation to map migration of underground contamination due to:
  - Operational incidents resulting in risks of contamination spread
  - Controlled releases into the environment during operation
- Use of hydrogeological data recorded during site selection in view of plant construction

02.0500 Removal of system fluids (water, oils, etc.)

- Removal of process fluids (liquors, oils etc.):
  - Removal of process liquids from systems
  - Transfer of process liquids to a liquid effluent processing station on or off-site
  - Not including waste treatment activities

02.0600 Removal of special system fluids (D_2O, sodium, etc.)

- Removal of any special process fluids (D_2O, sodium, etc.):
  - Removal of special process liquids
  - Transfer of special process liquids to a specific processing station, on or off-site
  - Not including waste treatment activities

02.0700 Decontamination of systems for dose reduction

- Decontamination of the process installations to reduce exposure rates, using more aggressive techniques than those applied during normal operation, keeping characteristics of used effluents compatible with technical specifications for operation on site, and including:
  - Technical process studies
  - Equipment construction or delivery
  - Utilisation of the system
  - Subsequent decommissioning of the system

02.0800 Removal of waste from decontamination

- Removal of radioactive waste produced during system decontamination for dose reduction
  - Removal of radioactive waste produced during decontamination activities
  - Transfer of radioactive waste to a specific processing station, on or off-site
  - Not including waste-treatment activities

02.0900 Removal of combustible material

- Increasing the nuclear safety of the shutdown installation by reducing fire hazards and the fire load in the individual rooms, removing superfluous combustible material such as:
  - Solvents
  - Hydraulic fluids
  - Cables
  - Electrical cabinets, etc.

02.1000 Removal of spent resins

- Removal of spent resins:
  - To evacuate a considerable radioactive potential from the installation
  - To facilitate post-shutdown operations
  - Not including waste-treatment activities
- Isolation of unused-resin purification stations pending subsequent decommissioning

02.1100 Removal of other waste from facility operations

- Removal of other operating waste from the facility:
  - To allow subsequent decommissioning work to be done in acceptable conditions
  - To reduce the risk of contamination spread in case of a deferred decommissioning
  - Not including waste-treatment activities

02.1200 Isolation of power equipment

- Isolation of power generating equipment
- Disconnecting power generating equipment from the grid

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

- Sale or transfer of "active" equipment and surplus spare parts of the facility to other nuclear facilities
- Sale or transfer of non-contaminated equipment and surplus spare parts of the facility to other nuclear or non-classified installations

03 PROCUREMENT OF GENERAL EQUIPMENT AND MATERIAL

Section 3 covers all activities relating to the purchasing of general equipment and materials at site level. It comprises 4 groups:

- General site-dismantling equipment
- Equipment for personnel/tooling decontamination
- Radiation protection and health physics equipment
- Security and maintenance equipment for long-term storage

Procurement of special-purpose or other specific equipment is included in the respective cost groups/items.

03.0100 General site dismantling equipment

- Investment and maintenance for general site-dismantling equipment, including installation, testing, licensing (operational activities to be included in decommissioning activities, however), essentially comprising lifting gear, such as:
  - Overhead cranes
  - Jib cranes
  - Forklift trucks
  - Trucks, etc.
- Hiring of special lifting gear, used in isolated operations, including installation, testing, licensing (operational activities to be included in decommissioning activities, however)

03.0200 General equipment for personnel/tooling

- Investment for and maintenance and subsequent dismantling of additional equipment for personnel and/or tooling decontamination, including installation, testing, licensing (operational activities to be included in decommissioning activities, however)

03.0300 General radiation protection and health physics equipment

- General radiation protection equipment such as portal monitoring systems at controlled area exits, including installation, testing, licensing (operational activities to be included in decommissioning activities, however)
- Portable monitoring equipment for dose rate measurements and/or contamination measurements, including installation, testing, licensing (operational activities to be included in decommissioning activities, however)
- Monitoring equipment for decommissioning operations and/or material release measurements, including installation, testing, licensing (operational activities to be included in decommissioning activities, however)
- Additional health physics equipment for personnel dose-uptake follow-up, including installation, testing, licensing (operational activities to be included in decommissioning activities, however)

03.0400 General security and maintenance equipment for long-term storage

- Equipment required for the surveillance of facilities either pending decommissioning or being partially dismantled, in view of minimising personnel costs during long-term storage, including installation, testing, licensing (operational activities to be included in decommissioning activities, however)
- Security fences, including installation, testing, licensing (operational activities to be included in decommissioning activities, however)

04 DISMANTLING ACTIVITIES

Section 4 covers all activities relating to the different actual dismantling operations. Depending on the selected option, dismantling activities and related cost items in view of a dormancy period or in view of other "standard" or specific decommissioning stages can be applicable. The section is divided into 24 groups:

- Decontamination of areas and equipment in all buildings to facilitate dismantling
- Drainage of spent-fuel pool and decontamination of linings
- Preparation for dormancy
- Dismantling and transfer of contaminated equipment and material to containment structure for long-term storage
- Sampling for radiological inventory characterisation in the installations after zoning
- Site reconfiguration, isolating and securing structures
- Facility (controlled area) hardening, isolation or entombment
- Radiological inventory categorisation for decommissioning and decontamination
- Preparation of temporary waste storage area
- Removal of fuel-handling equipment

- Design, procurement, and testing of special tooling/equipment for remote dismantling
- Dismantling operations on reactor vessel and internals
- Removal of primary and auxiliary systems
- Removal of biological/thermal shield
- Removal of other material and equipment from containment structure and all other facilities, or removal of entire contaminated facilities
- Removal and disposal of asbestos
- Removal of pool linings
- Building decontamination
- Environmental cleanup
- Final radioactivity survey
- Radioactive material characterisation
- Decontamination for recycling and reuse
- Personnel training
- Asset recovery: Sale/transfer of metal or materials, and salvaged equipment or components for recycle or reuse

04.0100 Decontamination of areas and equipment in buildings to facilitate dismantling

- Decontamination of areas and equipment in all buildings to be placed into dormancy, particularly those that will require periodic servicing, maintenance and/or surveillance, such as:
  - Release points
  - Heating, ventilation, air conditioning fan/filter rooms
  - Sampling points
  - Waste storage areas
  - Areas of historically high airborne radionuclide concentrations
  - Areas where groundwater infiltration has been recorded
- Decontamination and release of minor areas and peripheral structures which:
  - Would require excessive maintenance and/or monitoring during a dormancy period
  - Are restricted in accessibility over the duration of the dormancy period
- Decontamination of areas and equipment in all buildings in view of dismantling, primarily:
  - To prevent the spreading of contamination
  - To reduce work area radiation fields
  - To reduce worker contamination
  - To permit manual or simplified disassembly techniques
  - To improve environmental conditions
  - To permit access to previously inaccessible locations

Decontamination may include:

- Chemical treatment
- High-pressure rinsing
- Hot-spot removal and or shielding

- System modifications, etc.

04.0200 Drainage of spent-fuel pool and decontamination of linings

- Drainage of open pools having contained contaminated fluids
- Design, construction and setting up of additional purification equipment to allow the discharge of liquids
- Carrying-out of radiological surveillance analyses as draining proceeds
- Removal of contaminants found in the pools
- Cleaning of surfaces to limit the potential migration of loose particulate into the environment
- Decontamination of surfaces, depending upon the pool's surface characteristics (*e.g.*, coated, painted or steel-lined) and the ultimate disposition of the pool

04.0300 Preparation for dormancy

04.0301 *Zoning for long-term storage*

- Layout of dormancy period control area
- Minimisation of radiological controlled area requiring service and maintenance
- Decommissioning of areas and facilities exterior to the optimised zone
- Decontamination work in rooms, areas and at equipment in order to release (in general auxiliary) buildings not to be used in subsequent decommissioning operations
- Reorganisation, cleaning and decontamination operations in rooms, areas and of equipment in all buildings in order to reduce controlled area
- Redesignation, relocation or re-engineering of materials and equipment for minimum configuration, including:
  - Redefinition of the secured area
  - Modification or reconstruction of security
  - Surveillance and monitoring equipment
  - Consolidation of the site facility
- De-energising and isolation of non-essential systems
- Replacement of equipment and systems used during operations, with more efficient or less complex services, such as:
  - Ventilation
  - Lighting
  - Access control, etc.

04.0302 *Removal/disposition of inventory not suitable for long-term storage*

- Removal/disposition of inventory:
  - Whose construction, design integrity or present condition render it unsuitable for long-term storage
  - Where delay in the disposition would increase concerns of worker safety, complicate removal and/or significantly increase the cost of disposal
- Removal of hazardous and toxic materials whose containment and/or encapsulation could degrade or fail over time, increasing health and safety risks and subsequent cleanup costs

- Removal of peripheral inventory:
  - Not easily relocated to the storage boundary/controlled environment
  - For which immediate disposition is preferred due to convenience or concern regarding future remediation criteria

04.0400 Dismantling and transfer of contaminated equipment and material to containment structure for long-term storage

- Removal of equipment and material suitable for long-term storage to include the preparation and/or packaging of such material for environmental isolation
- Selective structural dismantling in support of component extraction and/or component disassembly
- Segmentation of activated metal components
- Removal of concrete
- Segmentation of contaminated piping, tanks and components
- Modifications to containment to accommodate packages including:
  - Structural enhancements for increased floor loadings
  - Accessibility enhancements for future extraction

04.0500 Sampling for radiological inventory characterisation in the installations after zoning in view of dormancy

- Radiological surveys in the installations
- Non-destructive and destructive sampling for radiological characterisation of equipment and surfaces in the facilities
- In-situ measurements of samples

04.0600 Site reconfiguration, isolating and securing structures

04.0601 ***Reconfiguration and maintenance of essential services and facilities to support long-term storage and/or decommissioning operations***

- Reorganisation of support services and essential facilities for long-term storage or decommissioning, including:
  - Electrical equipment
  - Ventilation systems
  - Fire protection equipment
  - Lifting devices
- Modifications to include process and electrical systems for:
  - Remote operation and monitoring (alarms)
  - Fire detection
  - Reduced maintenance

04.0602 ***Site boundary reconfiguration***

- Physical reconfiguration of boundary:
  - To meet security requirements of dormancy and/or decommissioning
  - To reduce costs

- Modification/reconfiguration of existing access ways (personnel and equipment), to include security (physical and electronic barriers)
- Construction of a re-configured conventional security fence with access points for personnel and vehicles to facilitate facility operations and work co-ordination
- Security to include:
  - Barrier construction
  - Intrusion prevention
  - Enhanced use of sensors

04.0603 ***Construction of temporary enclosures, stores, structural enhancements, etc., to support site remediation***

- Construction of temporary enclosures, stores, structural enhancements, etc.:
  - To support site remediation
  - To facilitate facility operations and work co-ordination
- Reuse of existing buildings whether or not after prior decontamination

04.0604 ***Stabilisation of radioactive and hazardous waste pending remediation***

- Design, construction, operation, surveillance and later dismantling of facilities and equipment required for the removal, isolation and stabilisation of radioactive and hazardous waste, the destination of which is not covered by the preceding items
- Reuse of existing buildings whether or not after prior decontamination

04.0700 Facility (controlled area) hardening, isolation or entombment

- Blocking and securing of all entrances to the controlled area, which are no longer needed
- Protection of remaining entrances against trespassing
- Mothballing, isolation of controlled area site
- Entombment of controlled area site

04.0800 Radiological inventory categorisation for decommissioning and decontamination

- Establishing decommissioning criteria for:
  - Decontamination
  - Recycling
  - Controlled disposal
  - Unrestricted release
- Measurement of the facility to be decommissioned as well as the surrounding environment, by:
  - Radionuclide modelling
  - Direct surveys
  - Sampling
  - Radiochemical analysis
- Characterisation for decontamination through:
  - Base-material identification
  - Process-fluid chemistry
  - Corrosion-film analysis

  - Residuals, etc.
- Characterisation for removal as needed for exposure control (ALARA), consideration in the sequence for:
  - Removal
  - Temporary shielding
  - Tooling selection
  - Decontamination, etc.
- Characterisation for waste packaging, considering:
  - Container selection
  - Radionuclide and volumetric packaging limitations
  - Conditioning/stabilisation
- Characterisation for transportation, considering:
  - Accident/safety analyses (dispersion, exposure)
  - Shielding
  - Documentation
  - Notification
- Characterisation for disposal by:
  - Determining the need for conditioning, stabilisation and isolation
  - Using the criteria established for disposal of low-level radioactive waste, including the identification and quantification of both long-lived and short-lived radionuclides
- Characterisation for storage, including documentation of waste form(s), and package contents:
  - Types and quantities of radioisotopes for future consideration
  - Repackaging
  - Recycling
  - Release
  - Disposal

04.0900 Preparation of temporary waste storage area

- Preparation of temporary waste storage yard by removing materials
- Zoning to identify the temporary waste storage yard

04.1000 Removal of fuel handling equipment

- Removal and extraction of fuel handling equipment and associated components from a temporary storage area, pool, canal, hot cell, etc., including:
  - Hoists
  - Bridges
  - Tooling
  - Transfer containers
  - Storage racks
  - Conveyors
  - Upenders
  - Carriages
  - Inspection devices
  - Cameras

- Manipulators
- Saws, etc.

04.1100 Design, procurement, and testing of special tooling/equipment for remote dismantling

04.1101 ***Design and procurement of special tools for dismantling the reactor vessel and internals***

- Considerations about dismantling alternatives for the reactor vessel and internals by cutting or by removal and disposal of the vessel and internals as a single package for which design and procurement of special tooling would be associated with the preparation, rigging and lifting of the package as well as shielding, weather enclosure, cradles, tiedowns, etc., needed to transport the vessel and internals
- Considerations about working environment and constraints such as:
  - Handling requirements
  - Packaging requirements
  - Transportation requirements
- Design of tooling, including:
  - 3-D modelling of the workpiece
  - Simulations
  - Research and development expenditures
  - Consultants
  - Use of mock-ups
  - Scale models and demonstrations
  - Adaptation of existing tooling
  - Manufacturing processes or related applications
- Generation of design specifications, including specifications for:
  - Operating and maintenance procedures
  - Hardware and software
  - Installation
  - Testing
  - Performance measurement
- Procurement/adaptation of tooling for remote disassembly/segmentation of complex geometric subcomponents for a range of materials and material thickness
- Procurement/adaptation of:
  - Highly automated articulated manipulators and other positioning devices
  - Handling equipment for remote segmentation
- Procurement/adaptation of:
  - Remote-viewing systems for underwater operations
  - Feedback and control systems for underwater operations
  - Turntables for underwater operations
  - Support systems for maintaining water clarity
  - Support systems for collecting cutting fines
  - Support systems for controlling or eliminating the formation of explosive mixtures of gases generated in the cutting or from the dissolution of water

04.1102 ***Design and procurement of special tools for dismantling other components or structures***

- Design of special tooling, the adaptation, modification and/or enhancement of existing tooling for dismantling, when manual disassembly is not practical or in instances where commercially available tooling is not suitable, reliable or practical for the application
- Procurement of the specialty tooling or field modification of commercially available hardware, where labour can be a considerable cost component
- Leasing of specialty tooling or having the tooling made available from a subcontracted service through which operational expertise is also acquired, including concrete coring, sawing or other cutting devices, demolition hammers, etc., which, if purchased, would be cost-prohibitive for smaller applications

04.1200 Dismantling operations on reactor vessel and internals

- Preparation of the work area for dismantling, extracting and packaging the waste for disposal
- Construction of dams on vessel nozzles or gates to isolate and contain the pool being used for disassembly (if performed underwater)
- Installation of handling devices and protection systems
- Disconnecting of reactor vessel and internals, including:
  - Control-rod blades and motors, rod guide tubes, RSA-guide tubes
  - Reactor pressure vessel top head
  - Reactor core top head
  - Steam dryer
  - Feedwater sparger ring
  - Core shroud, including fixing
  - Reactor pressure vessel including support skirt and insulation
- Monitoring of the disassembly
- Operation of the segmentation tooling
- Maintenance and change-out of support equipment (purification and ventilation filters)
- Accepting and preparation of the disposal containers as well as loading and processing containers for transport
- Removal of handling devices and protection systems

04.1300 Removal of primary and auxiliary systems

04.1301 ***Removal of primary and auxiliary systems in reactor facilities***

- De-energising, disconnecting, unbolting, disassembly and/or segmentation of primary and auxiliary equipment and components in reactor facilities, such as:
  - Vessels
  - Heat exchangers
  - Pumps
  - Pipes
  - Fittings
  - Others

- Removal, rigging/transport of the material to a local or centralised waste packaging/preparation area.

04.1302 ***Dismantling and removal of contaminated equipment, piping, liners and internal systems in non-reactor nuclear facilities***

- De-energising, disconnecting, unbolting, disassembly and/or segmentation of primary and auxiliary equipment and components in non-reactor nuclear facilities, such as:
  - Vessels
  - Heat exchangers
  - Pumps
  - Pipes
  - Fittings
  - Others
- Removal, rigging/transport of the material to a local or centralised waste packaging/preparation area

04.1400 Removal of biological/thermal shield

- Dismantling of the activated portion of the biological/thermal or sacrificial shield which may include only that portion of the structure with radionuclide levels in excess of the release criteria or the entire structure where partial dismantling is not an option
- Use of any special tooling (as indicated in paragraph 04.1102), shielded work platforms and manual or remotely operated equipment

04.1500 Removal of other material/equipment from containment structure and all other facilities, or removal of entire contaminated structures

- Removal of contaminated and activated materials (including structural), exceeding release levels, from:
  - Containment structure
  - All other facilities
- Removal of contaminated components that can only be dismantled at the end of the removal process, when all other components have already been removed, including:
  - Cables
  - Lifting devices
  - Liquid waste treatment systems
  - Installations in the conditioning and decontamination areas
  - Ventilation systems
- Removal of non-contaminated ancillary equipment in support of the final release survey, such that the removal of contamination can be demonstrated, including:
  - Any equipment, such as vessels, heat exchangers, pumps, pipes, fittings, others
  - Structural appurtenances
  - Liners
  - Ductwork
  - Penetrations
  - Embedments

- Subsurface structures, etc.

04.1600 Removal and disposal of asbestos

- Establishment of containment, whether by:
  - Temporary barriers
  - Tenting
  - Glove bags
- Provisions for:
  - Changing
  - Waste handling
  - Personnel showers, etc.
- Procurement of materials such as:
  - Fixatives
  - Bagging
  - Protective clothing
  - Filters (area and respiratory)
  - Any other consumables
- Removal, packaging and disposal of asbestos

04.1700 Removal of pool linings

- Removal of paint, coatings, steel or other materials from the pool walls and floor
- Surface scarification, or physical dismantling depending upon the depth of contamination/activation

04.1800 Building decontamination

04.1801 ***Removal of contamination from areas and structures in all buildings and stacks***

- Decontamination (removal) of contaminants in excess of release criteria from all structures on site by the appropriate processes and technology
- Dismantling of non-contaminated structures, fixtures, and other material for access

04.1802 Removal of embedded pipes in buildings

- Establishment of containment, whether by temporary barriers or by tenting
- Removal of concrete structures around the embedded piping
- Removal of the embedded piping

04.1803 ***Removal of structures/facilities to gain access to radionuclides that may have breached design boundaries***

- Removal of surface structures to pursue subsurface contaminates which have migrated to inaccessible locations over the operating life of the facility

04.1900 Environmental cleanup

04.1901 ***Removal of embedded pipes outside buildings***

- Establishment of containment, whether by temporary barriers or by tenting

- Removal of concrete structures around the embedded piping
- Removal of the embedded piping

04.1902 ***Removal of structures/facilities to gain access to radionuclides that may have breached design boundaries***

- Removal of surface structures to pursue subsurface contaminates which have migrated to inaccessible locations over the operating life of the facility
- Dismantling of structures:
  - Hot cells
  - Fuel-pool foundations
  - Excavations beneath buildings
  - Footing drain removal, etc.
- Redesign, modification or replacement of existing structures to allow floor, column and footing removal
- Contamination control requiring:
  - Erosion control/stabilising
  - Cofferdams
  - Site dewatering
  - Groundwater collection and treatment
  - Monitoring wells, etc.

04.1903 ***Removal of contamination from areas and structures outside all buildings and stacks***

- Environmental cleanup, including:
  - Removal of contaminated soil
  - Removal of sludge
  - Removal of on-site burial facilities

04.2000 Final radioactivity survey

- Comprehensive survey of the facility and site following the completion of decontamination:
  - Differentiated or categorised by structures
  - Systems and exterior areas based upon similar physical characteristics
- Preparation of final survey, including:
  - Erection of scaffolding
  - System tagout
  - Component disassembly, etc.
- Final survey including:
  - Specific personnel training
  - Equipment, instrumentation calibration and testing
  - Survey documentation
  - Verification (quality control)
  - Independent sample analysis
  - Confirmatory surveys, etc.

- Administrative and/or physical controls to isolate the surveyed areas, preventing recontamination once the survey has been completed

04.2100 Radioactive material characterisation

04.2101 *Characterisation of radioactive materials for recycling and reuse*

- Direct surveys, sampling, destructive/chemical analysis, etc., based upon:
  - Waste form, geometry, surface accessibility, etc.
  - Intended disposition of the material
  - Limits of acceptability for recycling and reuse
- Waste segregation/sorting as required for recycling
- Documentation of the waste form(s) for:
  - Identifying additional conditioning/treatment
  - Traceability/accountability in the subsequent reintroduction (reuse) of the material

04.2102 *Characterisation of radioactive materials for final disposal*

- Characterisation to required physical form and radionuclide content, *i.e.*, must be acceptable for disposal
- Considerations on the concentrations of:
  - Long-lived radionuclides, whose hazard will persist beyond the institutional controls of the disposal facility
  - Shorter-lived radionuclides which will determine the required engineered barriers for disposal
- Required documentation on waste form:
  - General requirements
  - Free liquid content
  - Hazardous/toxic/pyrophoric/explosive/biological constituents
- Information on how the waste will maintain its physical dimensions and form under expected disposal conditions

04.2200 Decontamination for recycling and reuse

- Segregation and treatment of scrap and salvaged equipment dependent upon:
  - The established criteria at which recycling and reuse is permitted
  - The waste form
  - The economics of decontaminating technologies
- Decontamination, for recycling and reuse, at a centralised processing centre for which the license incurs fees in accordance with a schedule of charges, typically based upon:
  - Material type
  - Contamination level
  - Radionuclide characteristics
  - The potential disposition of the material
- On-site decontamination including:
  - Mobile decontamination services

  - In-house equipment
  - Materials
  - Associated labour
- Post processing, including:
  - Survey of material for release
  - Release of material dependent upon established criteria and future use

04.2300 Personnel training

- Training of new personnel
- Retraining of personnel on a periodic basis (requalification)
- Classroom instructions as well as demonstrations of proficiency in a field environment
- Training in the use of:
  - Personal protection systems as respirators
  - Protective clothing
- Training in:
  - The use of instrumentation
  - Industrial safety and security
  - Industrial/hazardous material safety
  - Emergency management

04.2400 Asset recovery: Sale/transfer of metal or materials, and salvaged equipment or components for recycling or reuse

- Sale or transfer of scrap and/or materials that have been decontaminated or cleaned to the established criteria at which recycling and reuse is permitted
- Sale or transfer of salvaged equipment and/or components that have been decontaminated or cleaned to the established criteria for future use in other classified or non-classified installations

05 WASTE PROCESSING, STORAGE AND DISPOSAL

Section 5 comprises a large number of activities aiming at preparing the dismantled components either for final disposal as radioactive waste, or for release for restricted or unrestricted recycle or reuse:

- Waste processing, storage and disposal safety analyses
- Waste transport feasibility studies
- Special permits, packaging and transport requirements
- Processing of system fluids (water, oils, etc.) from facility operations
- Processing of special system fluids (D_2O, sodium, etc.) from facility operations
- Processing of waste from decontamination during facility operations
- Processing of combustible material from facility operations
- Processing of spent resins from facility operations
- Processing of other nuclear and hazardous materials from facility operations
- Storage of waste from facility operations
- Disposal of waste from facility operations
- Decommissioning waste processing

- Decommissioning waste packaging
- Decommissioning waste transport
- Decommissioning waste storage
- Decommissioning waste disposal

05.0100 Waste processing, storage and disposal safety analysis

- Hazards analyses and risk analyses for handling, packaging, storing, transporting and disposal of certain waste forms and specific radionuclides

05.0200 Waste transport feasibility studies

- Hazards analyses, risk analyses and alternatives analyses for waste transports
- Waste transport feasibility studies for:
  - Large quantities
  - Special forms
  - Unique destinations, etc.
- Detailed routing analyses for shipments requiring excessive clearance or weight accommodations

05.0300 Special permits, packaging and transport requirements

- Specific considerations concerning:
  - Package certification
  - Shielding
  - Local/federal review and approval, etc.
- Mobilisation of waste processing staging area
- Licensing for hazardous/radiological/criticality issues
- Licensing for transportation issues
- Licensing for storage or disposal issues
- Obtaining state and local permits

05.0400 Processing of system fluids (water, oils, etc.) from facility operations

05.0401 *Processing*

- Segregation of salvageable fluids
- Processing of system fluids (evaporation, chemical treatment, incineration, stabilisation, conditioning, etc.) using a portable unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Mobilisation/set-up
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Cost of ownership

  - Dismantling
  - Demobilisation

- Processing of system fluids (evaporation, chemical treatment, incineration, stabilisation, conditioning, etc.) using a permanent unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Design/construction of plant
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Mothballing/dismantling

05.0402 ***Packaging***

- Packaging of salvageable fluids
- Procurement of packages for waste and waste fluids
- Packaging of waste and waste fluids

05.0403 ***Transport***

- Physical and radiological survey of waste and waste fluids for transportation
- Transportation of waste and waste fluids to storage or disposal area

05.0500 Processing of special system fluids (D_2O, sodium, etc.) from facility operations

05.0501 ***Processing***

- Segregation of salvageable special system fluids
- Processing of special system fluids (evaporation, chemical treatment, incineration, stabilisation, conditioning, etc.) using a portable unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Mobilisation/set-up
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Cost of ownership
  - Dismantling
  - Demobilisation

- Processing of special system fluids (evaporation, chemical treatment, incineration, stabilisation, conditioning, etc.) using a permanent unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling

  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Design/construction of plant
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Mothballing/dismantling

05.0502 ***Packaging***

- Packaging of salvageable fluids
- Procurement of packages for waste and waste fluids
- Packaging of waste and waste fluids

05.0503 ***Transport***

- Physical and radiological survey of waste and waste fluids for transportation
- Transportation of waste and waste fluids to storage or disposal area

05.0600 Processing of waste from decontamination during facility operations

05.0601 ***Processing***

- Processing of waste from decontamination during facility operations (evaporation, chemical treatment, contaminant fixing, compaction, incineration, stabilisation, conditioning, etc.) using a portable unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Mobilisation/set-up
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Cost of ownership
  - Dismantling
  - Demobilisation
- Processing of waste from decontamination during facility operations (evaporation, chemical treatment, contaminant fixing, compaction, incineration, stabilisation, conditioning, etc.) using a permanent unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Design/construction of plant
  - Start-up/testing/permits
  - Training

- Short term operation (up to 3 years) or long-term operation (over 3 years)
- Mothballing/dismantling

05.0602 ***Packaging***

- Procurement of waste packages
- Packaging of conditioned waste

05.0603 ***Transport***

- Physical and radiological survey of waste for transportation
- Transportation of waste to storage or disposal area

05.0700 Processing of combustible material from facility operations

05.0701 ***Processing***

- Processing of combustible material from facility operations such as solvents, hydraulic fluids, cables and electrical cabinets, etc. (evaporation, chemical treatment, contaminant fixing, compaction, incineration, stabilisation, conditioning, etc.) using a portable unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Mobilisation/set-up
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Cost of ownership
  - Dismantling
  - Demobilisation
- Processing of combustible material from facility operations such as solvents, hydraulic fluids, cables and electrical cabinets, etc. (evaporation, chemical treatment, contaminant fixing, compaction, incineration, stabilisation, conditioning, etc.) using a permanent unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Design/construction of plant
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Mothballing/dismantling

05.0702 ***Packaging***

- Procurement of waste packages

- Packaging of conditioned waste

05.0703 ***Transport***

- Physical and radiological survey of waste for transportation
- Transportation of waste to storage or disposal area

05.0800 Processing of spent resins from facility operations

05.0801 ***Processing***

- Processing of spent resins from facility operations (evaporation, chemical treatment, contaminant fixing, compaction, incineration, stabilisation, conditioning, etc.) using a portable unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Mobilisation/set-up
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Cost of ownership
  - Dismantling
  - Demobilisation
- Processing of spent resins from facility operations (evaporation, chemical treatment, contaminant fixing, compaction, incineration, stabilisation, conditioning, etc.) using a permanent unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Design/construction of plant
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Mothballing/dismantling

05.0802 ***Packaging***

- Procurement of waste packages
- Packaging of conditioned waste

05.0803 ***Transport***

- Physical and radiological survey of waste for transportation
- Transportation of waste to storage or disposal area

05.0900 Processing of other nuclear and hazardous materials from facility operations

05.0901 ***Processing***

- Processing of other nuclear and hazardous materials from facility operations such as acids, oxides and mixed waste (evaporation, chemical treatment, contaminant fixing, compaction, incineration, stabilisation, conditioning, etc.) using a portable unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Mobilisation/set-up
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Cost of ownership
  - Dismantling
  - Demobilisation
- Processing of other nuclear and hazardous materials from facility operations such as acids, oxides and mixed waste (evaporation, chemical treatment, contaminant fixing, compaction, incineration, stabilisation, conditioning, etc.) using a permanent unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Design/construction of plant
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Mothballing/dismantling
- Melting of contaminated metal material

05.0902 ***Packaging***

- Procurement of waste packages
- Packaging of conditioned waste

05.0903 ***Transport***

- Physical and radiological survey of waste for transportation
- Transportation of waste to storage or disposal area

05.1000 Storage of waste from facility operations

05.1001 ***Preparation of storage facility***

- Siting of storage facility, if required
- Design of storage facility, if required

- Construction of storage facility, if required

05.1002 ***Waste storage***

- Operation of storage facility
- Maintenance of storage facility
- Periodical inspection of storage facility

05.1003 ***Storage of radioactive waste from facility operations***

- Storage of radioactive waste from facility operations in storage facility

05.1004 ***Decontamination of storage facility***

- Decontamination of storage modules
- Remediation of any contaminated hardware of storage facility
- Remediation of activated materials of storage facility

05.1005 ***Dismantling/disposal of storage facility***

- Dismantling of facility
- Radioactivity survey
- Disposal of waste arising from dismantling activities

05.1100 Disposal of waste from facility operations

05.1101 ***Preparation of disposal site***

- Siting of repository
- Design of repository
- Construction of repository

05.1102 ***Waste disposal***

- Operation of repository
- Closure of repository

05.1103 ***Disposal of radioactive waste from facility operations***

- Disposal of radioactive waste from facility operations on disposal site

05.1104 ***Disposal of non-radioactive waste from facility operations***

- Disposal of non-radioactive waste from facility operations on disposal site using:
  - Landfill
  - Incineration
  - Deep well

05.1200 Processing of decommissioning waste

05.1201 ***Processing of radioactive decommissioning waste***

- Processing of radioactive decommissioning waste (evaporation, chemical treatment, contaminant fixing, compaction, incineration, stabilisation, conditioning, etc.) using a portable unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling

  - Pads/foundations/spill control
  - Mobilisation/set-up
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Cost of ownership
  - Dismantling
  - Demobilisation
- Processing of radioactive decommissioning waste (evaporation, chemical treatment, contaminant fixing, compaction, incineration, stabilisation, conditioning, etc.) using a permanent unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Design/construction of plant
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Mothballing/dismantling
- Melting of contaminated metal material

05.1202 ***Processing of non-radioactive decommissioning waste***

- Processing of non-radioactive decommissioning waste (evaporation, chemical treatment, compaction, incineration, stabilisation, conditioning, etc.) using a portable unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Mobilisation/set-up
  - Start-up/testing/permits
  - Training
  - Short term operation (up to 3 years) or long-term operation (over 3 years)
  - Cost of ownership
  - Dismantling
  - Demobilisation
- Processing of non-radioactive decommissioning waste (evaporation, chemical treatment, compaction, incineration, stabilisation, conditioning, etc.) using a permanent unit, including:
  - Solids preparation and handling
  - Liquid preparation and handling
  - Vapour/gas preparation and handling
  - Pads/foundations/spill control
  - Design/construction of plant
  - Start-up/testing/permits

- Training
- Short term operation (up to 3 years) or long-term operation (over 3 years)
- Mothballing/dismantling

05.1203 ***Waste containers***

- Procurement of waste packages
- Low specific activity shipping containers, including:
  - Strong tight containers
  - Liners
  - Drums and pails
  - Shipping casks
- Miscellaneous special type shipping containers, including:
  - Shipping casks
  - Liners
  - Rail casks
- Temporary on-site storage racks or containers

05.1300 Packaging of decommissioning waste

05.1301 ***Packaging of radioactive decommissioning waste***

- Packaging of conditioned radioactive waste

05.1302 ***Packaging of non-radioactive decommissioning waste***

- Packaging of conditioned waste material

05.1400 Transport of decommissioning waste

05.1401 ***Transport of radioactive decommissioning waste***

- Physical and radiological survey of conditioned radioactive waste for transportation
- Handling of filled containers
- Loading/hauling/unloading of solids
- Pumping/hauling of liquids/sediments/sludges, including:
  - Pumping to transport tanker
  - Hauling to disposal site
  - Pumping to permanent container
- Transportation of conditioned radioactive waste to storage or disposal area

05.1402 ***Transport of non-radioactive decommissioning waste***

- Handling of filled containers
- Loading/hauling/unloading of solids
- Pumping/hauling of liquids/sediments/sludges, including:
  - Pumping to transport tanker
  - Hauling to disposal site
  - Pumping to permanent container

- Transportation of waste material to disposal site

05.1500 Storage of decommissioning waste

05.1501 ***Preparation of storage facility***

- Siting of storage facility, if required
- Design of storage facility, if required
- Construction of storage facility, if required

05.1502 ***Waste storage***

- Operation of storage facility
- Maintenance of storage facility
- Periodical inspection of storage facility

05.1503 ***Storage of radioactive decommissioning waste***

- Storage of radioactive decommissioning waste in storage facility

05.1504 ***Decontamination of storage facility***

- Decontamination of storage modules
- Remediation of any contaminated hardware of storage facility
- Remediation of activated materials of storage facility

05.1505 ***Dismantling/disposal of storage facility***

- Dismantling of facility
- Radioactivity survey
- Disposal of waste arising from dismantling activities

05.1600 Disposal of decommissioning waste

05.1601 ***Preparation of disposal site***

- Siting of repository
- Design of repository
- Construction of repository

05.1602 ***Disposal of decommissioning waste***

- Operation of repository
- Closure of repository

05.1603 ***Disposal of radioactive decommissioning waste on disposal site***

- Disposal of radioactive decommissioning waste on disposal site

05.1604 ***Disposal of non-radioactive decommissioning waste***

- Disposal of non-radioactive decommissioning waste material on disposal site by:
  - Landfill
  - Incineration
  - Deep well

06 SITE SECURITY, SURVEILLANCE AND MAINTENANCE

Section 6 mainly covers site protection, control and maintenance activities:

- Site security operation and surveillance
- Inspection and maintenance of buildings and systems in operation
- Site upkeep
- Energy and water
- Periodic and environmental survey

06.0100 Site security operation and surveillance

- Operation and maintenance of automated access control systems
- Operation and maintenance of monitoring systems and alarms
- Protection of remaining entrances against trespassing
- Security fencing
- Deployment of guards/security forces

06.0200 Inspection and maintenance of buildings and systems in operation

- Monitoring of systems and structures necessary to support dormancy and/or decommissioning, excluding security systems
- Maintenance/replacement of systems and structures necessary to support dormancy and/or decommissioning, excluding security systems
- Lay-up and caretaking
- Regulatory assessment/compliance and inspections

06.0300 Site upkeep

- Grounds keeping:
  - Mowing grass
  - Raking leaves, miscellaneous trash
- Road and parking lot maintenance
- Storm drain maintenance

06.0400 Energy and water

- Electricity
- Natural gas/fuel oil
- Potable water
- Sewage/waste water
- Steam
- Compressed air/nitrogen

06.0500 Periodic radiation and environmental survey

- Monitoring and recording airborne radiation levels inside and outside of structures
- Monitoring and recording water contamination levels in facility systems and storm drainage systems

- Soil sampling, analysis, and recording of results

07 SITE RESTORATION AND/OR CLEANUP AND LANDSCAPING

In general, Section 7 considers the non-radiological portions of plant decommissioning. It involves:

- Demolition or restoration of buildings
- Final cleanup and landscaping
- Independent verification of cleanup and/or site reuse standards being met
- Perpetuity funding/surveillance for limited or restricted release of property

07.0100 Demolition or restoration of buildings

07.0101 *Dismantling of "balance-of-plant" systems and building components*

- Dismantling of non-usable, clean balance-of-plant systems, including:
  - Component cooling systems
  - Make-up water systems
  - Feedwater systems
  - Condenser cooling systems
  - Condensate systems
  - Sampling systems
  - Turbine generator
  - Electrical MCCs
  - Instrumentation systems
  - Cable trays and conduits
  - Compressed air systems
  - Instrument air systems
  - Security systems
  - Fire protection systems
  - Air conditioning and heating
  - Other or equivalent systems

07.0102 *Dismantling of the structure*

- Full or complete demolition of partially demolished buildings or structures:
  - Damaged during the radiological removal stage
  - Deemed to be unstable because of age, structural condition or obsolescence
- Refurbishment of that portion of salvageable buildings or structures that can be made usable by reasonable restoration
- Dismantling of the decontaminated remaining portions of the:
  - Reactor auxiliary buildings
  - Used fuel storage buildings
  - Low-level waste storage buildings

  - Radioactive waste treatment buildings
- Dismantling of the remaining portions of the clean buildings and structures as the:
  - New fuel storage building
  - Cooling towers
  - Discharge structure
  - Turbine generator hall
  - Diesel generator building
  - Warehouses and shops
  - Railbeds
  - Roadbeds
  - Meteorological towers
  - Intake structure and screen systems
  - Security fencing
  - Security building
  - Other or equivalent systems
- Lifting out of foundations
- Crushing of produced rubble, including:
  - Separating concrete from reinforcement
  - Removal of material
  - Reuse of crushed rubble for backfilling

07.0103 ***Dismantling of the stack***

- Dismantling of the decontaminated remaining portions of the stack
- Lifting out of foundations
- Crushing of produced rubble, including:
  - Separating concrete from reinforcement
  - Removal of material
  - Reuse of crushed rubble for backfilling

07.0200 Final cleanup and landscaping

- Earthwork, including:
  - Rock excavation
  - Excavation/fill
  - Backfill
  - Site bulldozing and grading
- Adding clean fill where needed to conform site topography to adjacent landscape, including:
  - Borrowing
  - Hauling
  - Spreading
  - Grading

  - Compaction
- Landworks, including:
  - Scarification
  - Harrowing
  - Tracking
  - Contour furrowing
- Landscaping, including:
  - Stockpiling
  - Adding topsoil or loam to support re-vegetation of the site and stabilisation of the soil
  - Settlement markers
- Revegetation and planting, including:
  - Seeding/mulch/fertiliser
  - Sodding
  - Erosion control fabric
  - Shrubs
  - Trees ground cover
- Permanent markers
- Re-establish roads/structures/utilities
- Removal of barriers

07.0300 Independent compliance verification with cleanup and/or site-reuse standards

- Soliciting proposals from contractors for verification services and equipment
- Staff labour for selection of contractor
- Direct costs for:
  - Labour
  - Equipment
  - Materials
  - Sampling laboratory analytical services
  - Reporting
- Indirect costs for:
  - Contractor mobilisation
  - Contractor demobilisation
  - Per diem expenses
  - Relocation of personnel
  - Travel expenses
- Presentation of results to regulatory agency including:
  - Additional sampling
  - Revisions to report

07.0400 Perpetuity funding/surveillance for limited or restricted release of property

- Routine maintenance and surveillance of:
  - Remaining structures or buildings

  - Residual radioactivity under restricted site release conditions
- Furnish extra cap materials, and storage area for extra cap materials
- Site upkeep, including:
  - Mowing
  - Maintenance
  - Cleanup
- Signs, tests

08 PROJECT MANAGEMENT, ENGINEERING AND SITE SUPPORT

Section 8 covers project management and site support services during decommissioning operations:

- Mobilisation and preparatory work
- Project management and engineering services
- Public relations
- Support services
- Health and safety
- Demobilisation

08.0100 Mobilisation and preparatory work

08.0101 *Mobilisation of construction equipment and facilities*

- Transport vehicles ownership/operation and drivers
- Manifests, tolls, permits
- Escort vehicles ownership/operation
- Construction equipment ownership/operation and equipment operators
- Initial assembly and set-up

08.0102 *Mobilisation of personnel*

- Relocation of supervisory personnel

08.0103 *Set-up/construct temporary facilities*

- Temporary staff facilities, including:
  - Office trailers
  - Lunch/break trailer
  - Emergency medical trailer/facilities
  - Storage facilities
  - Laundry facilities
  - Toilets
- General technical facilities, including:
  - Photographic laboratory
  - Equipment maintenance shop
  - Warehouses

  - Truck scales
- Radiological protection laboratory
- Decontamination facilities for construction equipment/vehicles
- Decontamination facilities for personnel
- Guard houses, barricades
- Fire suppression systems, petrol, oil and lubricants dispensing station
- Housing, shop facilities
- Aggregate surfacing, security fencing, gates, roads and parking
- Culverts, walks, signs, grading

08.0104 ***Construct temporary utilities***

- Site lighting
- Power connection/distribution
- Telephone/communications hook-up
- Water connection/distribution
- Sewer connection/distribution
- Gas connection/distribution

08.0105 ***Temporary relocations***

- Roads/structures/utilities

08.0200 Project management and engineering services

08.0201 ***Project manager and staff***

- Decision making individuals at the facility to be decommissioned as well as those representing the prime decommissioning contractor
- Programme manager, project manager
- General superintendent, area superintendent, civil intendent
- Secretarial and/or clerical support for the higher levels of administration
- Plant management, which can be an integrated subset of the decommissioning project management team, and which is responsible for the:
  - Facility operation
  - Facility maintenance
  - Compliance with the existing operating license and technical specifications
- Continuous relationship with the:
  - Operator
  - Authorities
  - Expert consultants
  - Subcontractors
- Craft qualification programmes, start-up programmes, permits
- Monitoring cost development and work progress in time
- Vehicles, travel and per diem

08.0202 ***Planning and cost control***

- Planners and schedulers, cost control engineers, cost accountability, drafting, and accounting personnel
- Cost engineer and cost estimator, planning engineer, schedulers
- CPM (Critical Path Modelling) scheduling monthly updates
- Providing status and accountability to the project management staff

08.0203 ***Quality assurance and quality surveillance***

- Quality assurance engineers and quality control inspectors
- Assuring conformance with established procedure(s), verification of field compliance, extended to subcontractors and vendors if safety considerations/ requirements are concerned

08.0204 ***Procurement, warehousing, and materials handling***

- Purchasing specialists, buyers and associated administrative personnel
- Chief purchasing agent, purchasing agent, buyers, expediters
- Traffic manager, travel clerks, shipping clerks
- Inventory control manager, inventory control clerks, chief warehouse manager, receiving clerk, charge out clerk
- Tool house labour, common labour
- Clerks and typists
- Equipment and lifting material
- Handling all procurement from routine supplies to contracted services
- Emergency air freight, submittals, spare parts inventory, project signs
- Office supplies, mailing and shipping
- Vehicles, travel and per diem

08.0205 ***General/subcontractor administration***

- Contract administrators and associated clerical support
- Contract administrator, comptroller
- Personnel manager, office manager, interpreter
- Accountant, bookkeeper, timekeeper, paymaster, payroll clerks
- Stenographer, clerks, typists, receptionists, mail clerk, messengers, reproduction
- Establishing and reviewing terms and conditions as well as assessing liabilities and exposure in the subcontracting process
- Office supplies, mailing and shipping
- Vehicles, travel and per diem

08.0206 ***Documentation and records control***

- Document control personnel or record clerks
- Project photographs, video monitoring/recording system

- Overseeing the control, distribution and archiving of official documentation produced in the decommissioning

08.0207 ***Engineering support***

- Supporting the decommissioning process, including mechanical, electrical, instrumentation and control, heating, ventilation, air conditioning, nuclear, environmental, licensing, and civil/structural personnel
- Project engineer, civil engineer, mechanical engineer, electrical engineer
- Carpenter superintendent, mechanical superintendent, electrical superintendent
- Geologist, hydrologist, scientist
- Nuclear (radioactive) engineer, field engineer, surveyors, office engineer
- Draftsman, engineering clerks and typists
- Inspectors
- Construction laboratory technicians
- Equipment maintenance and motor pool, including:
  - Master mechanic, mechanics, mechanic helpers
  - Spare parts manager, parts clerk
  - Motor pool manager, service truck driver, motor pool equipment operator, motor pool driver, common labourer, fuel truck driver, lube truck driver
  - Crane, lifting equipment and labour
  - Truck scales
  - Petrol, oil and lubricants dispensing station
  - Waste water holding tanks
- Field shop drawing service, surveying:
  - Supplies and equipment
  - Engineering supplies and equipment
- Supporting the development of the "decommissioning plan", including:
  - Generation of work packages (for bid)
  - Generation of detailed procedures
  - Safety analyses
  - Cost-benefit/feasibility studies
  - Field modifications, etc.
- Mailing and shipping
- Vehicles, travel and per diem

08.0300 Public relations

- Focused through a representative of the facility owner (as project spokesman), although public hearing or presentations may involve many of the other personnel in the organisation
- Public relations officer
- Organisation of seminars, news releases, advertising, facility tours, etc., necessary to bring the project to a successful conclusion

08.0400 Support services

08.0401 ***Housing, office equipment, site services***

- Housing and supporting the decommissioning workforce
- Ownership of temporary construction facilities, including:
  - Office trailers and facilities, office furniture and office equipment
  - Lunch/break trailer, emergency medical trailer/facilities
  - Weather station
  - Warehouse and storage trailers and facilities
  - Laundry trailer and facilities, waste water holding tanks
  - Construction portable toilets
  - Photographic laboratory
  - Equipment maintenance shop
  - Truck scales
  - Decontamination facilities for construction equipment/vehicles
  - Decontamination facilities for personnel
  - Guard houses and security shack, barricades
  - Fire suppression systems, petrol, oil and lubricants dispensing station
  - Housing, shop facilities
  - Aggregate surfacing, temporary site security fencing, gates, roads and parking
  - Culverts, walks, signs, grading
- Operations of temporary construction facilities, including:
  - Operations manager
  - Chefs and cooks, kitchen help, food and food supplies
  - Janitors and cleaning services, maintenance and repair of temporary facilities
  - Cleaning supplies, garbage services, personal items, linen supplies
  - Laundry service
  - Haul road maintenance, temporary parking lot maintenance
- Maintenance of temporary facilities and utilities required in decommissioning operations, operational activities to be included in decommissioning activities, including:
  - Laundry
  - Temporary power and/or compressed air installations
  - Sanitary facilities, etc.
- Winterise project and temporary heat
- Snow removal, daily site cleanup, final site cleanup
- Protect existing property
- Project utilities, including:
  - Telephone usage
  - Electrical usage
  - Sewer usage
  - Water usage
  - Gas usage

- Emergency eye wash, body wash, shower
- On site communication system
- Medical examination, whole body counts

08.0402 ***Computer support***

- Staff integral with the decommissioning organisation (administrators and technicians), providing support activities as equipment repair and network maintenance
- Computer technicians
- Computer hardware and software
- On-call service organisations involved in providing technical support or a mainframe for running complex analyses and codes

08.0403 ***Decommissioning support including chemistry, decontamination and field supervision***

- Field/area superintendents for:
  - Work force allocation, direction, and supervision
  - Implementing the activities as specified in the engineering and planning with the general labour workforce
- Decontamination and chemistry technicians working under the plant operations group and involved in:
  - The control of plant chemistry
  - Any system-wide decontamination
- Hot laundry, including:
  - Hot laundry operations
  - Distribution and maintenance of controlled area clothing
- Hot sanitary

08.0404 ***Waste management support***

- Radwaste operators, waste packaging specialists
- Labour force involved in packaging the waste for disposal

08.0500 Health and safety

08.0501 ***Health physics***

- Health physics and radiation protection personnel
- Certified health physicist, ALARA (As Low As Reasonably Achievable) specialist
- Supporting the decommissioning engineering and planning as well as supervising the resulting decontamination and dismantling processes
- Ensuring that the approach and methodologies in use are within established guidelines and accepted health and safety practices

08.0502 ***Radiation protection and monitoring***

- Supporting field operations and maintain organisational control of the facility
- Radiation protection technologist, dosimetry specialist

- Setting work area/access requirements
- Maintaining documentation of the facility's changing radiological conditions
- Providing dosimetry and personnel protection, etc.
- Area monitoring, including:
  - Alarm systems
  - Geiger-Muller/scintillation survey metering
  - Ion chamber survey metering
  - Tritium monitoring
  - Special case monitoring
- Personal dosimetry, including:
  - Audible alarm systems
  - Film badging
  - Pocket ion chambers
- Personnel radiation counting, including:
  - Doorway monitoring
  - Hand and foot monitoring
  - Whole body monitoring
  - Handheld monitoring
- Dosimetry systems, including:
  - Electronic dosimeters/readers/accessories
  - Thermoluminescence dosimeters/readers/components
- Diagnostics, quality assurance and calibration, including:
  - Off-site calibration
  - On-site calibration
  - Calibration standards
- Operational activities, including:
  - Surveying
  - Radiation protection training
  - Work area monitoring
  - Personal protective equipment surveying
  - Radioactive contamination protective equipment surveying
  - Personnel decontamination

08.0503 ***Industrial safety***

- Safety and protection of workers in industrial environments
- Certified industrial hygienist
- Health and physics trainer, site safety and health officer, safety engineer, safety clerk
- Industrial hygiene technician, air monitoring technician, respiratory specialist, safety monitor
- Addressing the physical dangers of the work place
- Monitoring the work force and facility during the project
- Heat and cold stress monitoring, noise monitoring, odour monitoring

- Conduct worker conventional safety training
- Review implementing procedures for compliance
- First aid, including:
  - Field doctor
  - Field nurse
  - Medical supplies
  - Emergency supplies
  - Ambulance
  - Pilot car
- Fire protection, including:
  - Field fire chief
  - Field fire fighter
  - Fire fighter supplies
  - Fire truck
  - Water truck
  - Fire extinguishers
  - Fire suppression systems
- Traffic control, including:
  - Traffic flagmen
  - Traffic control equipment
  - Barricades
- Security, including:
  - Security clerk
  - Security chief
  - Security officer
  - Watchman
  - Guards
- Vehicles, travel and per diem

08.0600 Demobilisation

08.0601 ***Removal of temporary facilities***

- Temporary staff facilities, including:
  - Office trailers
  - Lunch/break trailer
  - Emergency medical trailer/facilities
  - Storage facilities
  - Laundry facilities
  - Toilets
- General technical facilities, including:
  - Photographic laboratory
  - Equipment maintenance shop

  - Warehouses
  - Truck scales
- Radiological protection laboratory
- Decontamination facilities for construction equipment/vehicles
- Decontamination facilities for personnel
- Guard houses, barricades
- Fire suppression systems, petrol, oil and lubricants dispensing station
- Housing, shop facilities
- Aggregate surfacing, security fencing, gates, roads and parking
- Culverts, walks, signs, grading

08.0602 ***Removal of temporary utilities***

- Site lighting
- Power connection/distribution
- Telephone/communications hook-up
- Water connection/distribution
- Sewer connection/distribution
- Gas connection/distribution

08.0603 ***Demobilisation of construction equipment and facilities***

- Transport vehicles ownership/operation and drivers
- Manifests, tolls, permits
- Escort vehicles ownership/operation
- Construction equipment ownership/operation and equipment operators
- Final disassembly and takedown

08.0604 ***Demobilisation of personnel***

- Relocation of supervisory personnel

09 RESEARCH AND DEVELOPMENT

Section 9 covers all expenditures on the development of decommissioning techniques and technologies:

- Research and development of decontamination, radiation measurement and dismantling processes, tools and equipment
- Simulation of complicated work on models

09.0100 Research and development of decontamination, radiation measurement and dismantling processes, tools and equipment

- Searching for general information, including:
  - Literature review
  - Data collection
  - Considerations on actual and future dismantling and decontamination strategies and techniques

- Status review to determine the actual positions for:
  - Free release
  - Decontamination with respect to cost savings
  - Comparative work in the world
- Development of new dismantling equipment
- Development or use of new decontamination techniques
- Development of adapted measurement devices and calculation techniques
- Development of adapted waste treatment techniques and disposal techniques
- Research and development on:
  - Remotely operated systems
  - Robotics and manipulators
  - Project management computer code systems
  - Computer codes for radioactive inventory estimation
  - Disposal facility performance codes and safety assessment codes

09.0200 Simulation of complicated work on model

- Physical mock-ups for training and ALARA planning
- Test or demonstration programmes
- Computer simulation of dismantling procedures

10 FUEL AND NUCLEAR MATERIAL

Section 10 covers costs relating to the evacuation of spent fuel elements and/or nuclear material, but excluding costs for reprocessing or final disposal alternatives:

- Transfer of fuel or nuclear material from facility or from temporary storage to intermediate storage
- Intermediate storage
- Dismantling/disposal of temporary storage facility
- Preparation of transfer of fuel or nuclear material from intermediate storage to final disposition
- Dismantling/disposal of intermediate storage facility

10.0100 Transfer of fuel or nuclear material from facility or from temporary storage to intermediate storage

- Procurement of additional equipment required for transport to intermediate storage of all fuel or nuclear material, including:
  - Cribs
  - Sealed bottles, etc.
- Transfer of fuel assemblies or nuclear material using transport casks or transfer containers
- Consideration of safety measures during transfer

10.0200 Intermediate storage

10.0201 ***Wet intermediate storage***

- Design and construction of wet intermediate storage, if required
- Maintenance of storage facility
- Periodical inspection of storage facility

10.0202 ***Dry intermediate storage and containers***

- Design and construction of dry intermediate storage, if required
- Containers for dry intermediate storage
- Maintenance of storage facilities
- Periodical inspection of storage facilities

10.0300 Dismantling/disposal of temporary storage facility

10.0301 ***Decontamination of temporary storage facility***

- Decontamination of storage modules
- Remediation of any contaminated hardware of temporary storage
- Remediation of activated materials of temporary storage

10.0302 ***Dismantling/disposal of temporary storage facility***

- Dismantling of facility
- Radioactivity survey
- Disposal of waste arising from dismantling activities

10.0400 Preparation of transfer of fuel or nuclear material from intermediate storage to final disposition

- Scheduling of final disposal or reprocessing
- Consideration of safety measures for transportation
- Transfer of fuel assemblies or nuclear material using transport containers

10.0500 Dismantling/disposal of intermediate storage facility

10.0501 ***Decontamination of intermediate storage facility***

- Decontamination of storage modules
- Remediation of any contaminated hardware of intermediate storage
- Remediation of activated materials of intermediate storage

10.0502 ***Dismantling/disposal of intermediate storage facility***

- Dismantling of facility
- Radioactivity survey
- Disposal of waste arising from dismantling activities

11 OTHER COSTS

Section 11 covers all other costs that cannot be specifically classified in the foregoing sections:

- Owner costs
- Consulting costs

- Regulatory fees, inspections, certifications, reviews, etc.
- Taxes
- Insurances
- Overheads and general administration
- Contingency
- Interest on borrowed money
- Asset recovery: Resale/transfer of general equipment and material

11.0100 Owner costs

11.0101 ***Implementation of transition plan***

- Orderly progression from operations to shutdown
- Staff reduction
- Re-assignment/training
- Key employee retention/incentive programmes

11.0102 ***Capital expenditures***

- Rents
- Fixed costs related to decommissioning

11.0200 General, overall (not specific) consulting costs

- Consultation for making the decommissioning plan
- Installation of computer systems
- Safety evaluations, etc.

11.0300 General, overall (not specific) regulatory fees, inspections, certifications, reviews, etc.

- Preparation of reports, administration
- Supervision of decommissioning activities
- Control of the release of dismantled components

11.0400 Taxes

- Value added taxes
- Local, community, federal taxes
- Environmental taxes
- Taxes on industrial activities

11.0500 Insurances

- Insurance in preparatory, dormancy and dismantling periods
- Builders risk insurance
- Equipment floater insurance
- Marine insurance
- Liability insurance
- Pollution liability insurance
- Home office (general and administrative) insurance

11.0600 Overheads and general administration

- Expenditures for administration, secretariat, typing work
- Field allowances and travel expenses
- Site dependent overheads

11.0700 Contingency

11.0701 ***Risk, financial assurance versus inherent uncertainties***

- Financial assurance versus inherent uncertainties in workscope
- Financial assurance versus inherent uncertainties in regulatory involvement
- Financial assurance versus inherent uncertainties in local and federal politics
- Financial assurance versus inherent uncertainties in waste disposal options

11.0702 ***Escalation of high-risk cost elements***

- Escalation of waste disposal charges
- General inflation over the period of performance

110800 Interest on borrowed money

- Interests on current loans
- Interest for financing

11.0900 Asset recovery: Resale/transfer of general equipment and material

- Sale or transfer of general site dismantling equipment such as:
  - Overhead cranes
  - Jib cranes
  - Forklift trucks
  - Trucks
  - Security fences, etc.
- Sale or transfer of equipment for personnel and/or tooling decontamination
- Sale or transfer of:
  - Radiation protection equipment
  - Monitoring equipment for dose-rate measurements
  - Contamination measurements
  - Decommissioning operations and/or material release measurements
  - Health physics equipment for personnel dose-uptake follow-up

Annex 4

STANDARDISED DEFINITIONS FOR COST-GROUPS

12 COST GROUPS (OF COST CATEGORIES)

For each cost item, 4 cost groups (of cost categories) have been defined:

- Labour costs
- Capital, equipment and material costs (= investment costs)
- Expenses
- Contingency

12.0100 Labour costs

Labour costs are defined as costs calculated on the basis of the workload for a particular cost item and the labour cost unit rate, including:

- Basic payments to employees, comprising allowances for:
  - Working hours
  - Public/legal holidays
  - Extra-legal holidays
  - Study leave
  - Specific absences
  - Sickness
  - Industrial accidents
- Basic payments to employees, also including:
  - Holiday allowances
  - Additional holiday allowances
  - End-of-the-year premiums
- Additional allowances for:
  - Permanencies
  - Relocation
  - Seniority
  - Early retirement
- Allowances for uncomfortable work, including:
  - Extra hours
  - Shift work
  - Protective clothing

- Social security, including contributions for:
  - Pensions
  - Health care
  - Sickness allowances
  - Disablement allowances
  - Family allowances
  - Unemployment
  - Industrial accidents funding
  - Occupational diseases
  - Contributions for study leave paid by the employer
  - Company closure fundings
  - Taxes on labour costs paid by the employer
- Insurance, including contributions for:
  - Guaranteed weekly or monthly wages
  - Additional pension funds
  - Medical care
  - Industrial accidents
  - Private life accidents
  - Life insurance
- Social charges, including:
  - Social fundings
  - Canteen and drink supplies
  - Trade-union guarantees
  - Social secretariat costs
- Overheads, including:
  - Rents
  - Management
  - Others

12.0200 Capital, equipment and material costs

Capital, equipment and material costs (= investment costs) are defined as costs for:

- Equipment to be used for a particular cost item
- Machinery to be used for a particular cost item

12.0300 Expenses

Expenses are defined as costs for consumer items or expendable items, or as costs for other expenditures related to decommissioning cost items where applicable, as for:

- Consumables
- Spare parts
- Protective clothing
- Travel expenses
- Legal expenses
- Taxes
- Value added tax
- Insurance
- Consultants costs
- Quality assurance costs
- Rents
- Office material
- Heating costs
- Water costs
- Electricity costs
- Computer costs
- Telephone/fax costs
- Cleaning
- Interest
- Public relation
- Licences/patents
- Decommissioning authorisation

12.0400 Contingency

Contingencies, expressed as a percentage of adopted costs per item (not for Item 11.0700, *Contingency*), are defined as excess costs, included as uncertainty factors to cope with circumstances beyond control as:

- Changes caused by incomplete design, documentation
- Changes resulting from unforeseen, uncertain, and/or unpredictable conditions, such as construction work disturbances caused by decommissioning operations
- Expected costs/savings associated with projected market conditions

Annex 5

GLOSSARY

The purpose of this glossary is to provide a source of words which are commonly used or have special meanings in the field of radioactive waste management, decommissioning and decontamination. However, it should be noted that some terms are used and defined differently in other areas of technology.

Technical terms used in only one country are not included; the aim has been to restrict the scope to terms which are used internationally. A few words relating to the financial and social aspects of radioactive waste management, decommissioning and decontamination are included, but these areas have not been covered in any depth.

In the organisation of the glossary, the use of modifiers (*e.g.*, adverbs and adjectives) has been kept to a minimum. Many phrases are indexed under the key word in the phrase. For example, the term "radioactive waste" appears under *waste, radioactive*. Cross-references to related terms are also provided. Where definitions are given in terms of other words for which definitions are provided in the glossary, the defined words appear in bold type face if it considered that it might be of value to the reader to consult them to fully understand the original term.

In the context of this glossary, the term "waste" refers, in general, to radioactive waste unless otherwise specified.

accident. Any unintended event, including operating errors, equipment failures or other mishaps, the consequences or potential consequences of which are not negligible from the viewpoint of protection or safety. (See also *incident* and *incident, serious*.)

activity. With regard to an amount of a radionuclide in a particular energy state at a given time, the quotient of *dN* by *dt*, where *dN* is the expectation value of the number of spontaneous nuclear transitions from that energy state in the time interval *dt*:

$$A = \frac{dN}{dt} \qquad \text{(the unit is } s^{-1}\text{)}$$

The special name for the unit of activity is "becquerel" (Bq): 1 Bq = $1 \cdot s^{-1}$. (Although "becquerel" is a synonym for reciprocal second, it is to be used only as a unit for activity of a radionuclide.)

In practice, the former special unit "curie" (Ci) is still sometimes used: 1 Ci = $3.7 \times 10^{10} \cdot s^{-1}$ (exactly).

(See also *radioactivity*.)

ALARA. The acronym for "*a*s *l*ow *a*s *r*easonably *a*chievable", a concept meaning that the design and use of nuclear facilities, and the practices associated with them, should be such as to ensure that exposures are kept as low as reasonably practicable, with technical, economic and social factors being taken into account. (See also *optimisation*.)

alpha-bearing waste. (See *waste, alpha-bearing*.)

analysis, cost-benefit. A systematic economic evaluation of the positive effects (benefits) and negative effects of undertaking an action. Cost-benefit analysis may be used for optimisation studies in radiation protection evaluations.

analysis, risk. An analysis of the risks associated with a technology wherein the possible events and their probabilities of occurrence are considered together with their potential consequences, the distribution of these consequences within the affected population(s), the time factor and the uncertainties of the estimates.

analysis, safety. The evaluation of the potential hazards associated with the implementation of a proposed activity.

area, controlled. Either:

(a) Any area to which access is controlled and in which radiation protection measures are or could be required for controlling exposures or preventing the spread of radioactive contamination during normal working conditions, including expected perturbations in the normal working conditions; or

(b) Any area where protection and safety provisions are needed for preventing or limiting the extent of potential exposures or contamination.

area, exclusion. A term commonly used to designate a zone which may be established around a nuclear facility or other radiation source, to which access by non-authorised persons is prohibited. (See also *area, controlled*.)

area, off-site. Any area outside the physical boundary of a site.

area survey. (See *survey, area*.)

ash. Non-combustible residue remaining after the burning of combustible waste. (See also *incineration*.)

assembly, fuel. (See *fuel bundle*.)

assessment, performance. An analysis to predict the performance of a system or subsystem, followed by comparison of the results of such analysis with appropriate standards or criteria. A performance assessment becomes a safety assessment when the system under consideration is the overall waste disposal system and the performance measure is radiological impact or some other global measure of impact on safety. Performance assessment can be used to describe the analysis and comparison of systems at a variety of levels and requirements.

assessment, safety. An analysis to predict the performance of an overall system and its impact, where the performance measure is radiological impact or some other global measure of impact on safety. (See also *assessment, performance*.)

audit. A documented activity undertaken to determine by investigation, examination and evaluation of objective evidence that there is adequate adherence to established procedures, instructions, specifications, codes, standards, administrative or operational programme requirements, and other applicable documents.

authorisation. The granting by a regulatory body of written permission for an operator to perform specified activities. An authorisation may be more informal or temporary than a licence.

authorised limit. (See *limit, authorised*.)

backfill. The material used to refill excavated portions of a repository (drifts, disposal rooms or boreholes) after waste has been emplaced.

barrier. A physical obstruction that prevents or delays the movement (*e.g.*, migration) of radionuclides or other material between components in a system, *e.g.*, a waste repository. In general, a barrier can be either:

(a) An engineered barrier; or

(b) A natural barrier which is inherent to the environment of the repository.

barriers, multiple. (See *barrier*.)

biosphere. That portion of the Earth's environment normally inhabited by living organisms. It comprises those parts of the atmosphere, the hydrosphere (ocean, seas, inland waters and subsurface waters) and the lithosphere normally related to the human habitat or environment. (See also *geosphere*.)

bitumen. The term bitumen refers to a wide range of hydrocarbons with high molecular weight, commercially available as a residue of petroleum or coal tar refining. There are two major components: asphaltene compounds, which give bitumen colloidal properties, and malthene compounds, which impart viscous liquid properties. Bitumen is used as a matrix for the immobilisation of low and intermediate-level waste.

bituminisation. The process of incorporating waste into a bitumen matrix as a means of immobilisation.

borehole. A cylindrical excavation, made by a rotary drilling device. Boreholes are drilled during site investigation and testing and are also used for waste emplacement in repositories.

bundle, fuel. (See *fuel bundle*.)

burial. (See *disposal, near-surface*.)

burial ground. A term that appeared frequently in earlier radioactive waste management literature and refers to a site used for near-surface disposal of waste. (See also *disposal, near-surface*.)

calcination. A process involving the evaporation of a waste solution to sufficient dryness and the heating of the residue in air to produce oxides of the metallic constituents.

calibration (of a model). A process carried out by comparison of model predictions with field observations and experimental measurements. A model may be calibrated by using data obtained from a particular location or for a limited range of conditions. It may then be considered valid for use in those circumstances but not necessarily in all circumstances. (See also *validation*.)

canister. The primary closed or sealed container for spent fuel or vitrified high-level waste. (See also *cask* and *container, waste*.)

cask. A massive vessel for the transportation and/or storage of spent fuel and other radioactive materials. The cask serves several functions. It provides chemical, mechanical, thermal and radiological protection, and dissipates decay heat during handling, transportation and storage.

cement. Various substances used for bonding or setting to a hard material. Portland cement, the most common, is a mixture of calcium silicates and aluminates made by heating limestones with clay containing aluminosilicate in a kiln. Cement is a main ingredient in final products referred to as: concrete if it contains aggregates (usually small stones); or without aggregates, a grout.

chemical decontamination. The removal or reduction of radioactive contamination from surfaces by chemical processes. (See also *decontamination*.)

clearance. The removal of radioactive materials or radioactive objects within authorised practices from any further (radiological) control by the regulatory body.

clearance levels. A set of values, established by the regulatory body in a country or state, expressed in terms of activity concentrations and/or total activities, at or below which sources of radiation can be released from nuclear regulatory control. (See also *exemption*.)

close-out. In the context of uranium mill tailings impoundments, the operational, regulatory and administrative actions required to place a tailings impoundment into long-term conditions such that little or no future surveillance and maintenance are required. The same concept may apply to mining debris piles, heap and in-situ leaching piles, and mines.

closure, permanent. The status of or action directed at a disposal facility at the end of its operating life. A disposal facility is placed into permanent closure usually after completion of waste emplacement, by covering for a near-surface disposal facility, by backfilling and/or sealing of a geological repository and the passages leading to it, and termination and completion of activities in any associated structures. (See also *control, subsequent*.)

cold or **inactive testing**. The testing of a method, process, apparatus or instrumentation designed to handle radioactive materials by using non-radioactive materials or materials which may contain radioactive tracers.

colloid. A state of subdivision of matter in which the particle size varies from that of true "molecular" solutions to that of a coarse suspension. The diameters of the particles range between 1 and 1,000 nm and the particles are dispersed in a liquid phase and do not become sediment.

Transuranic radionuclides have the tendency to coagulate and form macromolecules by polymerisation under natural conditions.

commissioning. The process during which facility components and systems, having been constructed, are made operational and verified to be in accordance with design specifications and have met the required performance criteria. Commissioning may include both non-radioactive and radioactive testing.

compaction. Either:

(a) A treatment method where the bulk volume of a compressible material is reduced by application of external pressure - hence an increase in its density (mass per unit volume); or

(b) Compaction of soil materials covering a near-surface disposal facility to reduce its permeability. (See also *drum crushing* and *volume reduction* and *treatment*.)

compaction, in-drum. The volume reduction of waste in a drum. In practice, after initial compaction more waste is added and the process is repeated until the drum is filled to the desired level. (See also *drum crushing*.)

compartment. Any part of the environment or process which may conveniently be considered as a single entity. Used in developing mathematical models.

competent authority. (See *regulatory body*.)

conceptual model. (See *model, conceptual*.)

concrete. (See *cement*.

conditioning. A set of operations that produce a waste package suitable for handling, transportation, storage and/or disposal. Conditioning may include the conversion of the waste to a solid form, enclosure of the waste in containers, and, if necessary, the provision of an overpack. (See also *immobilisation* and *packaging*.)

construction. The process of manufacturing and assembling the components of a facility, the erection of civil works and structures, and the installation of components and equipment.

container, waste. The vessel into which the waste form is placed for handling, transportation, storage and/or eventual disposal; also the outer barrier protecting the waste from external intrusions. The waste container is a component of the waste package. For example, molten HLW glass would be poured into a specially designed container (canister) where it would cool and solidify. (See also *barrier* and *canister* and *cask* and *waste package*.)

containment. Any method or physical structure that prevents the dispersion of radionuclides.

contamination. The presence of radioactive substances in or on a material or in the human body or other place where they are undesirable or could be harmful.

control, institutional. (See *institutional control*.)

control, subsequent. Any long-term safety measure, such as land-use restrictions, imposed to ensure site (*e.g.*, near-surface repository) safety after permanent closure.

controlled area. (See *area, controlled*.)

cooling. Process allowing the radioactivity to decay and the rate of heat generation to decrease as in the case of vitrified high-level waste and spent fuel. (See also *storage*.)

core. Either:

(a) In a nuclear reactor, the central arrangement of fuel elements, control rods and supporting structures; or

(b) In mining, geotechnical and civil engineering, a sample of material obtained by drilling.

corrosion. A chemical or electrochemical attack on the surface of a material, thereby destroying the surface. Continual corrosion may penetrate or consume the material. In waste management the term is often applied to glasses and ceramic waste forms as well as to metals. General corrosion is uniform erosion over the whole surface of the material, while local corrosion is accelerated penetration at sensitive places such as stressed areas. Crevice corrosion is chemical degradation concentrated in holes, joints, bolt heads or wherever there is a physical discontinuity. Pitting corrosion is the selective localised formation of rounded cavities in the surface of the metal.

cost-benefit analysis. (See *analysis, cost-benefit*.)

criteria. A set of conditions on which a decision or judgement can be based. They may be qualitative or quantitative and should result from established principles and standards. In radioactive waste management, criteria and requirements are set by a regulatory body and may result from specific application of a more general principle. (See also *specifications*.)

de minimis. (See *exemption*.)

decommissioning. A set of actions taken at the end of the useful life of a nuclear facility in retiring it from service with adequate regard for the health and safety of workers and members of the public and protection of the environment. The ultimate goal of decommissioning is unrestricted release or use of the site. The time period to achieve this goal may range from a few to several hundred years. Subject to the national legal and regulatory requirements, a nuclear facility or its remaining parts may also be considered decommissioned if it is incorporated into a new or existing facility, or even if the site in which it is located is still under regulatory or institutional control. This definition does not apply to some nuclear facilities used for mining and milling of radioactive materials (close-out) or for the disposal of radioactive waste (closure).

decommissioning, level of. The extent of the decommissioning process accomplished at a stipulated point in time. This would represent the attainment of intermediate steps within the discrete phases of decommissioning. (See also *decommissioning phase*.)

decommissioning, phased. Decommissioning carried out in a series of operations separated by one or more periods of time. (See also *decommissioning phase*.)

decommissioning insurance. A mechanism for either:

(a) Ensuring that sufficient funds for a facility's decommissioning activities and expenses are provided, including those for premature closure of the facility; or

(b) Providing funds to cover only the costs of premature decommissioning in the event that other funding mechanisms are insufficient.

decommissioning option. One of various decommissioning strategies, such as immediate dismantling and safe storage and deferred dismantling, which may be considered when decommissioning is being planned. A variety of factors, such as further use of the site and the availability of technologies and waste management facilities, will influence which decommissioning strategy is ultimately chosen.

decommissioning phase. Any well defined and discrete part of the decommissioning process or work.

decommissioning stage. Previous IAEA documents have referred to three discrete stages of decommissioning (storage with surveillance, restricted release and unrestricted release). As a result of decommissioning experience, an increasing number of Member States now use different terminologies and approaches, and therefore this glossary no longer refers to the three stages identified above. (See also *decommissioning phase*.)

decommissioning waste. (See *waste, decommissioning*.)

decontamination. The removal or reduction of radioactive contamination, for example, by a physical and/or chemical process. (See also *contamination*.)

decontamination factor. The ratio of the initial level of contaminating radioactive material to the residual level achieved after decontamination. The term may refer to a specified radionuclide or to gross radioactivity.

deep geological disposal. (See *disposal, geological*.)

design. The process and result of developing a concept, detailed plans, supporting calculations and specifications for a nuclear facility and its components.

diffusion. The movement of atoms or molecules in a gas, liquid or solid from a region of higher concentration of the diffusing species to regions of lower concentration.

direct disposal. The disposal of conditioned spent fuel without reprocessing.

discharge, routine. A planned and controlled release of radionuclides to the environment. Such releases should meet all restrictions imposed by the appropriate regulatory body. (See also *effluent*.)

dismantling. The disassembly and removal of any structure, system or component during decommissioning. Dismantling may be performed immediately after permanent retirement of a nuclear facility or may be deferred.

dispersion. The resulting effect of processes such as transport, diffusion and mixing of waste or effluents (*e.g.*, liquid and gaseous releases) in water or air, ultimately resulting in dilution.

disposal. The emplacement of waste in an approved, specified facility (*e.g.*, near-surface or geological repository) without the intention of retrieval. Disposal may also include the approved direct discharge of effluents (*e.g.*, liquid and gaseous waste) into the environment with subsequent dispersion. (See also *discharge, routine*.)

disposal, geological. The isolation of waste, using a system of engineered and natural barriers at depths up to several hundred metres in a geologically stable formation. Typical plans call for disposal of long-lived and high-level waste in geological formations.

disposal, near-surface. The disposal of waste, with or without engineered barriers, on or below the ground surface where the final protective covering is of the order of a few metres thick, or in caverns a few tens of metres below the earth surface. Typically short-lived, low and intermediate-level waste are disposed of in this manner. This term replaces “shallow land/ground disposal”.

disposal, shallow ground. (See *disposal, near-surface*.)

dose. A measure of the radiation received or “absorbed” by a target. The quantities termed “absorbed dose”, “organ dose”, “equivalent dose”, “effective dose”, “committed equivalent dose”, or “committed effective dose” are used, depending on the context. The modifying terms are often omitted when they are not necessary for defining the quantity of interest. (See also *exposure*.)

dose, effective. The quantity E, defined as a summation of the tissue equivalent doses, each multiplied by the appropriate tissue weighting factor:

$$E = \sum_{T} W_T \cdot H_T$$

where H_T is the equivalent dose in tissue T and W_T the tissue weighting factor for tissue T.

From the definition of equivalent dose, it follows that:

$$E = \sum_{T} W_T \cdot \sum_{R} W_R \cdot D_{T,R} = \sum_{R} W_R \cdot \sum_{T} W_T \cdot D_{T,R}$$

where W_R is the radiation weighting factor for radiation R and $D_{T,R}$ the average absorbed dose in the organ or tissue T. The unit of effective dose is $J.kg^{-1}$, termed the "sievert" (Sv).

drum. A type of waste container similar in appearance to an oil drum which may be sealed by a fitted lid. Typical volumes for drums are 100, 200 and 400 litre. (See also *waste package*.)

drum crushing. A method of waste compaction that involves pressing an entire drum and its contents into a smaller volume. Several crushed drums can then be placed into a larger drum or container. (See also *compaction, in-drum*.)

dry storage. (See *storage, dry*.)

effective dose. (See *dose, effective*.)

effective half-life. (See *half-life, effective*.)

effluent. Any gaseous or liquid radioactive material which is discharged into the environment. (See also *discharge, routine*.)

embedding. The immobilisation of solid waste (*e.g.*, metallic materials) by surrounding it with a matrix material in order to produce a waste form. (See also *immobilisation*.)

emplacement. The placement of a waste package in a designated location for storage or disposal.

encapsulation. The immobilisation of dispersed solids (*e.g.*, ash, powder) by mixing with a matrix material in order to produce a waste form. (See also *immobilisation*.)

enclosure, safe. A condition of a nuclear facility during the decommissioning process in which surveillance and maintenance of the facility take place. The duration of safe enclosure can vary from a few years to the order of 100 years. (See also *decommissioning, phased*.)

engineered barrier. (See *barrier*.)

environmental impact. The physical, ecological, cultural and socio-economic effects of an installation (planned, in operation, in decommissioning, *e.g.*, a repository) or a technology.

environmental impact statement. A set of documents recording the results of an evaluation in which the physical, ecological, cultural and socio-economic effects of a planned installation (*e.g.*, a repository) or a new technology.

environmental remediation or **restoration**. A set of actions taken to rectify or clean up radioactively contaminated sites in which other hazardous substances may also be present.

evaporation. The concentration of a liquid by conversion of some fraction of the volatile material content to the vapour state by latent heat. Evaporation, a treatment method, is used to concentrate some types of radioactive solutions. (See also *waste concentrate* and *treatment*.)

exclusion (from regulatory control). A designation, by the regulatory body in a country or state, of sources of radiation that are not subject to nuclear regulatory control because they are not amenable to control (*e.g.*, cosmic rays and potassium-40 in the human body). They are said to be excluded from the regulatory process. (See also *exemption*.)

exclusion area. (See *area, exclusion*.)

exemption or **exempt**. A designation, by the regulatory body in a country or state, for sources of radiation that are not subject to nuclear regulatory control because they present such a low radiological hazard. Under this designation, a distinction can be made between sources which never enter the regulatory control regime (control is not imposed) and sources which are released from regulatory control (control is removed), in both cases because the associated radiological hazards are negligible. The latter is especially pertinent to radioactive waste management, where sources of radiation are released from nuclear regulatory control in accordance with established clearance levels. (See also *clearance levels* and *exclusion*.)

exempt waste. (See *waste, exempt*.)

exposure. The act or condition of being subject to irradiation. Exposure can be either external exposure (irradiation by sources outside the body) or internal exposure (irradiation by sources inside the body). Exposure can be classified as either normal exposure or potential exposure; either occupational, medical or public exposure; and, in intervention situations, either emergency exposure or chronic exposure. The term exposure is also used in radiodosimetry to express the amount of ionisation produced in air by ionising radiation.

facility. (See *nuclear facility*.)

field experiment. A test conducted with radioactive materials under ambient (outdoor) conditions, usually with regard to near-surface disposal or to radionuclide migration in the environment. The test is usually carried out in such a way that the radionuclides are restricted to a specific area.

filtration. The separation of solids from liquids or gases by passing the mixture through the interstices of a suitable medium, *e.g.*, filter paper, cloth or glass wool.

fixation (of radionuclides). A method of physically bonding radionuclides to a continuous solid surface in order to prevent their dispersion. The term often refers to the application of paint or a similar material to a contaminated surface in order to prevent the radionuclides from becoming airborne or transferred by casual contact.

fuel, nuclear. The fissionable and fertile material used in a nuclear reactor for the purpose of generating energy.

fuel, spent. The irradiated fuel not intended for further use in current form.

fuel bundle or **assembly**. A number of fuel rods held together by plates and separated by spacers attached to the fuel cladding. Spent fuel may be stored or disposed of in this configuration.

fuel cycle, nuclear. The series of operations associated with the production of nuclear energy, including mining, milling, processing and enrichment of uranium or thorium; manufacture of nuclear fuel; operation of nuclear reactors; reprocessing of nuclear fuel; decommissioning; and any activity for radioactive waste management and any research or development activity related to any of the foregoing.

fuel rod or **pin**. The smallest structurally discrete part of a nuclear reactor fuel bundle or assembly which has the fuel as its principal constituent; usually a thin metallic tube containing a stack of uranium dioxide pellets.

gaseous waste. (See *waste, gaseous*.)

geological barrier. (See *barrier*.)

geological repository. (See *repository, geological*.)

geosphere. May include either:

(a) The lithosphere;

(b) The lithosphere, hydrosphere and atmosphere combined; or

(c) Any of the so-called spheres or layers of the Earth.

glass (as waste matrix material). An amorphous material with a molecule distribution similar to that of a liquid but with a viscosity so great that its physical properties are those of a solid. Glasses used in the solidification of liquid high-level waste are generally based on a silicon-oxygen network. Additional network formers such as aluminium, or modifiers such as boron, lead to aluminosilicate or borosilicate glass. In all types of glass waste forms radioactive atoms are chemically bound within the amorphous network.

g**roundwater**. That part of subsurface water that is in the saturated zone, including underground streams. The term excludes water of hydration. Groundwater can be brought to the surface by pumping.

grout. (See *cement*.)

HLW. The abbreviation for high-level waste. (See *waste, high-level*.)

half-life, effective. The time required for the activity of a radionuclide in a living organism to decrease, by a combination of biological processes and radioactive decay, to one half of its initial value.

heat-generating waste. (See *waste, heat-generating*.)

HEPA filter (high-efficiency particulate air filter). A filter used for removing submicrometre and larger particles from a gaseous stream. (See also *scrubber* and *off-gas*.)

high-level waste. (See *waste, high-level*.)

high-level waste tank. (See *waste storage tank, high-level*.)

hot particle. Any small radioactive particle having a high specific activity.

hot spot. Any area of radioactive contamination higher than average.

ILW. The abbreviation for intermediate-level waste. (See *waste, low and intermediate-level*.)

immobilisation. The conversion of a waste into a waste form by solidification, embedding or encapsulation. Immobilisation reduces the potential for migration or dispersion of radionuclides during handling, transportation, storage and disposal. (See also *conditioning*.)

in-situ testing. A series of tests conducted within a geological environment that is essentially equivalent to the environment of a potential repository. A special underground laboratory may be built for in situ testing or tests may be done in an actual repository excavation. Only in such a facility can the full range of repository environment properties and waste repository system interactions be measured. (See also *field experiment*.)

incident. A technical event or anomaly which, although not directly or immediately affecting safety, is liable to lead to subsequent re-evaluation of safety provisions.

incident, serious. According to the INES (International Nuclear Event Scale), an occurrence where either:

(a) External releases of radioactivity above authorised limits, resulting in a dose to the most exposed individual off the site of the order of tenths of a millisievert (dose equivalent - whole-body dose);

(b) High radiation levels and/or contamination on the site due to equipment failures or operational incidents. Overexposure of workers (individual exposure exceeding 50 mSv); or

(c) Incidents in which a further failure of safety systems could lead to accident conditions, or a situation in which safety systems would be unable to prevent an accident if certain initiators were to occur.

incineration. A waste treatment process of burning combustible waste to reduce its volume and yield an ash residue.

incinerator ash. (See *ash*.)

infiltration. A generally slow entry of water, made available at the ground surface. It can refer to the entry of rain water in the surface soil or the penetration of water from a water bearing stratum into an open or backfilled mine.

installation. (See *nuclear facility*.)

institutional control. The control of a waste site (*e.g.*, disposal site) by an authority or institution designated under the laws of a country or state. This control may be active (monitoring, surveillance, remedial work) or passive (land use control) and may be a factor in the design of a nuclear facility (*e.g.*, near-surface disposal facility).

institutional control, reliance of. The degree to which reliance can be placed on the ability of man-made institutions to confine safely the radioactivity in and prevent intrusion into a nuclear facility. (See also *institutional control*.)

integrated approach. A logical and preferably optimised strategy used in the planning and implementation of a waste management programme as a whole from waste generation to disposal such that the interactions between the various stages of waste management are taken into account so that decisions made at one stage do not foreclose certain alternatives at a subsequent stage. For example, the generation of waste is highly dependent on the design, planning and operation of a nuclear facility. (See also *control, institutional*.)

interim storage. (See *storage*.)

intermediate-level waste. (See *waste, low and intermediate-level*.)

intervention. An action intended to reduce or avert exposure or the likelihood of exposure to sources which are not part of a controlled practice or which are out of control as a consequence of an accident.

ion exchange. A usually reversible exchange of one ion with another, either on a solid surface, or within a lattice. A commonly used method for treatment of liquid waste. (See also *treatment*.)

irradiated fuel. (See *fuel, spent*.)

isotopic dilution. The dilution of one isotope of an element, usually a radioactive one, with another isotope of the same element, the latter being stable and naturally occurring.

LLW. The abbreviation for low-level waste. (See *waste, low and intermediate-level*.)

level of decommissioning. (See *decommissioning, level of*.)

licence. A formal, legally prescribed document issued to the applicant (*i.e.*, operating organisation) by the regulatory body to perform specified activities related to the siting, design, construction, commissioning, operation, decommissioning of a nuclear facility, closure of a disposal facility, close-out of a mining and mill tailings site, or institutional control. (See also *authorisation*.)

licensee. The holder of a licence issued by the regulatory body to perform specific activities related to the siting, design, construction, commissioning, operation, decommissioning of a nuclear facility, closure of a disposal facility, close-out of a mining and mill tailings site, or institutional control. The applicant becomes the licensee after it receives a licence issued by the regulatory body.

liner. A layer of either:

(a) Material placed between a waste form and a container to resist corrosion or any other degradation of a waste package; or

(b) Clay, plaster, asphalt or other impermeable material placed around or beneath a tailing impoundment to prevent leakage and/or erosion.

long-lived waste. (See *waste, long-lived*.)

long term. With regard to radioactive waste disposal, periods of time exceeding the time during which active institutional control can be expected to last.

low-level waste. (See *waste, low and intermediate-level*.)

manipulator. A mechanical device used for remote handling.

matrix. With regard to radioactive waste management, a non-radioactive material used to immobilise waste. Examples of matrices are bitumen, cement, various polymers and glass. (See also *conditioning* and *immobilisation*.)

medium-level waste. (See *waste, low and intermediate-level*.)

migration. The movement of materials (*e.g.*, radionuclides) through various media (*e.g.*, barrier materials or soil) usually by being carried or transported by fluid flow. (See also *diffusion* and *transport*.)

minimisation. A concept which embodies the reduction of waste with regard to its quantity and activity to a level as low as reasonably achievable. Waste minimisation begins with nuclear facility design and ends with decommissioning. Minimisation as a practice includes source reduction, recycling and reuse, and treatment with due consideration for secondary as well as primary waste materials. (See also *pre-treatment* and *treatment* and *volume reduction*.)

mixed waste. (See *waste, mixed*.)

model. In applied mathematics, an analytical representation or quantification of a real system and the ways that phenomena occur within that system. The model is usually written as a computer algorithm.

model, conceptual. A set of qualitative assumptions used to describe a system or subsystem for a given purpose. At a minimum, these assumptions concern the geometry and dimensionality of the system, initial and boundary conditions, time dependence, and the nature of the relevant physical and chemical processes. The assumptions should be consistent with one another and with existing information within the context of the given purpose.

model, pathways. A mathematical description used to determine the relative significance of possible radionuclide transport vectors, *e.g.*, air, groundwater, surface water, intrusive roots and animals.

monitoring. The measurement of radiological or non-radiological parameters for reasons related to the assessment or control of exposure and the interpretation of such measurements. Monitoring can be continuous or non-continuous.

multibarrier or **multiple barrier**. (See *barriers, multiple*.)

natural barrier. (See *barrier*.)

near-surface disposal. (See *disposal, near-surface*.)

non-conformance (quality assurance). A deficiency in characteristics, documentation or procedure which renders the quality of an item, process or service unacceptable or indeterminate.

non-nuclear industry waste. (See *waste, non-nuclear industry*.)

non-radioactive waste. (See *waste, non-radioactive*.)

nuclear facility. A facility and its associated land, buildings and equipment in which radioactive materials are produced, processed, used, handled, stored or disposed of (*e.g.*, repository) on such a scale that consideration of safety is required.

nuclear fuel. (See *fuel, nuclear*.)

nuclear fuel cycle. (See *fuel cycle*.)

nuclear installation. (See *nuclear facility*.)

nuclear waste. (See *waste, radioactive*.)

off-gas. The gas streams discharged from a facility. Typical processes in waste management facilities such as dissolution, evaporation, incineration, vitrification, bituminisation and cementation, will generate process off-gases which contain water and acid vapours, aerosols, radioactive and gaseous chemical constituents. The treatment of these streams is an important consideration. (See also *discharge, routine* and *effluent* and *waste, gaseous*.)

off-site area. (See *area, off-site*.)

operation. All activities performed to achieve the purpose for which the nuclear facility was constructed, including maintenance, refuelling, in-service inspection and other associated activities.

operational period (operating period). The period during which a nuclear facility (*e.g.*, a disposal facility) is being used for its intended purpose until it is decommissioned or is submitted to permanent closure.

operator or **operating organisation**. With regard to waste management, the organisation (and its contractors) which performs activities to select and investigate the suitability of a site for a nuclear facility, and/or undertakes to design, construct, commission, operate and decommission such a facility. This term is preferred to "implementing organisation" which appeared in earlier literature.

optimisation. With regard to radiation protection practice, the process of reducing the expected detriment of radiation exposures to humans, through use of protective measures to as low as reasonably achievable (ALARA), taking into account the technical, economic and social factors.

overpack. A secondary (or additional) external container for waste.

package, spent fuel. (See *spent fuel package*.).

package, waste. (See *waste package*.)

packaging. The preparation of radioactive waste for safe handling, transportation, storage and disposal by means of enclosing radioactive waste in a suitable container. (See also *conditioning* and *canister* and *container, waste* and *immobilisation* and *waste package*.)

particulate. A solid aerosol or particle carried in process off-gases or air-streams or suspended in the air.

pathways model. (See *model, pathways*.)

performance. With regard to radioactive waste management, a measure of how effective a waste disposal system is in isolating waste, and in retarding and dispersing eventual releases of radionuclides in accordance with design specification and requirements. Performance can also refer to the individual parts of a system. For example, the performance of a container may refer to how a waste container remains intact and prevents the release of radionuclides over a period of time.

performance assessment. (See *assessment, performance*.)

phased decommissioning. (See *decommissioning, phased*.)

physical mechanical decontamination. (See *decontamination*.)

physical protection. Series of measures for the protection of nuclear material or facilities designed to prevent unauthorised access or removal of fissile material or sabotage with regard to safeguards.

plume. The spatial distribution of a release of airborne or waterborne material as it disperses in the environment.

post-closure. Period of time following the final shaft sealing and surface facility decommissioning of an underground disposal facility (*i.e.*, geological repository). Some type of surveillance or control will likely be maintained during this period, particularly for near-surface disposal facilities. (See also *control, subsequent* and *pre-closure period* and *closure, permanent*.)

practice. Any human activity that introduces additional sources of exposure or exposure pathways or extends exposure to additional people or modifies the network of exposure pathways from existing sources, to increase the exposure or the likelihood of exposure of people or the number of people exposed.

pre-closure period. The period of time spanning the construction and operation of a disposal facility up to and including the final shaft sealing and surface facility decommissioning. (See also *post-closure period* and *closure, permanent*.)

pre-disposal. Any waste management steps carried out prior to waste disposal such as:

(a) Pre-treatment;
(b) Treatment;
(c) Conditioning;
(d) Storage;
(e) Transportation activities.

pre-treatment. Any or all the operations prior to waste treatment, such as:

(a) Collection;
(b) Segregation;
(c) Chemical adjustment;
(d) Decontamination.

processing. (See *waste processing*.)

quality. The totality of features and characteristics of an item, process or service that bears on its ability to satisfy a given requirement.

quality assurance. All those planned and systematic actions necessary to provide adequate confidence that an item, process or service will satisfy given requirements for quality, for example, those specified in a licence.

quality control. Any action which provides means to control and measure the characteristics of an item, process, facility or person in accordance with quality assurance requirements.

radiation protection or **radiological protection**. Any series of measures associated with limitation of the harmful effects of ionising radiation on people, such as limitation of external exposure to such radiation, limitation of incorporation of radionuclides as well as the prophylactic limitation of injury resulting from either of these. (See also *ALARA* and *optimisation*.)

radioactive contamination. (See *contamination, radioactive*.)

radioactive effluent. (See *effluent*.)

radioactive waste. (See *waste, radioactive*.)

radioactive waste management. (See *waste management*.)

radioactivity. The property of certain nuclides to undergo spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides. The process is accompanied by the emission of one or more types of radiation, such as alpha particles, beta particles and gamma rays.

radionuclide. A nucleus (of an atom) that possesses properties of spontaneous disintegration (radioactivity). Nuclei are distinguished by their mass and atomic number.

radiotoxicity. The ability of a radionuclide to produce injury, by virtue of its emitted radiation, when incorporated into the body.

radionuclide transport. (See *transport, radionuclide*.)

radwaste. (See *waste, radioactive*.)

reactor waste. (See *waste, reactor*.)

records. A set of documents, including instrument charts, certificates, log books, computer printouts and magnetic tapes kept at each nuclear facility and organised in such a way that they provide a complete and objective past and present representation of facility operations and activities including all phases from design through closure and decommissioning (if the facility has been decommissioned). Records are an essential part of quality assurance.

recycling. The reutilisation of materials and equipment in subsequent operations after transformation, *i.e.*, for metals, after melting and recycling of the ingots.

regulatory body. An authority or a system of authorities designated by the government of a country or state as having legal authority for conducting the licensing process, for issuing licences and thereby for regulating the siting, design, construction, commissioning, operation, closure, close-out, decommissioning and, if required, subsequent institutional control of the nuclear facilities (*e.g.*, near-surface repository) or specific aspects thereof. This authority could be a body (existing or to be established) in the field of nuclear related health and safety, mining safety or environmental protection vested and empowered with such legal authority.

release. (See *discharge, routine*.)

release or **use, conditional**. A designation, by the regulatory body in a country or state, to restrict the release or use of equipment, materials, buildings or the site because of its potential radiological hazards. The release may be constrained in some way, usually because the fate of the material being considered is known, so that only a limited number of reasonably possible exposure routes have to be considered in deriving the conditional release levels. The release may then be granted with certain conditions, *e.g.*, it may prescribe a definite fate for the material being considered.

release or **use, unconditional**. A designation, by the regulatory body in a country or state, that enables the release or use of equipment, materials, buildings or the site without radiological restriction. The full and complete unconditional release of a material requires that all reasonably possible exposure routes are examined and taken into account in the derivation of the unconditional release levels, irrespective of how that material is used and to where it may be directed.

remedial action. Any action taken when a specified action level is exceeded, to reduce radiation doses that might otherwise be received, in an intervention situation involving chronic exposure.

repository. A nuclear facility (*e.g.*, geological repository) where waste is emplaced for disposal. Future retrieval of waste from the repository is not intended. (See also *disposal*.)

repository, geological. A nuclear facility for waste disposal located underground (usually more than several hundred metres below the surface) in a stable geological formation to provide long-term isolation of radionuclides from the biosphere. Usually such a repository would be used for long-lived and/or high-level waste. (See also *disposal, geological*.)

repository, near-surface. A nuclear facility for waste disposal located at or within a few tens of metres from the Earth's surface. Such a repository is suitable for the disposal of short-lived low and intermediate-level waste.

repository environment. The area or entity referred to by the sum of all conditions and influences, physical, chemical and biological, that pertain to the waste package/barrier/repository system. (See also *near field*.)

reprocessing. The recovery of fissile and fertile material for further use from spent fuel by chemical separation of uranium and plutonium from other transuranic elements and fission products. Selected fission products may also be recovered. This operation also results in the separation of waste.

requirement. A condition defined as necessary to be met by a product, material or process. (See also *criteria* and *specifications*.)

restricted release or **use**. A designation, by the regulatory body in a country or state, to restrict the release or use of equipment, materials, buildings or the site because of its potential radiological hazards.

reuse. The re-utilisation of materials and equipment in subsequent operations in their original form, without any further transformation, *i.e.*, for tanks, pumps, motors, valves, chemical reagents, process materials, etc.

risk. Either:

(a) In general, risk is the probability or likelihood of a specified event occurring within a specified period or in specified conditions; or

(b) With regard to the safety assessment of radioactive waste repositories, risk may be used as a measure of safety. In this context it is defined as the product of the probability that an

individual is exposed to a particular radiation dose and the probability of a health effect arising from that dose.

risk analysis. (See *analysis, risk*.)

routine discharge. (See *discharge, routine*.)

safe enclosure. (See *enclosure, safe*.)

safe storage. (See *storage, safe*.)

safeguards, IAEA. A verification system within the framework of the international non-proliferation policy applied to peaceful uses of nuclear energy, and entrusted to the IAEA by its Statute, by the Treaty on the Non-Proliferation of Nuclear Weapons and by the Treaty for the Prohibition of Nuclear Weapons in Latin America (Tlatelolco Treaty).

safety analysis. (See *analysis, safety*.)

safety assessment. (See *assessment, safety*.)

Safety Fundamentals (IAEA Safety Series). A category of IAEA publications that comprise basic objectives, concepts and principles to ensure safety.

Safety Guides (IAEA Safety Series). A category of IAEA publications that supplement Safety Standards by giving recommendations relative to the fulfilment of basic requirements and principles on the basis of international experience.

Safety Practices (IAEA Safety Series). A category of IAEA publications that provide practical examples and detailed methods regarding procedures and techniques which can be used for the application of Safety Standards or Safety Guides.

Safety report. A document required from the operating organisation by the regulatory body containing information concerning a nuclear facility (*e.g.*, a waste repository), the site characteristics, design, operational procedures, etc., together with a safety analysis and details of any provisions needed to restrict risk to personnel and the public.

Safety Standards (IAEA Safety Series). A category of IAEA publications that establish, for particular activities or specific application areas, basic requirements which in the light of experience and the current state of technology must be satisfied to ensure safety.

scenario. An assumed set of conditions or events used in facility planning/design, assessment or regulatory activities.

scenario, worst-case. The scenario for release and transport of radionuclides from a nuclear facility (*e.g.*, a waste storage or disposal facility) to the biosphere that represents the most severe accident situation conceivable on the basis of pessimistic but still realistic assumptions. A single "worst-case" scenario may be difficult to define. Thus, a set of "conservative, but realistic" scenarios is frequently used in sensitivity and uncertainty analyses for safety assessment to cover other scenarios with minor consequences.

scrubber. The piece of equipment used for removing desired particulates from gaseous effluents by passing them through a body, stream or spray of water. (See also *HEPA filter* and *waste, gaseous*.)

seal. The engineered barrier placed in passages within and leading to a repository to isolate the waste and to prevent seepage or leakage of water into or radionuclide migration from the repository area. Sealing is performed as part of the repository closure.

sealed source. A radioactive source designed in such a form that the probability of dispersion of its radioactivity contents is extremely low. Sealed sources may be used, *i.e.*, in teletherapy and brachytherapy, and in scientific devices which contain radioactive substances, as well as in a number of medical and industrial applications.

secondary waste. (See *waste, secondary*.)

segregation. An activity where waste or materials (radioactive and exempt) are separated or are kept separate according to radiological, chemical and/or physical properties which will facilitate waste handling and/or processing. It may be possible to segregate radioactive from exempt material and thus reduce the waste volume.

sentencing. An activity to segregate materials and send them for selected processing and/or disposal based on a complete understanding of their physical, chemical and radiological characteristics.

shielding. A material interposed between a source of radiation and persons, or equipment or other objects, in order to absorb radiation and thereby reduce radiation exposure.

shipping. (See *transportation*.)

shipping cask. (See *cask*.)

short-lived waste. (See *waste, short-lived*.)

shutdown. The permanent or temporary termination of a process or operation. (See also *closure*.)

site. The area containing, or under investigation for its suitability to construct, a nuclear facility (*e.g.*, a repository). It is defined by a boundary and is under effective control of the operating organisation.

site characterisation. The detailed surface and subsurface investigations and activities at candidate disposal sites to obtain information to determine the suitability of and to evaluate long-term performance of a waste disposal facility at the site.

siting. The process of selecting a suitable disposal site. The process comprises the following stages:

(a) Concept and planning;
(b) Area survey;
(c) Site characterisation;
(d) Site confirmation.

sludge. The suspended particles in the waste solution that are separated by sedimentation or by other solid/liquid separation processes.

solidification. The immobilisation of gaseous, liquid or liquid-like materials by conversion into a solid waste form, usually with the intent of producing a physically stable material that is easier to handle and less dispersible. Calcination, drying, cementation, bituminisation and vitrification are some of the typical ways of solidifying liquid waste. (See also *conditioning* and *immobilisation*.)

solidified radioactive waste. (See *waste, solidified radioactive*.)

source. Any physical entity that may cause radiation exposure, for example by emitting ionising radiation or releasing radioactive material.

source reduction. A prominent component of a waste minimisation strategy, involving plant and equipment design and process control, and aiming at minimising amounts of waste generated during facility operation, when designing a new facility.

specific activity. The activity of a radioisotope per unit mass of a material, either:

(a) In which the radioisotope occurs; or

(b) Consisting of only that isotope.

specifications. The series of detailed requirements to be satisfied by a product, a service, a material or process, indicating the procedure by means of which it may be determined whether the specified requirements are satisfied. (See also *criteria* and *requirements*.)

spent fuel. (See *fuel, spent*.)

spent-fuel package. The conditioned spent fuel in a form suitable for transportation, storage and/or disposal.

storage, interim. The placement of waste in a nuclear facility where isolation, environmental protection and human control (*e.g.*, monitoring) are provided with the intent that the waste will be retrieved for exemption or processing and/or disposal at a later time.

storage, dry. The placement of solidified heat-generating waste (*e.g.*, spent fuel) in a nuclear facility, that allows for the removal of decay heat through the convection of air (passive or active), with the intent that the waste will be retrieved for processing and/or disposal at a later time.

storage, wet. The placement of solidified heat-generating waste (*e.g.*, spent fuel) in a water filled pool storage facility, either at the site of a nuclear reactor or away from reactor, with the intent that the waste will be retrieved for processing and/or disposal at a later time.

subsurface water. All water in both saturated and unsaturated zones beneath the land surface.

surface water. Any water which fails to penetrate into the soil and flows along the surface of the ground, eventually entering a lake, a river or the sea.

surveillance. The series of activities performed to ensure that conditions at a nuclear facility remain within the authorised limits. For a near-surface disposal facility, surveillance normally continues past the periods of operation and closure. (See also *monitoring* and *close-out*.)

survey, radiation. A systematic investigation and measurement of radiation and/or contamination levels.

survey, area (siting process). One of the stages of siting a waste repository, during which a broad region is examined to eliminate unsuitable areas and to identify other areas which may contain suitable sites. (See also *siting*.)

systems approach. (See *integrated approach*.)

testing. The examination, review, analysis or investigation of the capability of an item to meet specified requirements by subjecting the item to a set of physical, chemical, environmental and/or operational conditions.

transport, radionuclide. The action of a particular vector that results in movement (migration) of radionuclides in the geosphere, *e.g.*, radionuclide transport by groundwater. This usage does not include intentional transportation of radioactive materials by man (transportation of nuclear waste in casks, etc.). (See also *migration*.)

transportation. The series of operations and conditions associated with and involved in the movement of radioactive material by any mode on land, water or in the air. The terms transport and shipping are also used.

transuranic waste. (See *waste, transuranic*.)

treatment. The series of operations intended to benefit safety and/or economy by changing the characteristics of the waste. Three basic treatment objectives are:

(a) Volume reduction;

(b) Removal of radionuclides from the waste;

(c) Change of composition.

After treatment, the waste may or may not be immobilised to achieve an appropriate waste form.

TRU. The abbreviation for transuranic. (See *waste, transuranic*.)

underground disposal. (See *disposal, near-surface* and *disposal, geological*.)

unrestricted release or **use**. A designation, by the regulatory body in a country or state, that enables the release or use of equipment, materials, buildings or the site without radiological restriction. (See also *restricted release*.)

validation (of a model). A process carried out by comparison of model predictions with field observations and experimental measurements. A model is considered validated when sufficient testing has been performed to ensure an acceptable level of predictive accuracy over the range of conditions over which the model may be applied. (Note that the acceptable level of accuracy is judgmental and will vary depending on the specific problem or question to be addressed by the model) (See also *verification* and *calibration*.)

vault. An above-ground or below-ground reinforced concrete structure containing an array of storage cavities, each of which could hold one or more spent fuel canisters or waste packages. Shielding is provided by the concrete of the structure. Heat removal is principally by forced or natural movement of gases over the exterior of the cavities. Heat rejection to the atmosphere is either direct or via a secondary cooling system.

verification (of a model). The process of showing that a mathematical model, or the corresponding computer code, behaves as intended, *i.e.*, that it is a proper mathematical representation of the conceptual model and that the equations are correctly encoded and solved. (See also *validation*.)

viscosity. The tendency of a fluid to resist relative motion within itself; the induced stresses dissipate energy in the fluid. A highly viscous liquid drags in a molasses-like manner. The SI unit is newton per second per square metre ($N.s/m^2$).

vitrification. The incorporation of materials into a glass or glass-like form. Vitrification is commonly applied to the solidification of liquid high-level waste from the reprocessing of spent fuel. (See also *glass*.)

vitrified waste. (See *waste glass*.)

volume reduction. The decrease in the physical volume of waste. Examples of methods to achieve volume reduction are compaction, incineration, evaporation and decontamination. Volume reduction results in an increase in radionuclide concentration. (See also *minimisation*.)

waste In the context of this glossary, the term "waste" refers to radioactive waste unless otherwise specified. (See *waste, radioactive*.)

waste, alpha-bearing. Any radioactive waste containing one or more alpha emitting radionuclides, in quantities and/or concentrations above clearance levels. Alpha-bearing waste can be short-lived or long-lived.

waste, decommissioning. Any radioactive waste from decommissioning activities.

waste, exempt. With regard to radioactive waste management, waste that is released from nuclear regulatory control in accordance with clearance levels because the associated radiological hazards are considered negligible. The designation may be in terms of activity concentration and/or total activity and may include a specification of the type, chemical/physical form, mass or volume of waste. (See also *clearance levels* and *exclusion* and *exemption*.)

waste, gaseous. An airborne and gaseous stream containing radionuclides. Depending on the level of activity, gaseous waste is either discharged (*e.g.*, after treatment) or is retained for further processing and disposal.

waste, heat-generating. Any waste which is sufficiently radioactive that the energy of its decay significantly increases its temperature and the temperature of its surroundings. For example, spent fuel and vitrified high-level waste generate heat and thus require cooling for several years.

waste, high-level (HLW). Either:

(a) The radioactive liquid containing most of the fission products and actinides originally present in spent fuel and forming the residue from the first solvent extraction cycle in reprocessing and some of the associated waste streams;

(b) Solidified high-level waste from (a) above and spent fuel (if it is declared a waste); or

(c) Any other waste with an activity level comparable to (a) or (b).

High-level waste in practice is considered long-lived. One of the characteristics which distinguishes HLW from less active waste is its level of thermal power.

waste, intermediate-level. (See *waste, low and intermediate-level*.)

waste, liquid. Any radioactive waste in liquid form which may contain dissolved, colloidal or dispersed solids. Because liquids are mobile and dispersible, solidification is generally expected.

waste, long-lived. Any radioactive waste containing long-lived radionuclides having sufficient radiotoxicity in quantities and/or concentrations requiring long-term isolation from the biosphere. The term "long-lived radionuclide" refers to half-lives usually greater than 30 years. (See also *waste, alpha-bearing* and *waste, high-level* and *waste, short-lived*.)

waste, low-level (LLW). (See *waste, low and intermediate-level*.)

waste, low and **intermediate-level**. Any radioactive waste in which the concentration of or quantity of radionuclides is above clearance levels established by the regulatory body, but with a radionuclide content and thermal power below those of high-level waste. Low and intermediate-level waste is often separated into short-lived and long-lived waste. Short-lived waste may be disposed of in near-surface disposal facilities. Plans call for the disposal of long-lived waste in geological repositories.

waste, mixed. Any radioactive waste that contains non-radioactive toxic or hazardous materials that could cause undesirable effects in the environment. Such waste has to be handled, processed and disposed of in such a manner that takes into account the chemical as well as its radioactive components.

waste, non-nuclear industry. Any material arising from the use and handling of material containing naturally occurring radionuclides (*e.g.*, phosphate mining) and for which there is no use foreseen by the producer or handler - as opposed to waste produced in the nuclear fuel cycle.

waste, primary or **raw**. Any waste unchanged from the form and quantity in which it was generated - waste that has not been processed. (See also *treatment*.)

waste, radioactive. For legal and regulatory purposes, material that contains or is contaminated with radionuclides at concentrations or activities greater than clearance levels as established by the regulatory body, and for which no use is foreseen. (It should be recognised that this definition is purely for regulatory purposes, and that material with activity concentrations equal to or less than clearance levels is radioactive from a physical viewpoint, although the associated radiological hazards are considered negligible.)

waste, reactor. Any waste resulting from the operation of a nuclear power plant.

waste, secondary. A form and quality of waste that results as a by-product from processing of waste.

waste, short-lived. Any radioactive waste which will decay to a level considered to be insignificant from a radiological viewpoint in a time period during which institutional control can be expected to last. Radionuclides in short-lived waste will generally have half-lives shorter than 30 years. (See also *waste, long-lived*.)

waste, solidified radioactive. Any liquid waste that has been converted into a solid waste form, by calcination, drying or incorporation into a solid matrix such as glass, cement, bitumen or polymer. (See also *conditioning* and *immobilisation* and *solidification*.)

waste, transuranic. Any alpha-bearing waste containing nuclides with atomic numbers above 92, in quantities and/or concentrations above clearance levels. (See also *waste, alpha-bearing* and *waste, long-lived*.)

waste, vitrified. (See *waste glass*.)

waste acceptance criteria. The criteria relevant to the acceptance of waste packages for handling, storage and disposal.

waste acceptance requirements. The requirements relevant to the acceptance of waste packages for handling, storage and disposal. (See also *requirements*.)

waste arisings. The quantity of waste generated by any stage in the nuclear fuel cycle, by research reactors and by the production and utilisation of radioisotopes.

waste characterisation. The determination of the physical, chemical and radiological properties of the waste to establish the need for further adjustment, treatment, conditioning, or its suitability for further handling, processing, storage or disposal.

waste concentrate. The product resulting from the treatment (*e.g.*, by evaporation or chemical precipitation) of a liquid waste solution. (See also *treatment*.)

waste conditioning. (See *conditioning*.)

waste container. (See *container, waste*.)

waste disposal. (See *disposal*.)

waste disposal system. The entire disposal environment as a whole, including the geological surroundings, the engineering system of a repository (*e.g.*, barriers) and the waste packages.

waste form. The waste in its physical and chemical form after treatment and/or conditioning (resulting in a solid product) prior to packaging. The waste form is a component of the waste package.

waste generator. The operating organisation of the facility where the waste is generated. (See also *operator*.)

waste handling. The physical manipulation (sorting, moving, etc.) of waste or waste packages.

waste immobilisation. (See *immobilisation.*)

waste inventory. A detailed, itemised record maintained by the operator in accordance with regulations. The inventory may contain data such as physical quantity (the number of waste canisters or containers), the activity of the waste, the radionuclide content and/or waste form characteristics.

waste management, radioactive. All activities, administrative and operational, that are involved in the handling, pre-treatment, treatment, conditioning, storage and disposal of waste from a nuclear facility. Transportation is taken into account.

waste minimisation. (See *minimisation.*)

waste package. The product of conditioning that includes the waste form and any container(s) and internal barriers (*e.g.*, absorbing materials and liner), as prepared in accordance with requirements for handling, transportation, storage and/or disposal.

waste package specifications. The set of quantitative requirements to be satisfied by the waste package for handling, transportation, storage and disposal.

waste pre-treatment. (See *pre-treatment.*)

waste processing. Any operation that changes the characteristics of a waste, including waste pre-treatment, treatment and conditioning.

waste storage tank, high-level. A tank for the storage of high-level liquid waste. Such tanks are likely to be double-walled, contain provisions for cooling the waste and be shielded. They will be subjected to strict quality assurance procedures.

waste treatment. (See *treatment.*)

wet storage. (See *storage, wet.*)

worst-case scenario. (See *scenario, worst-case.*)

Annex 6

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During the two years of the co-ordinated action with IAEA, EC and OECD/NEA, the following persons contributed to the development of the standardised list of cost items and cost item definitions, or participated in the discussions related to harmonisation of the obtained or developed items and/or definitions.

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