Date: ~~1~~ 12 ~~September~~ November 2014

IAEA SAFETY STANDARDS
for protecting people and the environment

Status: STEP ~~7~~8

First review of the draft publication by the review Committees

Document combined by G. Linsley 2-6 Aug 2010
Reviewed by Ralf/Ted 9-13 Aug 2010
Reviewed by Melanie, Patrice, Nick 19 Aug 2011
Revised based on 27-31 August CS with Patrice/Ralf/Ted/Peter
Revised during CS 2-6 Sep 2013 – Patrice, Bruce, Vladan
Revised during CS 31 Mar - Apr 4 2014 - PF, MP, KL, RV, TS, and VL
Prepared for the CS 14-18 July 2014 by VL
Revised during CS 14-18 July 2014 – PF. MP, KL, RV, TS, JK and VL
Revised by VL 21-24 July 2014, comments by KL 27 July
Finalized by DR and VL 4-7 August 2014
CCM comments 28 August incorporated
SSCs comments resolved Oct-Nov 2014

Decommissioning of Nuclear Installations

Draft Safety Guide
DS452 (Revision of Safety Guides WS-G-2.1 and 2.4)

IAEA
International Atomic Energy Agency

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. With the maturing of the nuclear industry in the past decades, many States have constructed and commissioned facilities[1] that use radioactive materials or sources in a variety of applications ~~were constructed and commissioned in the past~~. Many of them are reaching the end of their operational lifetimes and will be facing permanent shutdown[2] in the near future. Other factors, such as national energy policies or changing energy markets may result in facilities permanently shutting down earlier than planned. These facilities will need to be decommissioned, after permanent shutdown. In order to provide a consistent approach to the decommissioning of both new and existing facilities, as well as to incorporate lessons learned from previous decommissioning projects, Member States have expressed the desire for decommissioning guidance within the context of an internationally accepted programme of safety publications.

1.2. As defined in the IAEA Safety Requirements GSR Part 6 [1], "Decommissioning refers to administrative and technical actions taken to allow removal of some or all of the regulatory controls from a facility...". While decommissioning is the last stage in facilities' lifetime, aspects of decommissioning, such as designing for ~~waste~~ minimization of radioactive waste, decommissioning planning, and record keeping, need to be considered throughout facilities' lifetime.

1.3. Decommissioning actions involve decontamination, dismantling and removal of structures, systems and components (SSCs), including management of radioactive waste and radiation protection, as well as radiological surveys to support decommissioning. These actions are carried out to achieve a progressive and systematic reduction in radiological hazards during decommissioning and are taken on the basis of planning and assessment to ensure safety and protection of ~~people~~ the workers, the public and the environment, and to demonstrate that the facility meets the planned decommissioning end state.

1.4. Decontamination, dismantling, and other decommissioning actions may be carried out immediately following permanent shutdown or may be deferred until after a safe enclosure period. As a consequence, the time period for conduct of decommissioning actions may typically range from a few months, for simple and small facilities, to decades (for example, to allow for radioactive decay), for large and complex nuclear installations. ~~and~~Decommissioning may include phased release of parts

[1] In this publication, "facility" or "facilities" means buildings and their associated land and equipment, including the surface and subsurface soil, and any surface or subsurface water or aquifers.

[2] The term "permanent shutdown", as used in this publication, means that the facility has ceased operations and operation will not be recommenced.

of the facility from regulatory control during conduct of decommissioning actions. On completion of all planned decommissioning actions and on reaching the planned end state, the authorization for decommissioning can be terminated and the sites and remaining structures of the former facilities, if any, will be available for unrestricted or restricted re-use.

1.5. Depending on the national regulatory system, decommissioning of nuclear installations might be subject to the granting of a license for decommissioning or an authorization to perform decommissioning actions in the framework of a license granted for the whole lifecycle of the facility. In this Safety Guide, the term "license for decommissioning" is used for both regulatory concepts. ~~For large and complex facilities, which are the subject of this Safety Guide, the authorization for decommissioning usually takes a form of a license. Thus in this Safety Guide the term "license for decommissioning" is used instead of "authorization for decommissioning"~~.

1.6. Decommissioning of nuclear installations is usually conducted as a project. A decommissioning project is a collaborative initiative, involving supporting analyses and studies, which is carefully planned to ensure safety of planned actions, and to achieve partial or complete removal of regulatory controls from an installation. It is a temporary rather than permanent work system that is constituted by teams within or across organizations to accomplish safe decommissioning. A decommissioning project usually starts ~~once a project organization is established. That typically happens~~ when preparation of the final decommissioning plan is initiated or, in some cases, when a decommissioning license is granted.

1.7. Adequate planning and implementation of decommissioning actions is required to ensure the protection of the workers, the public and the environment. With the increasing expansion of the nuclear industry worldwide and with many nuclear facilities nearing the end of their operational lifetimes, experience has shown the importance of considering planning aspects of decommissioning for new facilities during siting, design and construction. When an end of operation approaches or immediately after permanent shutdown occurs, detailed planning for decommissioning (i.e., development of a final decommissioning plan) is needed prior to the commencement of decommissioning actions. However, there are still some existing facilities close to the end of their operational life or already permanently shutdown, which do not have a decommissioning plan in place, so for such facilities ~~there is a need to develop~~ a final decommissioning plan should be developed as soon as possible.

1.8. This Safety Guide is part of the set of publications within the framework of the IAEA Safety Standards Programme, which, amongst other activities, addresses decommissioning. This set includes Safety Fundamentals [2], Safety Requirements [1] and Safety Guides in the IAEA Safety Standards Series.

1.9. This Safety Guide supersedes Decommissioning of Nuclear Power Plants and Research

Reactors, issued in 1999[3], and Decommissioning of Nuclear Fuel Cycle Facilities, issued in 2001[4]. Guidance concerning the decommissioning of medical, industrial and research facilities can be found in [3].

1.10. Requirements and guidance on the radiation protection, regulatory control of discharges of radioactive effluents to the environment and associated management of radioactive waste are provided in the IAEA Safety Standards [4,5].

1.11. Requirements and guidance on radiological criteria for the removal of regulatory control from materials, equipment and sites is provided in the IAEA Safety Standards [4,6,7].

1.12. Requirements and guidance on transport of radioactive material and the associated environmental and safety aspects are covered in the IAEA Safety Standards [8,9].

OBJECTIVE

1.13. The objective of this Safety Guide is to provide guidance to regulatory bodies, operators, technical support organizations and other interested parties on planning for decommissioning, conducting decommissioning actions, demonstrating completion of decommissioning, and terminating the license for decommissioning of nuclear installations. It aims to assist Member States in ensuring that decommissioning of these installations is conducted in a safe and environmentally acceptable manner in accordance with good international practice.

SCOPE

1.14. This Safety Guide addresses decommissioning considerations and actions for safe decommissioning of nuclear installations (nuclear fuel fabrication plants, research reactors including subcritical and critical assemblies, nuclear power plants, spent fuel storage facilities, enrichment plants, reprocessing facilities and facilities for predisposal management of radioactive waste). The definition of installations does not include facilities for processing of uranium or thorium ores; however, much of the guidance provided in this Safety Guide may be applicable to these types of facilities. –This Safety Guide does not address decommissioning of mining facilities or medical, industrial and non-reactor research facilities. For radioactive waste disposal facilities it provides information relevant for decommissioning of support infrastructure, i.e. parts of the facilities other than the disposal section itself. The disposal section is not subject to decommissioning, but to closure.

---

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Power Plants and Research Reactors, IAEA Safety Standard Series No. WS-G-2.1, IAEA, Vienna (1999).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Fuel Cycle Facilities, IAEA Safety Standard Series No. WS-G-2.4, IAEA, Vienna (2001).

1.15. Decommissioning considerations and actions addressed in this Safety Guide take place from siting and design of an installation until termination of license for decommissioning. On the basis of general considerations regarding safety, radiation protection, protection of human health and the environment, as well as related regulatory aspects, this document provides guidance on the selection of a decommissioning strategy, development of decommissioning plans and implementation of the final decommissioning plan~~management principles~~. This document discusses application of the graded approach in decommissioning of nuclear installations, key decommissioning considerations during the installation lifecycle, planning and safety assessment for decommissioning, financing of decommissioning, transition from operation to decommissioning, management of decommissioning, conduct of decommissioning actions, completion of decommissioning, and termination of the license for decommissioning.

1.16. Decommissioning of nuclear installations involves a wide range of actions in the presence of numerous radiological and non-radiological hazards and associated risks. The level of detail for meeting decommissioning requirements varies depending on the type and complexity of the nuclear installation, its radioactive inventory and the potential hazards expected during decommissioning, but the general approach to decommissioning remains the same. This general approach is adapted to the specific installation's situation by the application of a graded approach, which may impact the selection of the decommissioning strategy, planning details, conduct of decommissioning actions and ~~final~~ end state.

1.17. This Safety Guide addresses the radiological risks, resulting from actions associated with decommissioning of nuclear installations, and management of waste and materials, arising from the decommissioning actions. It is developed primarily for installations with a normal operational history, ~~without significant abnormal events during operation,~~ which was followed by a planned shutdown. However, many of the considerations are also applicable to decommissioning after an ~~abnormal event~~accident that has resulted in serious damage or extensive contamination of the installation's premises and the surrounding area. In these cases, this Safety Guide may be used as a basis for developing special decommissioning provisions to address post-accident situations.

1.18. The management of fresh or spent nuclear fuel, the management of other process materials used during operation, and the management of radioactive waste generated during the operational phase are activities which are repeatedly or continuously performed during operation of a nuclear installation under the operational license. Thus, these actions are not usually considered part of a decommissioning project. If removal of operational waste and spent fuel is not possible prior to decommissioning, it should be reflected in the final decommissioning plan and should be performed under the ~~decommissioning~~ license for decommissioning or under a separate operational license for storage of operational waste and spent fuel~~, usually as the first phase of decommissioning~~. Other IAEA publications address these aspects [10-13].

1.19. It is important to recognize that the hazards associated with nuclear installations often involve chemical, biological and industrial hazards, in addition to the radiological hazards, and consideration needs to be given to achieving a balanced approach in addressing all hazards. For example, non-radiological hazards, such as those due to the release of asbestos or polychlorinated biphenyl (PCB), can also arise during decommissioning actions. This Safety Guide does not explicitly address non-radiological hazards, but they need to be given due consideration ~~during~~ in all aspects of decommissioning.

1.20. In case when only part of an installation is being decommissioned, this Safety Guide only applies to decommissioning actions. However, the potential safety implications with respect to interaction between any decommissioning actions and any continuing installation operations need to be addressed.

1.21. Management of mining and milling residues, such as tailings and waste rock, is outside the scope of this publication and is considered in other IAEA Safety Standards [14]. While this Safety Guide covers facilities associated with processing and interim storage of radioactive waste, it does not address disposal of radioactive waste and closure of waste repositories. Those issues are considered in other IAEA publications [15-18].

1.22. This publication applies to planned authorized activities. Although some reference is made to remediation in the context of facility decommissioning, this document does not apply to remediation situations, as these are considered in other IAEA Safety Standards [4, 19].

1.23. Security aspects have to be considered during decommissioning, but they are outside the scope of this publication. The IAEA issues recommendations on nuclear security in the IAEA Nuclear Security Series [20]. Requirements pertaining to interfaces of safety with nuclear security are established in Ref. [21]. Safeguards aspects may continue to exist during decommissioning (as stated in paragraph 4.29), especially for nuclear fuel cycle facilities, but are outside the scope of this publication.

STRUCTURE

1.24. The structure of this Safety Guide is arranged to reflect both the common features of decommissioning, as well as those which are special to the following categories of nuclear installations: (i) nuclear power plants and research reactors and (ii) other nuclear fuel cycle facilities. ~~Chapter~~ Section 2 addresses the issues related to protection of people and the environment, including the application of a graded approach for the whole decommissioning process and optimization of protection and safety. ~~Chapter~~ Section 3 describes responsibilities of the major parties involved in decommissioning. Management of decommissioning is discussed in ~~Chapter~~ Section 4, while ~~Chapter~~ Section 5 discusses the selection of a decommissioning strategy. ~~Chapter~~ Section 6 addresses

financing of decommissioning. Planning for decommissioning during all stages of installation lifecycle is discussed in Section~~Chapter~~ 7. Section~~Chapter~~ 8 describes conduct of decommissioning of nuclear installations. Section~~Chapter~~ 9 discusses completion of decommissioning, including surveys and reporting to support termination of decommissioning license. This Safety Guide follows the structure of the General Safety Requirements Part 6 [1].

1.25. Annex ~~1~~ I provides an outline of a final decommissioning plan. Annex ~~2~~ II provides an example of the content of a final decommissioning report. Annex ~~3~~ III provides an example of the content of a final radiological survey report. Annex ~~4~~ IV provides a list of typical supporting documents to the final decommissioning plan. Annex ~~5~~ V provides examples of considerations for safety assessment during decommissioning of nuclear installations. Annex ~~6~~ VI provides a list of publications, which contain additional information on specific organizational, technical and safety topics related to decommissioning.

2. PROTECTION OF PEOPLE AND PROTECTION OF THE ENVIRONMENT

Requirement 1 of GSR Part6 [1]: Optimization of protection and safety in decommissioning

Exposure during decommissioning shall be considered to be a planned exposure situation and the relevant requirements of the Basic Safety Standards shall be applied accordingly during decommissioning. [1]

2.1. The principles of radiation protection and safety for radiation sources are provided in IAEA Safety Standards Series publication [4,22]. During decommissioning, the workers, the public and the environment must be properly protected against radiological risks.

2.2. Arrangements for radiation protection programme during decommissioning should be included as part ofaddressed in the decommissioning plan and should be based on the national requirements for radiological radiation protection.. Optimization should be implemented, taking into account the specifics of the decommissioning project.

2.3. Although the principles and aims of radiation protection during operation and during decommissioning are fundamentally the same, the methods and procedures for implementing the radiation protection may differ due to change of physical conditions of the installation during decommissioning, access to highly activated components or contaminated equipment or areas, and removal of SSCs. During decommissioning actions, the principal focus of radiation protection is the protection of workers against occupational radiation exposure from planned and unplanned situations. Special situations may need to be considered, which may require the use of temporary measures, specialized equipment and the implementation of certain non-routine procedures.

2.4. Proper consideration should be given to the protection of workers, the public and the environment against consequences of incidents that may occur during decommissioning. A multilevel system of sequential, independent provisions for protection and safety (defence in depth), that is commensurate with the likelihood and the magnitude of the potential exposures, should be maintained.

2.5. An example of an incident where protection of workers should be considered may include workers having to work closely to contaminated components being dismantled that could lead to a significant exposure or spread of contamination. Special attention should be given to prevent and mitigate exposure to workers by implementing specific and appropriate personnel protective controls. Personnel protective equipment may need to be re-designed to make it appropriate to specific work conditions, for example to achieve enhanced resistance of the protective gloves to puncture, in order to avoid injuries with internal contaminationwhich may result in an intake of radionuclides.

2.6. Incidents or accidents that may occur during decommissioning may have radiological impact outside the boundaries of the installation undergoing decommissioning. To protect on-site personnel,

the public and the environment against the spread of radioactive material, active safety systems like ventilation and fire protection systems may need to be retained for some period during decommissioning. In case of on-site or off-site contamination, actions may be necessary to remediate the contamination areas or to confine releases of radioactive substances, for instance contaminated water. Such issues are not addressed in this ~~safety~~ Safety ~~guide~~Guide, as they are well addressed in other IAEA ~~safety~~ Safety ~~standards~~ Standards [4,19, ~~22~~23].

2.7. Remedial~~tion~~ actions for the immediate area surrounding an installation that is part of the operating authorization may be part of the decommissioning project when a nuclear installation has been permanently shut down after an accident. Decommissioning does not include remediation actions outside the area included in the operating authorization. Special attention should be paid to the removal of emergency provisions which may have been implemented to mitigate the consequences of the accident. Records and data of the nature and extent of such existing safety provisions should be considered during planning for decommissioning.

2.8. In addition to protection of workers and the public, licensees should consider protection of the environment during planning and implementing decommissioning. Adequate controls should be defined to ensure mitigation of significant impacts to the environment, both on-site and to the surrounding area. An environmental impact assessment[5] should be developed concurrently with the final decommissioning plan, consistent with national requirements. Environmental protection should be maintained during decommissioning and after its completion, if a site is released with restrictions on its future use. Specific provisions should be implemented by the licensee, depending of the final ~~end state~~end state described in the final decommissioning plan.

2.9. The licensee should indicate in the environmental impact assessment for decommissioning, which supports the final decommissioning plan, ~~the final decommissioning plan~~ how compliance with applicable requirements for protection of the environment will be ensured, including responsibilities and measures for monitoring, control and surveillance during decommissioning and after its completion, if needed.

Requirement 2 of GSR Part6 [1]: Graded approach in decommissioning

[5] Environmental impact assessments are not defined in the IAEA safety standards, although they are included in many international instruments and national legislations and regulations. In the context of a Safety Guide in preparation on radiological environmental impact assessment for facilities and activities, the definition from the Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention) is adopted. According to Article 1 of the Espoo Convention, 'environmental impact assessment' means a national procedure for evaluating the likely impact of a proposed activity on the environment, while 'impact' means any effect caused by a proposed activity on the environment, including human health and safety, flora, fauna, soil, air, water, climate, landscape and historical monuments or other physical structures, or the interaction among these factors. It also includes effects on cultural heritage or socioeconomic conditions resulting from alterations to those factors.

A graded approach shall be applied in all aspects of decommissioning in determining the scope and level of detail for any particular facility, consistent with the magnitude of the possible radiation risks arising from the decommissioning. ~~[1]~~

2.10. The graded approach should be applied during all aspects of decommissioning in a way that does not compromise safety and ensures compliance with all relevant safety requirements and criteria.

2.11. The application of a graded approach supports effective use of resources, and helps to optimize efforts invested in planning, development of decommissioning documentation, conduct of supporting analyses and assessments, and conduct of decommissioning actions, while complying with the safety requirements. Depth of the analyses and level of details in the documentation should be commensurate with and should take into account factors such as:

- Size and type of the installation (including its complexity and history, for example burial of historical waste from past practices on-site);
- Physical state of the installation, specifically the integrity of the SSCs. In particular, the extent to which ageing or abandonment may have compromised building structures, for example, due to a long period of poor maintenance;
- Radiological (source term), biological and chemical inventories and hazards associated with the decommissioning of the installation;
- Lifecycle stage of the installation (siting, design, construction, commissioning, operation, shutdown or decommissioning), i.e., if analyses are needed for preparation of an initial decommissioning plan at a design stage or for a preparation of a final decommissioning plan prior to conduct of decommissioning actions;
- Scope of the project (e.g., for a part of an installation, a whole installation, a single installation at a multi-facility site or an entire multi-facility site); extent to which the proposed decommissioning actions could adversely affect ongoing operations with safety significance elsewhere at the facility or at nearby facilities;
- Uncertainty of information (e.g., the quality and extent of the characterization of the installation) and the reliability and availability of relevant supporting information (e.g., drawings and records of modifications) to be used as input data for planning and associated safety assessment;
- Complexity and risks associated to the decommissioning phases and actions; and
- ~~Final e~~End state of the decommissioning of the installation (e.g., unrestricted or restricted use, total removal of all the structures or reuse of some structures or parts of the facility).

2.12. Successful decommissioning depends on adequate and organized planning and systematic conduct of the decommissioning actions in accordance with the license conditions. Grading has an impact throughout the decommissioning project, specifically in the following areas:

- Characterization efforts (scope and extent);
- Documentation, e.g., the scope of the final decommissioning plan, its content and the degree of detail necessary (including the safety assessment) may vary depending on the complexity and hazard potential of the installation, and should be consistent with national regulations;
- Licensing process;
- Identification of SSCs (already present or new ones), which are needed for the safe decommissioning of the nuclear installation, and associated control requirements;
- Control of decommissioning actions;
- Monitoring programme;
- ~~Licensing process;~~
- Management of the decommissioning project (e.g., organizational structure); specific guidance on management of decommissioning is presented in ~~Chapter~~ Section 4;
- Staffing and training; ~~and~~
- Regulatory oversight; and
- Involvement of interested parties.

2.13. Regulatory oversight should be performed by the regulatory body during decommissioning. The frequency and scope of inspections should be established to be consistent with the intensity of decommissioning actions and associated risks, and can be significantly reduced during periods of safe enclosure. In some cases, regulatory oversight may continue after the completion of decommissioning and termination of the license for decommissioning, for example in case of restricted release of the site.

2.14. Depending ~~of~~ on the nature and extent of the decommissioning actions to be performed, regulatory oversight should focus on the actions having a significant impact on safety or on the milestones during decommissioning such as:

- Main modification of the installation with removal from services of SSCs important for safety or commissioning of new SSCs;
- Transition between phases of the decommissioning project, especially when an ~~end state~~end state of a phase is decisive for the start of the works of the next phase;
- Commissioning and operation of supporting facilities for management of radioactive waste;
- Campaign of removal of radioactive waste;
- Release of land and buildings from regulatory control.

2.15. During conduct of decommissioning, the licensee may implement ~~an~~ internal ~~management system~~procedures to allow minor modifications of decontamination and dismantling techniques, which do not have a significant impact on safety. Such ~~management system~~procedures should be approved and should be subject to oversight by the regulatory body prior to and during its implementation, according to national requirements.

Requirement 3 of GSR Part6 [1]: Assessment of safety for decommissioning

Safety shall be assessed for all facilities for which decommissioning is planned and all facilities undergoing decommissioning. [1]

2.16. Decommissioning of nuclear installations is associated with numerous radiological and non-radiological hazards. In addition to existing radiological hazards associated with a permanently shutdown installation, decommissioning actions performed involve new hazards which must be considered, for example use of cutting tools or generation of airborne contamination and secondary radioactive waste[6]. Therefore, an important objective of decommissioning planning is to adequately assess and manage the safety aspects of decommissioning actions.

2.17. Safety assessment should be performed to support development of the final decommissioning plan and to support conduct of associated specific decommissioning actions by demonstrating that the safety and the protection of the workers and the public are optimized and that the exposures do not exceed relevant limits or constraints.

2.18. According to to the complexity of decommissioning actions and the duration of decommissioning project, the final decommissioning plan may be supported by a single safety assessment for the entire project, or by an overarching safety assessment (umbrella assessment), which covers the entire project and provides input and links to more detailed safety assessments that may be developed for each decommissioning phase or work package.

2.19. The safety assessment should be conducted to define protective measures, implementing an optimization approach for radiological radiation protection, with due regard to industrial safety, in accordance with the requirements [2324] and recommendations of the Safety Guide [2425].

2.20. The licensee should adequately control the work of any subcontractors involved in development of the safety assessment. The results of the safety assessment or part of the safety assessment, which may be developed by subcontractors, based on their relevant knowledge and experience in specific decommissioning techniques, should be reviewed, approved and implemented by the licensee, in accordance with the integrated management system, to ensure overall safety during decommissioning.

2.21. The results of safety assessments will determine which safety functions and related SSCs, that were necessary to ensure safety during the operational phase, will no longer be needed after operations has ceased. However, some of the safety functions will continue to be required during decommissioning, and decommissioning can also give rise to identification of new safety functions

[6] A form and quality of radioactive waste that results as a by-product from processing of the primary radioactive waste.

and commissioning of associated SSCs. An overarching safety assessment should demonstrate consistency of the safety measures during entire decommissioning, and should be updated when necessary, to reflect the ongoing changes in the status of the installation, as decommissioning works progress.

2.22. The safety assessment should demonstrate that interdependencies between planned decommissioning actions are taken into account, and that negative impact of one action to another, as well as generation of additional hazards is prevented.

~~2.21.~~2.23.

3. RESPONSIBILITIES ASSOCIATED WITH DECOMMISSIONING

3.1. The decommissioning process for nuclear installations involves several organizations, the key ones being the licensee, its contractors and sub-contractors, regulatory authorities and governmental institutions. This part of the Safety Guide addresses the responsibilities of the government, the regulatory body and the licensee during planning, conduct and completion of decommissioning of nuclear installations.

Requirement 4 of GSR Part6 [1]: Responsibilities of the government for decommissioning

The government shall establish and maintain a governmental, legal and regulatory framework within which all aspects of decommissioning, including management of the resulting radioactive waste, can be planned and carried out safely. This framework shall include a clear allocation of responsibilities, provision of independent regulatory functions and requirements in respect of financial mechanisms for decommissioning. [1]

3.2. In preparing and implementing the national policy for decommissioning, which may be part of the national policy for management of radioactive waste, the government should define the overall objectives of decommissioning. The policy should be developed by the government in cooperation with relevant organizations, including licensees, and in consultation with the public.

3.3. A framework for regulating decommissioning should be established in the national legislation. The enabling legislation should be straightforward, feasible and consistent with the relevant national policies, so that the need for its subsequent amendment is minimized. This is important because the process of amending the legislation is usually a slow and resource intensive one.

3.4. Although it is preferable to have regulatory responsibilities for decommissioning within a single regulatory body, such responsibilities are often in some Member States divided among several bodies already having responsibilities for protection and safety. It should be ensured that the regulation of all aspects of nuclear safety, radiation, nuclear, transport and, waste safety, industrial and environmental safety is covered adequately and that the responsibilities of the governmental bodies involved are clearly specified and allocated. The legislation should establish clear lines of authority and responsibility, so as to avoid gaps or overlaps.

3.5. One of the main responsibilities of the government is to ensure that mechanisms for providing adequate financial resources are put in place, so that an appropriate level of funding is available to decommission facilities, including nuclear installations, in a safe and timely manner.

3.6. If decommissioning has to be performed in a situation when the government has not established a legal and regulatory framework, for example to address safety issues related to deteriorating structures, it should be planned and managed on a case by case basis in consultation with the regulatory body(ies) having responsibility for nuclear safety, radiation, ~~nuclear,~~ transport and~~,~~ waste safety, industrial and environmental safety. In such cases, the licensee should consult the regulatory body with regard to development and implementation of a decommissioning plan.

Requirement 5 of GSR Part6 [1]: Responsibilities of the regulatory body for decommissioning

The regulatory body shall regulate all aspects of decommissioning throughout all stages of the facility's lifetime, from initial planning of decommissioning during the siting and design of the facility, to the completion of decommissioning actions and the termination of authorization for decommissioning. The regulatory body shall establish the safety requirements for decommissioning, including requirements for management of the resulting radioactive waste, and shall adopt associated regulations and guides. The regulatory body shall also take actions to ensure that the regulatory requirements are met. ~~**[1]**~~

3.7. When developing regulations, the regulatory body should identify clearly the facilities and activities to which regulatory requirements are to be applied consistently. The regulatory body must establish safety criteria and regulations for all aspects of decommissioning, including management of radioactive waste, should oversee their implementation and should control compliance by the licensees with the criteria and regulations during planning, conduct of decommissioning actions and completion of decommissioning, including termination of the license for decommissioning.

3.8. The regulatory body ~~is required to give consideration to~~should supplementing its regulations with guidance documents, where appropriate, to help the licensees in complying with the criteria and regulatory requirements.

3.9. The regulatory body should follow a consistent procedure for establishing, revising and revoking regulations and guides, involving interested parties. The regulatory body should ensure that regulations and guides are kept up to date and should establish procedures for their periodic review.

3.10. Experience in implementing the regulations should be examined and any problems or difficulties that may arise should be duly considered. The status of applicable requirements should also be examined in the light of the state-of-the-art of science and technology, e.g. new safety related developments and lessons learned from national and international decommissioning experience.

3.11. The regulatory body should develop a process for consideration of the license application for decommissioning, including the regulatory review process. This process should provide the identification of milestones, decision points and the period of time for the regulatory review. The process could include performing an acceptance review, performing review of the final

decommissioning plan and its supporting documents in accordance with national requirements. Interested parties ~~must~~ should be given an opportunity to comment on the final decommissioning plan and safety related supporting documents before the license is granted, on the basis of national regulations.

3.12. The regulatory body should develop ~~procedures~~ guidance that the licensee is expected to follow in preparing the license applications, as well as guidance on how the licensee could ensure the criteria and requirements are met so the decommissioning license can be terminated.

3.13. The regulatory body should require notification by the licensee of any significant changes to the planned actions as described in the final decommissioning plan and that might have ~~with~~ an implication to safety of the decommissioning or to the ~~final~~ end state. Such changes should be subject to an assessment by the licensee, with account taken of the nature and potential magnitude of the associated risk. The regulatory body ~~is required to~~should review this assessment and to consider an amendment to, or a renewal of the decommissioning license.

3.14. In order for decommissioning to be performed in a safe and efficient manner, the regulatory body ~~is required to~~should contribute to the definition of ~~identify~~ funding mechanisms that can be used to ensure that appropriate funds will be available when needed[7]. The amount of funds needed and the timeline for the expenditure of the funds should be based on a decommissioning cost estimate.

3.15. On-site inspection is one of the elements of the regulatory regime and ~~a significant portion of~~ the regulatory body~~'s~~ should allocate adequate resources ~~should be allocated~~ to this task. The regulatory body should develop an inspection programme, which should include the following key elements: a system of prioritizing inspections; on-site visits of inspectors; review of radiation safety assessments made by the licensees; investigation and follow-up of events; and submission of information on compliance with safety criteria by licensees. If not regulated separately, the inspection programme should include industrial safety elements as well.

3.16. The regulatory body should perform inspections during decommissioning using established inspection procedures. The regulatory body should inspect actions such as decontamination, dismantling, management of decommissioning waste, application of radiation protection measures, and monitoring performed to confirm compliance with the license, and the license conditions. Inspections should ensure compliance with the safety objectives and criteria defined in the final decommissioning plan, compliance with the results and conclusions of the detailed safety assessment and compliance with decommissioning limits and conditions. The regulatory body should especially ensure that the key decommissioning actions are inspected (e.g., dismantling of activated components,

[7] The definition of the funding mechanism may be the responsibility of other Governmental organizations.

removal of large and heavy components), as well as some specific actions which involve survey of an area that may be inaccessible in the future (e.g., subsurface areas).

3.17. The regulatory body should ensure that existing enforcement policy, addressing radiological health and safety, and protection of the environment, covers decommissioning aspects. The regulatory body should ~~issue detail~~develop and use procedures for determining and exercising enforcement actions~~, as well as the rights and obligations of the licensee~~.

~~3.17.~~3.18. The regulatory body should maintain communication with licensees to determine the future decommissioning timelines and schedules as well as changes in schedules. Knowledge of licensee timelines and changes to schedules allow the regulator to plan its activities and to ensure having appropriate staffing levels and experience to avoid regulatory-related decommissioning delays.

~~3.18.~~3.19. The regulatory body should inform the public and interested parties about the key decisions with regard to decommissioning of nuclear installations for the purpose of transparency and in order to address public concerns related to safety of decommissioning. Information should be provided to interested parties as soon as they are available [~~25~~26]. In addition, the regulatory body should get involved in public consultation in order to answer public's questions and concerns.

~~3.19.~~3.20. As stated in GSR Part 6 [1], ~~The~~ the regulatory body must establish the requirements for ensuring that records important for the planning and implementation of the decommissioning activities are collected and retained by the licensee. There are also records developed during the decommissioning project that will be important for legal purposes after the installation license has been terminated. ~~and t~~These records ~~need to~~should be identified and preserved, and the responsibility for their retention should be allocated clearly.

~~3.20.~~3.21. A good safety culture is an important part of a decommissioning project since actions are being performed that may not be routine and specialist personnel may be used to perform some of these actions. The safety culture may suffer and it is the responsibility of the regulatory body to promote the licensee to maintain a good safety culture throughout the life of the decommissioning project. In addition, the regulatory body should maintain its own management system and sufficient and trained staff, in order to ba able to fulfil its responsibilities for decommissioning.

Requirement 6 of GSR Part6 [1]: Responsibilities of the licensee for decommissioning

The licensee shall plan for decommissioning and shall conduct the decommissioning actions in compliance with the authorization for decommissioning and with requirements derived from the national legal and regulatory framework. The licensee shall be responsible for all aspects of safety, radiation protection and protection of the environment during decommissioning. ~~[1]~~

~~3.21.~~3.22. Prior to permanent shutdown of a nuclear installation, the licensee should ~~meet~~ discuss and agree with the regulatory body ~~to discuss~~ the timing of decommissioning, expectations of the regulatory body, proposed decommissioning actions, and applicable regulations and guidance. During the lifetime of an installation, ~~T~~the licensee should select a strategy for decommissioning that is consistent with national policies, prepare and maintain decommissioning plans (i.e. an initial decommissioning plan and a final decommissioning plan), and ensure that adequate financial resources will be in place for the decommissioning project when needed. It has been demonstrated that an early co-operation between the regulatory body and the licensee improves the planning and implementation of decommissioning, and can reduce the delays in obtaining regulatory approval.

~~3.22.~~3.23. In preparing for decommissioning, the licensee may perform activities such as removal of spent fuel, operational and historical waste stored on-site during operation. Such activities should be bounded by the current operational license of the installation to ensure the nuclear installation is maintained in safe configuration during transition from operation to decommissioning, until the final decommissioning plan is approved for implementation and decommissioning license is granted.

3.24. The licensee is responsible for ~~maintaining~~ ensuring that trained and qualified workers are available to safely conduct decommissioning actions, for the overall safety performance, for demonstrating that the end state of decommissioning ensures compliance with the criteria defined in the final decommissioning plan and for retaining decommissioning records, as required.

~~3.23.~~3.25. The responsibilities of the licensee for decommissioning end with the termination of the license for decommissioning by the regulatory body.

~~3.24.~~3.26. More details on how the licensee is fulfilling its responsibilities for decommissioning are provided in the ~~chapters~~ Sections 4-9 of this Safety Guide.

4. MANAGEMENT OF DECOMMISSIONING

Requirement 7 of GSR Part6 [1]: Integrated management system for decommissioning

The licensee shall ensure that its integrated management system covers all aspects of decommissioning. [1]

4.1. The licensee must should establish, implement, assess and continually improve an integrated management system for decommissioning. The management system must should cover all aspects of the decommissioning and be commensurate to the size, complexity and nature of the decommissioning project. The licensee should implement an appropriate integrated management system before the commencement of decommissioning actions and that system should extend to all phases of the decommissioning project.

4.2. The application of the requirements for an integrated management system should take into account a graded approach for safety (e.g., type of decommissioning documents required and level of details required). The licensee should take into account safety aspects and the magnitude of risk and make efforts commensurate with the complexity of the task to be performed, such as when developing plans and procedures for performing decommissioning tasks, determining oversight activities and defining trainings needed for the work force to ensure the task will be performed safely.

4.3. The integrated management system provides a single common framework in which decommissioning is undertaken. This framework should include planning, conduct and completion of decommissioning, including management of decommissioning records. General requirements and guidance on integrated management systems can be foundare provided in other IAEA Safety Standards Series publications [2627-2829]. A description or reference to the management system, including a definition of its scope and intent, should be included in the final decommissioning plan.

4.4. The organizational structure that is to be adopted for decommissioning should define roles, responsibilities, authorities, and key personnel of the licensee, including contractors. A work breakdown structure (WBS) should be established for the overall management of the decommissioning project. A high level WBS, which describes decommissioning actions, should be included in the final decommissioning plan. The detailed WBS should describe the project from top-level project description down to work packages and individual tasks, including logic links, predecessors and critical path.

4.5. Within the integrated management system, safety is the most important objectivefactor, overriding all other factors. Safety management refers to those aspects of the management system that are put in place to ensure that an acceptable level of safety is maintained; including radiation protection and safety during decommissioning.

4.6. The licensee should develop a safety management policy, cooperatively with all personnel involved in the decommissioning project. This enables the licensee to promote a strong safety culture, ensuring that all individuals have the responsibility to identify and to bring any safety concerns to the decommissioning management. In order to maintain effective management of safety, the licensee should ensure that there is commitment to safety by all personnel.

4.7. The decommissioning management should ensure that the safety policy applies to all individuals and includes the authority for stopping work, the responsibility to report safety concerns and the requirements for maintaining a safe working environment. ~~A fundamental principle f~~For the effective management of safety ~~is~~ the appointment of experienced managers is important, with the lead in safety matters coming from the highest levels of management. The safety policy of the licensee and the behaviour and attitudes of experienced managers should be exemplary and should permeate the licensee at every level and extend to other organizations that perform delegated tasks.

4.8. There should be no complacency at any level about the need for continuous attention to safety. It is particularly important in decommissioning, where installation configuration is undergoing continuous changes. The management should foster an attitude of willingness to learn in relation to safety matters and should promote an open exchange of information upward, downward and horizontally within the organization.

4.9. The licensee should provide appropriate levels of control, supervision and training to all organizations involved in the decommissioning project in order to ensure a high level of safety performance is maintained, particularly when high hazard tasks are to be performed or when a large number of contractors are engaged.

4.10. Decommissioning actions may involve additional organizations, including contractors and sub-contractors, who may not be familiar enough with the installation and the management system of the licensee. The licensee can delegate specific tasks to subcontractors, but cannot abdicate the overall responsibility for safety.

4.11. Responsibilities and interfaces between the different organizations should be defined by the licensee, as the overall responsibility for safety remains with the licensee. As part of the integrated management system, mechanisms to control contractors and subcontractors must be established, agreed by all involved organizations and recorded.

4.12. Based on an evaluation of the skills and knowledge needed to decommission a nuclear installation, a team composed of decommissioning specialists and appropriate site personnel should be formed to manage the decommissioning project. Specialized expertise may be necessary in areas such as:

- Characterization;

- Radiation protection;
- Safety assessment;
- Cost estimation;
- Regulatory/licensing expertise;
- Decontamination, dismantling and demolition;
- Robotics and remote source handling;
- Waste processing (i.e. pretreatment, treatment and conditioning);
- Site restoration.

Although new skills may be required for decommissioning, attention should be given to preserving the knowledge of key personnel, who is familiar with the installation from its operational phase.

4.13. As decommissioning involves many new actions associated with new hazards, which were never faced during operation of the installation, the licensee should develop and implement a robust decommissioning training programme for personnel, no matter if former operation staff is involved or the works are performed by contractors. The training may be in the form of oral briefings, practical exercises, training lectures or comprehensive training courses.

4.14. When preparing for some decommissioning actions, specialized training may be needed, which involves the use of mock-ups, ~~and~~ models and computer-based simulations to ensure the actions can be carried out safely and incorporate lessons learned into the working procedures. Additional refresher trainings may be needed for infrequently conducted decommissioning actions.

4.15. In some cases, contractors may be used to perform all or some aspects of decommissioning (planning, conduct, completion actions). This is likely to occur after a long period of safe enclosure, or when specialized decommissioning skills or expertise are needed, for example, use of specific decontamination processes or application of specific dismantling/demolition tools. Either way, all personnel involved in decommissioning actions, both the licensee personnel and the personnel of the contractors, should be made familiar with the procedures for safe and effective conduct of their duties, according to their specific roles. Thus, all project personnel who will perform decommissioning tasks should receive basic training in radiological protection and safety. Additionally, depending on the actions to be performed, some personnel should receive specific training in:

- Installation's design and, layout ~~and zoning arrangements applied~~;
- Technical characteristics of the installation and its operational history;

- Decommissioning works planned and associated procedures;
- Use of personal protective equipment, such as masks and pressurized suits;
- Industrial safety aspects, including hazards present, resulting risks and their control;
- Radiation protection;
- Practices and procedures for management of materials and waste;
- Emergency preparedness and response.

4.16. Training requirements need to be identified, documented and communicated to the contractors, and before a specific decommissioning procedure is applied, it should be demonstrated that the personnel is adequately trained.

4.17. For decommissioning of a complex nuclear installation it is beneficial sometimes to conduct the project using a multi-phased approach, for example progressing from "low hazard" areas to "higher hazard" areas of the installation. From a training point of view, such approach enables gradual development and improvement of decommissioning skills and experience, whilst reducing potential risk to decommissioning workers. Another possible approach is to remove the most radioactive materials first to create a better radiological working environment for subsequent phases.

4.18. All decommissioning actions should be carried out in accordance with approved working procedures, which are developed taking into account the output of the safety assessment (limits and conditions for safe decommissioning, derived on the basis of the safety assessment). The procedures should define how the decommissioning actions are to be carried out and, where appropriate, should identify steps to be taken in the event of an abnormal occurrence. The procedures should be issued and controlled in accordance with the provisions of the integrated management system.

4.19. Decommissioning workers may initiate and should participate in the process of developing the working procedures. The decommissioning knowledge and experience of the personnel should be utilized when drafting working procedures, and any learning and improvements, coming from inactive trials (testing a technique or tool in a radiologically clean environment) and from previous decommissioning works, should be incorporated into the working procedures.

4.20. Each work procedure should be sufficiently detailed, so a qualified individual is able to perform the required actions ~~without direct supervision~~. Consideration should be given to the layout, the general design of the nuclear installation, staffing requirements and decommissioning experience at the installation concerned. Procedures should be developed in accordance with established requirements and recommendations related to quality management.

4.21. To ensure consistency in format and content, working procedures must be prepared in accordance with the administrative procedure that governs the development, review and control of such documents, including a provision for periodic review. There should be a mechanism to verify that a procedure has been approved (e.g. by means of signatures) and that it is current (e.g. through a list of the latest revision dates).

4.22. Depending on Member States' experience, the approval process for the working procedures may be different, and should be commensurate to the safety risk posed by the actions described in the procedure. Persons with appropriate competence and experience should be designated to prepare and verify procedures. Human factors should be taken into account to develop safe, reliable and effective working procedures.

4.23. Administrative procedures used during the operational phase of the nuclear installation may be relevant during decommissioning. However, these procedures should be reviewed and modified to ensure that they are appropriate for decommissioning actions that will be undertaken. The licensee should approve all procedures, as well as their revisions and changes, to ensure the decommissioning actions will be performed safely and the work is integrated into the overall decommissioning work plan and schedule.

4.24. The administrative procedures should identify the decommissioning records to be retained and archived, consistent with the licensee's record management plan. When deferred dismantling is adopted, records should be periodically checked to confirm they are being preserved in a safe and retrievable media and format. These records may include: installation logbooks, video footage and photographs to aid future decommissioning of the installation and to aid future training. Preferably, more than one copy of the key records should be kept in different locations.

4.25. Periodic ~~Daily~~ briefings adapted to the complexity of the decommissioning actions should be performed as they are an integral part of controlling decommissioning actions. They give an opportunity to the work controller to check the workers' understanding of the scope of actions to be undertaken and their understanding of related decommissioning limits and conditions (set of rules and parameters for safe decommissioning). Undertaking ~~daily~~ periodical reviews of the actions helps to identify key learning and to discuss relevant experiences from conduct of similar actions in other projects/facilities.

4.26. Should the licensee change after permanent shutdown or during decommissioning, procedures must be in place to ensure the transfer of responsibilities is controlled and understood, as the licensee maintains responsibility for safety and for compliance with the license conditions. The new licensee responsible for decommissioning should have qualified managers and technical expertise to manage the decommissioning project and should have financial resources to ensure safe decommissioning of the installation.

4.27. The configuration management process should be capable of accommodating a high rate of changes to the nuclear installation and its records, including drawings. The objective of this process is to keep records and procedures consistent with the existing physical status of the nuclear installation at any time.

4.28. At the completion of decommissioning, the final decommissioning report is prepared, which should document~~s~~ the end state of ~~the~~ decommissioning of the nuclear installation, and should provide~~s~~ reference to the decommissioning records, typically including radiological surveys, effluent and environmental monitoring, personnel monitoring and types and volumes of waste generated, as well as the waste destination. More details on the final decommissioning report are provided in Section 9 of this Safety Guide.

4.29. Security and safeguard concerns will be reduced as decommissioning occurs since nuclear and radioactive material is being removed from the installation. Since non-nuclear contractors might be assigned major dismantling tasks, site access and security may still remain an important issue. During deferred dismantling, security concerns will remain a consideration through the entire period the installation is in the safe enclosure phase of the project.

5. DECOMMISSIONING STRATEGY

Requirement 8 of GSR Part6 [1]: Selecting a decommissioning strategy

The licensee shall select a decommissioning strategy, which will form the basis for the planning for decommissioning. The strategy shall be consistent with the national policy on management of radioactive waste. [1]

5.1. The overall purpose of a decommissioning strategy is to serve as a basis for the decommissioning plan, and, in turn, to facilitate achieving the end state of the decommissioning project. The decommissioning strategy must be consistent with the national policy on decommissioning and radioactive waste management policy.

5.2. Two decommissioning strategies have been defined by the IAEA: immediate dismantling and deferred dismantling. These strategies are defined in the General Safety Requirements GSR Part 6 [1]. The "No action" strategy (leaving the installation after operation as it is, and waiting for decay of radioactive inventory) should not be regarded as an acceptable decommissioning strategy.

5.3. The selection of the decommissioning strategy should be based on an analysis of various options, which may lead to selecting a combined or intermediate strategy, which consists of some degree of immediate dismantling actions, followed by a preservation of the remaining parts of the nuclear installation, which are then dismantled after a period of safe enclosure. Such combined strategy can include an early dismantling of some parts of the installation, usually externally accessible areas and auxiliary systems, while placing others, e.g., the reactor core, into a safe enclosure mode.

5.4. The selection of a decommissioning strategy follows a progressive process. A "preferred decommissioning strategy" should be proposed when developing the initial decommissioning plan. It should be reviewed and updated during the lifetime of the nuclear installation and confirmed when decision for permanent shutdown is taken by the licensee. Immediate dismantling is the preferred strategy, as it enables to avoid transferring the burden of decommissioning to the future generations. The immediate dismantling strategy should be understood as immediate and complete dismantling in a timely manner, with no decommissioning phases delayed for many decades. In this context, release from regulatory control without restrictions should be the preferred end state and ultimate objective of decommissioning, when a final disposal for the radioactive waste is available.

5.5. A justification for selection of particular strategy must should be provided to demonstrate advantages of the selection made and reasons for its choice, especially if deferred dismantling is selected, as it implies to some extent transfer of responsibilities for decommissioning to the future

generations. Any strategy which involves waiting periods should ~~strongly~~ be justified in terms of safety, management of decommissioning waste and radiation protection issues.

5.6. Based on the selected strategy, the final decommissioning plan should describe the timing and sequencing of decommissioning actions, emphasizing optimization of safety and protection of workers, the public and the environment.

5.7. Decommissioning, whether based on an immediate or a deferred dismantling strategy, should commence shortly after permanent shutdown. Any transition period between permanent shutdown and approval of the final decommissioning plan should be as short as possible, and should be managed under the operational license. Decommissioning ~~is expected to~~should commence after the transition period and ~~to~~ should continue in phases or as a single project until an approved decommissioning end state is reached.

5.8. Main factors influencing the selection of the decommissioning strategy are:

- National policies and regulatory framework;
- Type of nuclear installation, interdependencies with other facilities or infrastructure located at the same site;
- Proposed reuse and desired end state;
- Physical (for example, ageing components and structures) and radiological status of the nuclear installation;
- Safety aspects;
- Availability of expertise (knowledge, skills, experience), technologies and infrastructure (tools, equipment, supporting facilities and services);
- Environmental ~~and socioeconomic~~ impact;
- Social and economic factors and socioeconomic impact;
- Availability of infrastructure for radioactive waste management, including facilities for pretreatment, treatment, conditioning and storage, as well as existing or anticipated disposal options;
- Availability of financial resources for decommissioning.

~~5.9.~~ More detailed considerations related to the above-mentioned factors are provided later in this ~~section~~Section.

~~5.10.~~5.9. A selection of a deferred dismantling strategy should not rely solely on lack of financial resources. As discussed in the ~~chapter~~ Section 6 of this Safety Guide, the financial arrangements for decommissioning should be established early during the lifetime of the nuclear

installation to enable safe decommissioning in a timely and efficient manner, so lack of financial provisions should not be a driving factor when selecting a decommissioning strategy.

~~5.11.~~5.10. The licensee should check at regular intervals if the decommissioning strategy is still appropriate. Updates of the final decommissioning plan and supporting safety documentation (e.g. safety assessment for decommissioning) during conduct of decommissioning should reflect the progress of the work, the continuous removal of the generated waste and the evolution of radiological and physical status of the installation, in order to demonstrate that a safe configuration is maintained at all times and that the decommissioning project is still aligned with the decommissioning strategy selected.

~~5.12.~~5.11. For a multi-facility site, a site strategy for decommissioning should be developed to identify and evaluate the interdependencies between the facilities, both under operation or permanently shut down for decommissioning. This site strategy for decommissioning should be a basis for selection of individual decommissioning strategies for individual facilities on-site, and for development of facilities' decommissioning plans. Each individual decommissioning strategy should be consistent with the site strategy, and should properly accommodate interfaces between the facilities. These interdependencies should be detailed in the individual final decommissioning plans for the facilities. The site strategy for decommissioning should be made available to the regulatory body upon request.

~~5.13.~~5.12. A site strategy for decommissioning, reflected in the individual decommissioning plans for each installation on-site, should identify opportunities and synergies between individual decommissioning projects, in order to optimize resources, efforts and skills, as well as to optimally use supporting facilities. There may exist some site considerations, which impact the selection of an individual decommissioning strategy and development of decommissioning plan for a nuclear installation located on a multi-facility site, for example:

- General approach to decommission the facilities having the highest priorities in terms of safety, waste management and radiation protection, prior to the facilities with lower priority issues, considering ageing and obsolescence of SSCs;
- Decision to begin decommissioning with less contaminated/activated facilities/buildings, prior to the more contaminated ones, taking benefit from experience and radioactive decay;
- Optimization of decommissioning actions across the site and their sequence using pooled resources and skills as appropriate, to avoid underutilization of workers (may not be applicable in case of multiple owners/licensees on a multi-facility site);
- Coordination of the use of specialized contractors and sub-contractors as appropriate, taking into account the availability of the best qualified personnel, equipment, and infrastructure at a given time, according to the decommissioning schedule for each individual installation;

- Establishing common facilities providing support for the predisposal management of radioactive waste (~~treatment~~i.e. processing, storage and removal from the site) and coordinating their use for different decommissioning projects on the site; this may require revised installation boundaries due to the allocation of buildings, equipment and infrastructure to the waste management tasks;
- Optimization of discharges of gaseous and liquid effluents from individual operating facilities and facilities under decommissioning with respect to the license approved by the regulatory body for the entire site;
- Need to use consistent approaches for final remediation actions and consistent criteria for release of site from regulatory control across the entire site, no matter if the site release is done partially, after completion of each individual decommissioning project, or at once, after completion of the last decommissioning project on the site.

~~5.14.~~5.13. Licensees in charge of several decommissioning projects for different facilities at different sites in the same State could develop an overall decommissioning strategy (corporate strategy) in order to optimize the decommissioning projects of individual facilities and related solutions for management of radioactive waste.

~~5.15.~~5.14. Unforeseen permanent shutdown could occur during operation of a nuclear installation based on economical, technical or sometimes political reasons. In such cases, the decision to permanently shut down an installation cannot be anticipated by the licensee~~.~~, Consequently, a review ~~and a revision~~ of the preferred decommissioning strategy may be necessary on the basis of the situation that initiated the sudden shutdown, in order to evaluate whether a revision of the strategy is required.

~~5.16.~~5.15. A premature permanent shutdown of a nuclear installation may also be result of an accident. In this case, the first objective is to bring the installation into a safe ~~condition~~state, before reviewing the decommissioning strategy and reviewing or implementing any final decommissioning plan. The recovery actions undertaken are precursors to decommissioning actions, and the~~ir~~ consequences of the recovery actions should be addressed in the final decommissioning plan.

~~5.17.~~5.16. After a safe state of the installation involved in an accident is achieved by implementation of the recovery actions, a comprehensive survey of the physical and radiological conditions of the installation needs to be performed to determine if the selected decommissioning strategy is still feasible. When developing the final decommissioning plan after an accident, special attention should be given to the physical and radiological conditions, considering that it may be impossible to repair damaged SSCs, even if an acceptable safe state has been reached.

~~5.18.~~5.17. ~~Accident~~ Incidents or accidents ~~situations~~ may lead to a spread of contamination outside of the buildings of the nuclear installation, implying the need to implement remediation actions on the site where the installation is located. Such actions on-site are usually considered a part of the overall decommissioning of the installation, for example could be the last phase of the decommissioning project. The extent of the on-site contamination may be such to require change of the previously selected strategy and the ~~final~~ end state, as well as establishment of long term decommissioning and remediation plans. Off-site contamination, as consequence of an accident, is out of the scope of this Safety Guide, and is addressed in Safety Guide [19].

~~5.19.~~5.18. Entombment, in which all or part of the nuclear installation is encased in a structurally long lived material, is not an acceptable strategy for planned decommissioning. It may be considered as a last option for decommissioning of accident damaged installations, if other options are not possible due to high exposures to workers or technical difficulties.

~~5.20.~~5.19. Even if it may be the only appropriate alternative, the choice of entombment may lead to technical and regulatory difficulties due to lack of specific regulations and guidance in most of the Member States and lack of an international consensus. Additionally, intention to apply entombment may cause problems with the public acceptance. In this context, all the efforts should be made to reduce the parts of the installation which will be subject to entombment and to reduce to the extent possible the radioactive inventory which will be encased on-site, especially the long lived radionuclides. Entombment actions should not reduce the technical feasibility for surveillance and maintenance of the remaining barriers and actions should be implemented considering that options should be kept open to allow the possibility to apply better technical solutions in the future.

FACTORS INFLUENCING THE SELECTION OF A DECOMMISSIONING STRATEGY

National policies and regulatory framework

~~5.21.~~5.20. The adopted national policy(ies) on decommissioning and management of radioactive waste may influence the choice of possible decommissioning strategies or combinations of options. For example, some basic decommissioning strategies may be excluded for political or other non-technical reasons. Such policy requirements may be established for particular installation types, and may not apply universally to all the different types of facilities, e.g. nuclear power plants, research reactors, nuclear fuel cycle installations.

Type of nuclear installation, interdependencies with other facilities or infrastructure located at the same site

~~5.22.~~5.21. There may be different considerations related to the selection of a decommissioning strategy for ~~the~~ a nuclear installation~~s~~, based on its type, size and complexity, activities performed

during operation of the installation, residual inventory of radionuclides, or the location of the nuclear installation and its relations and interdependencies with other facilities on the same site.

~~5.23.~~5.22. The type of the nuclear installation to be decommissioned, its past functions and the extent of remediation needed (e.g., soil/sediment and surface and groundwater) may have a major impact on the selection of its decommissioning strategy.

~~5.24.~~5.23. The decommissioning strategy for a particular installation should also take~~s~~ into account the characteristics of the site where the installation is located. The capabilities of the other facilities (if existing on-site, either in operation or in shutdown mode) may be used, as well as the experience of the site's personnel. Such considerations may affect the options available for selection of a strategy.

~~5.25.~~5.24. The diversity of types of nuclear facilities makes characterization of the installation a critical step in the process of selecting a decommissioning strategy because the characterization results are used when defining the scope of the proposed project.

~~5.26.~~5.25. Additionally, the location of the nuclear installation may pose unique challenges to decommissioning. For example, a nuclear installation may be surrounded by many other facilities on a complex nuclear site, or a research reactor could be located in an operating medical facility, or in a university environment.

~~5.27.~~5.26. When selecting a decommissioning strategy where more than one nuclear installation is located on a site, it may be beneficial to place the ~~facilities~~ nuclear installations already permanently shut down into a safe enclosure status until the remaining installations are permanently shut down. Then the decommissioning of all installations could be performed in a single campaign, avoiding any negative impact to the operating installations and allowing better utilization of personnel.

Proposed reuse and desired end state

~~5.28.~~5.27. There may be a request for the reuse of the part of the site or the entire site, or for reuse of existing building structures ~~for different purposes~~ after completion of decommissioning. The timeframe for such a reuse of the site, either restricted or unrestricted, is an important consideration for the selection of a decommissioning strategy. If the site is needed for siting and construction of new facilities in the near future, such a request will lead to a preference for selection of the immediate dismantling strategy.

~~5.29.~~5.28. In case of decommissioning of research reactors, very often the desired end state is reuse of all or parts of the former reactor building for other, non-radiological purposes, particularly in a medical or university setting. Therefore, the desired end state would be decontamination of the

existing building structures to a level suitable for the new use, and usually such an end state is required to be achieved in several years. Taking into account only this aspect, ~~a~~ the preferred decommissioning strategy will be immediate dismantling.

~~5.30.~~5.29. There may be other reasons which simplify the selection of a decommissioning strategy for a nuclear installation or eliminating some strategies from consideration. For example, the public opinion and expectations to decommission a nuclear installation in a short period of time and to release the site from regulatory controls may also give a priority to immediate dismantling strategy.

Physical and radiological status of the installation

~~5.31.~~5.30. The physical and the radiological status of the nuclear installation at the end of its operational phase should be considered when selecting the decommissioning strategy.

~~5.32.~~5.31. The extent of contamination will depend greatly on past operational practices, the age and type of the installation. The age and generation of an installation will have influenced the types of material used in construction, which in turn results in different levels and types of radioactivity.

~~5.33.~~5.32. The integrity and conditions of the buildings and SSCs should be assessed at the end of the operation time in the perspective of decommissioning needs. If necessary, buildings and SSCs should be secured and maintained for the timeframe of the decommissioning project. If this cannot be accomplished, immediate dismantling actions should be undertaken.

~~5.34.~~5.33. Depending on the activation and contamination levels within a nuclear installation and the related composition of radionuclides, the selection of the decommissioning strategy may have an impact on radiation exposure to workers, public and environment. High radiation levels may make the deferred dismantling a more appropriate strategy because radioactive decay may allow radiation levels to decrease over time.. When no benefit from radioactive decay is expected, immediate dismantling is the preferred strategy.

Safety aspects

~~5.35.~~5.34. When selecting a decommissioning strategy, the licensee should consider the results of the periodic safety reviews performed during the operation of the nuclear installation. Results of conformity checks and re-assessment should be addressed and analysed to confirm the "preferred decommissioning strategy" is still applicable. When the decision to permanently shut down a nuclear installation is a result of such periodic safety review process, the identified weakness of the safety demonstration should be considered carefully in the perspective of decommissioning.

~~5.36.~~5.35. The technical feasibility of the dismantling actions should be assessed in order to ensure that the "preferred decommissioning strategy" can be implemented safely considering the modifications and changes of the design, which may have been undertaken during operation.

Availability of expertise, technologies and infrastructure

~~5.37.~~5.36. The availability and utilization of institutional knowledge should be considered in choosing a decommissioning strategy (e.g., documentation of the operational history and/or retention and utilization of key personnel familiar with site specific conditions). This documentation and expertise could decrease the potential for events such as industrial accidents or undue exposures and may help to reduce problems associated with loss of corporate memory. Availability of staff with operational knowledge may be an argument for immediate dismantling.

~~5.38.~~5.37. The availability of existing systems and infrastructure (e.g., air supplies, ventilation systems, overhead cranes) and considerations on their ageing may make immediate dismantling advantageous due to maintenance upkeep or recertification of the component at a later time.

Environmental and socioeconomic impact

~~5.39.~~5.38. When the impact on the local economy is an important issue, immediate dismantling may be the preferred strategy because this may reduce the immediate negative social effect by continuing to provide employment for the local workforce.

~~5.40.~~5.39. For most nuclear installations, the number of employees and local support needed to support decommissioning will generally be less than the number employed and the local support needed during the operation of the installation. If deferred dismantling is selected as the strategy, the workforce will be reduced considerably during the safe enclosure period, and then may increase again during later dismantling.

~~5.41.~~5.40. The environment around the installation may have changed since the building was constructed. An example might be ~~the encroachment of other university buildings around a research reactor building that was once on the edge of a campus and relatively isolated. Another example might be~~ the change in environmental conditions such as the raising of water levels making deferred dismantling unfeasible.

Availability of infrastructure for radioactive waste management

~~5.42.~~5.41. Aspects of waste generation and waste management can have an impact on the selection of a decommissioning strategy. Some of the most important aspects are:

(a) ~~Overall n~~National waste management policy (e.g., one that prefers clearance);

(b) Types, categories and amount of waste (e.g., including historical and remaining operational waste);

(c) Waste ~~treatment~~ processing facilities or infrastructure for all types of radioactive waste;

(d) Arrangements for transport of radioactive waste;

(e) Availability of storage capacity; and

(f) Availability of ~~final~~ disposal capacity.

~~5.43.~~5.42. In the absence of facilities and infrastructure for ~~treatment~~ processing of radioactive waste, or when the storage or disposal capacities are not available, the preferred decommissioning strategy is likely to be deferred dismantling. If on-site or external waste ~~treatment~~ processing and storage facilities are available, then either immediate dismantling or deferred dismantling are viable decommissioning strategies. If the waste management infrastructure is available, including waste disposal capacities, then immediate dismantling would be the preferred strategy.

6. FINANCING OF DECOMMISSIONING

Requirement 9 of GSR Part6 [1]: Financing of decommissioning

Responsibilities in respect of financial provisions for decommissioning shall be set out in national legislation. These provisions shall include establishing a mechanism to provide adequate financial resources and to ensure that they are available when necessary for ensuring safe decommissioning. ~~[1]~~

6.1. Responsibilities for financing of decommissioning and a mechanism to provide adequate financial resources for the safe decommissioning of nuclear installations need to be defined by the government as part of the national legal framework and need to be in place prior to the start of installation operation.

6.2. Financial resources for decommissioning should be consistent with the chosen decommissioning strategy and with decommissioning actions described in the decommissioning plan. The costs associated with decommissioning aspects include costs of the following:

(a) Decommissioning planning, including initial decommissioning planning prior to starting installation operation, then preparation of the final decommissioning plan during transition from operation to decommissioning, and including detailed planning needed during conduct of decommissioning actions;

(b) Pre-decommissioning actions (including actions performed during the transition phase), e.g., radiological characterization, license application and approval, post-operational decontamination of the systems;

(c) Decommissioning actions, as described in the decommissioning plan, such as decontamination, dismantling of SSCs, demolition of buildings and structures, steps in the management of decommissioning waste which are defined as part of the decommissioning project, refurbishment of existing systems needed to support decommissioning, replacement or commissioning of new systems needed for decommissioning; and

(d) Actions after termination of the decommissioning license, e.g. monitoring in case of release of the installation with restrictions, preparation of the final decommissioning documentation and archival storage of decommissioning records, ongoing handling and processing ~~management~~ of waste after completion of decommissioning, temporary storage of waste and its subsequent ~~final~~ disposal.

6.3. The decommissioning cost estimate covers all actions required to plan and perform the decommissioning. There will be additional costs for other actions, which may be included as part of the decommissioning, depending on the national legal framework. These typically include financing

for management of operational waste, pre-decommissioning actions during transition phase, waste storage and disposal and spent fuel management.

6.4. It is important for the decommissioning cost estimate to distinguish between operating expenses and decommissioning expenses.

6.5. The development of a cost estimate and its updates is based on the initial and final decommissioning plans. The level of detail of the data needed and used for the cost estimate, and the accuracy of the estimate will vary depending on the lifecycle stage of the nuclear installation, and depending on the level of detail provided in the initial and final decommissioning plans.

6.6. With regard to the accuracy and associated uncertainties of the decommissioning cost estimate, there are typically three types of cost estimates during the installation's lifetime:

- Order of magnitude – this type of cost estimate can be utilized prior to receiving the operational license and is based on the initial decommissioning plan;
- Budgetary estimate – this type of cost estimate is based on the data provided in the updated decommissioning plans;
- Definitive estimate – this type of cost estimate can be utilized after completion of detailed planning of the decommissioning actions, and is based on the data provided in the final decommissioning plan and in the associated working level documentation (procedures).

6.7. Responsibility for preparing the cost estimate and its updates resides with the licensee, but the work may be done by a contractor. There should be an entity independent from the licensee to be involved in the cost estimate itself or in its review, in accordance with the national regulatory framework.

6.8. Cost estimates and financial provisions should be reviewed periodically and adjusted as necessary to allow for proper consideration of inflation and other factors, such as technological advances or waste management costs and regulatory changes, especially in case of deferred dismantling, where the decommissioning process may take decades with long safe enclosure period.

6.9. Mechanisms of providing financial assurance might include insurance, trust funds, surety-bonds, prepayments or other financial guarantees, for example internal or external funds. A combination of these methods can also be utilized. Many research reactors are state owned, and thus the state budget covers the costs for decommissioning. In any case, financial provisions have to be in place prior to approval of the issuance of a license, license renewal or license extension for the operation of the nuclear installation.

6.10. The mechanism by which financial assurance is guaranteed should be robust, so that it will withstand changes in government (for government owned and financed ~~facilities~~nuclear installations), changes in ownership of a private company, especially following sale of the company to a party that is resident outside of the State, or changes within financial institutions (where financial assurance is guaranteed, e.g., by a bond secured by the financial institution). ~~This mechanism should be sufficiently robust to provide for decommissioning needs in the event of a premature shutdown of the installation.~~

6.11. In case of post-accident decommissioning, after completion of the recovery actions, when the installation is brought to a safe condition, a revised cost estimate should be made based on the reassessment of the selected decommissioning strategy and according to the revised final decommissioning plan.

6.12. If the end state of a decommissioning project is release from regulatory control with restrictions, the financial provisions have to include costs associated with the long-term monitoring, surveillance, and implementation of the defined restrictions, to ensure all the necessary controls remain effective and long term safety is maintained for the entire period of time when these controls are necessary.

7. PLANNING OF DECOMMISSIONING DURING THE LIFETIME OF THE INSTALLATION

Requirement 10 of GSR Part6 [1]: Planning ~~of~~ for decommissioning

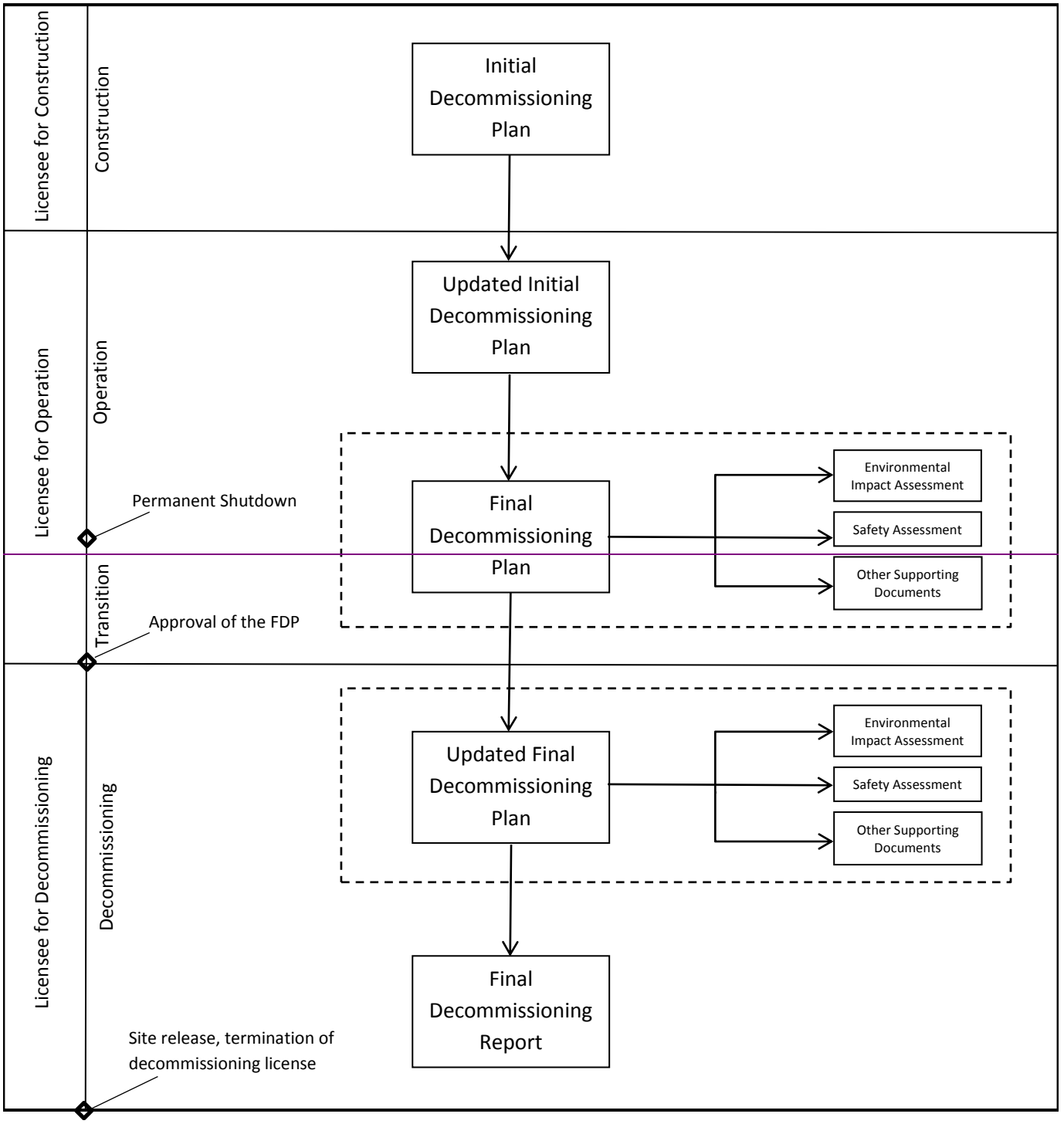
The licensee shall prepare a decommissioning plan and maintain it throughout the lifetime of the facility, in accordance with the requirements of the regulatory body, in order to show that decommissioning can be accomplished safely to meet the defined end state. ~~[1]~~

7.1. Decommissioning planning throughout the lifecycle of a nuclear installation is important to facilitate conduct of decommissioning, to minimize exposures to decommissioning workers, the public and the environment, to minimize radioactive waste generation and to estimate the decommissioning costs.

7.2. Two types of decommissioning plans are envisioned; an initial decommissioning plan and a final decommissioning plan. For a given nuclear installation, the degree of detail will increase significantly from the initial to the final decommissioning plan. A decommissioning plan should be prepared based on the selected decommissioning strategy and should be submitted for approval by the regulatory body, in accordance with the national regulatory framework.

7.3. Decommissioning should be facilitated by planning and preparatory work undertaken during the entire lifecycle of the installation. Figure 1 illustrates the relations between the lifecycle of the nuclear installation and the decommissioning plans required. Decommissioning plans should be periodically reviewed and updated. Information about the decommissioning plans is provided in the sections of this Safety Guide immediately following the Figure 1. Aspects to be considered during the lifetime of the nuclear installation, as well as aspects related to unforeseen shutdown, are dealt with in later ~~sections~~ parts of this ~~chapter~~Section.

7.4. For many nuclear installations, operating for many years, decommissioning may not have been considered at the design stage or during construction and subsequent operation. For these installations, planning for decommissioning should start as early as possible. Furthermore, in addition to planning for decommissioning, possible modifications to buildings and systems during the remaining operational lifetime should be used to incorporate features that will facilitate decommissioning, for example use of components made of materials resistant to activation, introduction of purification systems to reduce spread of contamination or creation of access points for easier decontamination of hot cells.


Licensee for Construction
Construction
Initial Decommissioning Plan
Licensee for Operation
Operation
Updated Initial Decommissioning Plan
Final Decommissioning Plan
Environmental Impact Assessment
Safety Assessment
Other Supporting Documents
Permanent Shutdown
Transition
Approval of the FDP
Licensee for Decommissioning
Decommissioning
Updated Final Decommissioning Plan
Environmental Impact Assessment
Safety Assessment
Other Supporting Documents
Final Decommissioning Report
Site release, termination of decommissioning license

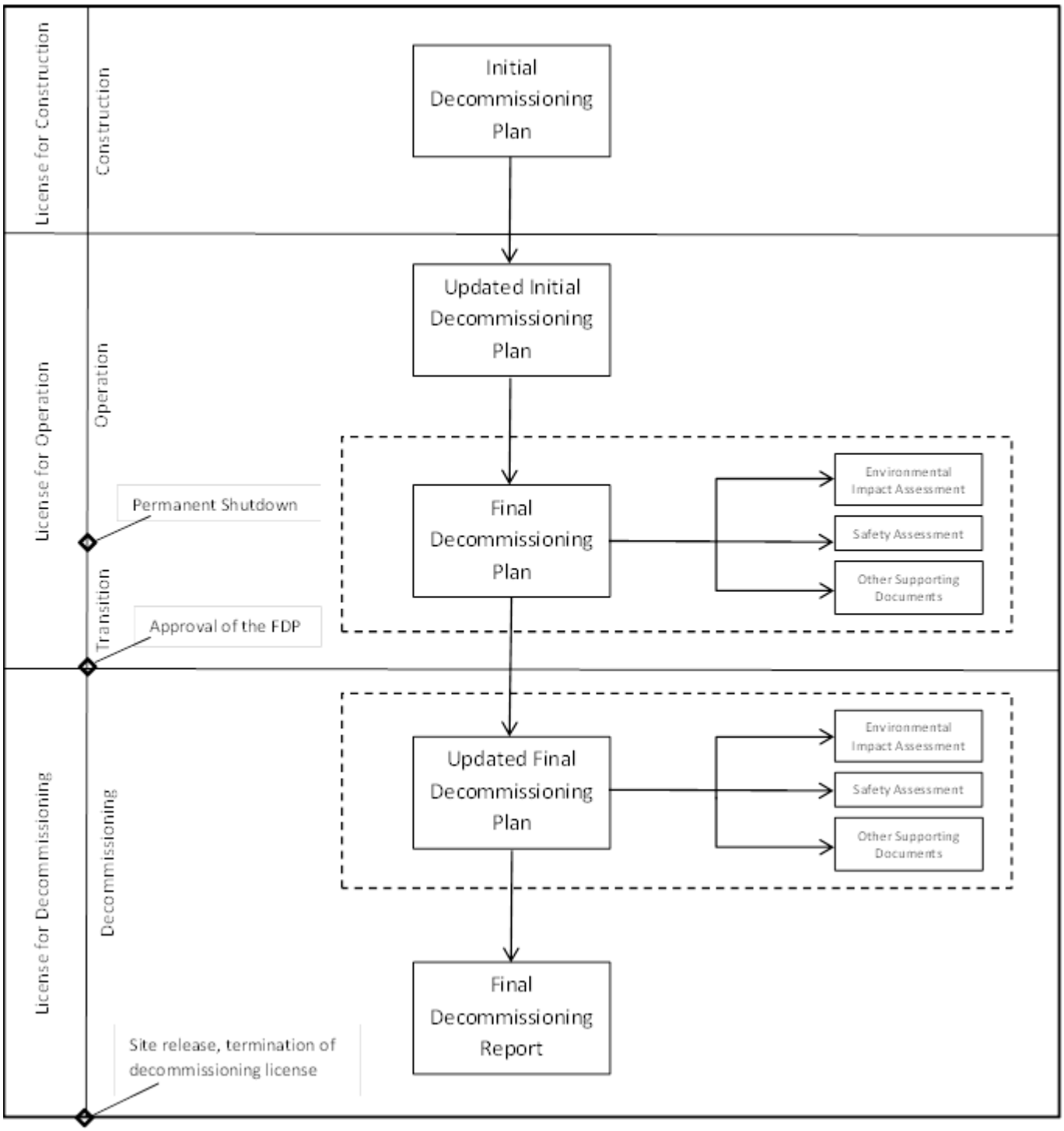


Fig. 1. ~~Decommissioning~~ An example of decommissioning plans during the lifecycle of a nuclear installation

7.5. When designing new nuclear installations, the licensee should take into account decommissioning considerations prior to application to the regulatory body for a construction authorization.

7.6. Relevant features and aspects, which should be considered during the design and construction stages of a nuclear installation to facilitate decommissioning, and which may also enhance the safe operation and maintenance of the nuclear installation, include the following:

(a) Minimize the number and size of contaminated areas to facilitate decontamination during decommissioning;

(b) Facilitate access to ~~process equipment,~~ structures, systems and ~~large~~ components, including compartmentalization of processes (incorporate hatches, large doors);

(c) Minimize the use of underground piping and of embedded pipes in the building structures (use pipe trenches, pipe sleeves);

(d) Use modular construction in order to facilitate the dismantling of structures, systems, equipment and components (biological shielding);

(e) Separate and isolate non-radioactive and radioactive components and systems, such as separation of electrical and mechanical components;

(f) Facilitate easy removal and/or decontamination of material or equipment, including built-in decontamination mechanisms, such as protective coverings and liners in process cells and areas where liquids may be present;

(g) Use materials that are resistant to activation, that are resistant to degradation by chemicals and that have sufficient wear resistance to minimize the spread of activated corrosion products;

(h) Design the nuclear installation to avoid undesired accumulations of chemical or radioactive materials, and utilize processes for minimizing and/or reducing the volumes of waste;

(i) Enable remote decontamination, maintenance and monitoring where necessary;

(j) Enable operational waste or temporarily stored waste to be easily retrieved; and

(k) Minimize the use of hazardous substances which could result in mixed hazardous and ~~radiological~~ radioactive waste.

7.7. During construction or at latest before commencement of the initial operation of the installation, samples of “radiologically clean” (non-activated and non-contaminated) construction materials (for example, concrete, steel, graphite, aluminium) should be collected and kept for establishment of relevant background levels (content of naturally-occurring radionuclides) and for chemical analyses in support of activation studies.

7.8. A baseline radiological site survey should be planned and performed for the proposed site of the planned nuclear installation and its surrounding area to establish background concentration levels of natural and man-made radionuclides for use in assessing the future impact of the installation. The

licensee should identify the key radionuclides and the media (e.g., soil and sediment or surface and groundwater) to be sampled and measured, so the results could be used for:

(a) Future evaluation of the impact of the nuclear installation to the site and the surrounding area due to its operation;

(b) Determining the acceptability of proposed decommissioning options (e.g., strategy, initial decommissioning plan); or

(c) Establishing and demonstrating compliance with proposed end state.

7.9. The background data should be updated prior to commissioning of any new nuclear installation or construction of additional buildings and structures on an existing site, including an evaluation of naturally occurring radionuclides in building materials, to maintain the possibility for termination of the decommissioning license in the future without necessity of demolishing the buildings.

INITIAL DECOMMISSIONING PLAN

7.10. The early development of an initial decommissioning plan ensures that decommissioning has been considered in designing the installation. The initial decommissioning plan will be limited in detail, because it is based on experience from previous projects and assumptions which have to be validated at a later time (see the sub-section on Initial Decommissioning Plan Updating). This initial decommissioning plan must be submitted by the licensee to the regulatory body in support of the license application or authorization for commissioning and/or operating the nuclear installation. This plan:

(a) Should preferably be based on the immediate dismantling strategy; however, deferred dismantling of individual nuclear installations may be considered, for example, in the case of a multi-facility site;

(b) ~~Includes~~ Should include a generic feasibility study of decommissioning, based on the selected decommissioning strategy, considering design provisions and operational experience for facilitating decommissioning, including the proposed ~~end state~~end state (preferably release without restrictions), related key decommissioning actions and basic safety issues;

(c) ~~Includes~~ Should include the approach for management of radioactive waste, providing initial identification of waste classes and initial estimate of waste quantities; and

(d) ~~Provides~~ Should provide a basis for a preliminary cost estimate of the decommissioning project and identifies the means to obtain financial provisions for the decommissioning.

INITIAL DECOMMISSIONING PLAN UPDATING

7.11. During operations, the initial decommissioning plan has to be reviewed and updated periodically, typically every five years or as prescribed by the regulatory body according to the national regulatory framework. Other reasons which may lead to update the initial decommissioning plan include:

(a). Design or process modifications;

(b). Changes in financial conditions, funding assurance, or funding requirements;

(c). Changes to relevant regulatory or safety requirements and criteria, e.g., radiation protection standards;

(d). Change of the selected decommissioning strategy and/or planned end state;

(e). ~~Availability~~ Commissioning of a radioactive waste disposal ~~capacity~~ facility and availability of waste acceptance requirements or criteria for ~~waste~~ disposal;

(f). Operational and decommissioning experience feedback, including technological developments;

(g). Extension of installation operating period; and

(h). Incidents, events or situations with relevant consequences for decommissioning, such as changes in the radiological inventory estimation.

7.12. Updates of the initial decommissioning plan will become more reliable, based on actual operational experience and data, as the nuclear installation approaches the end of its operational life.

7.13. A waste management plan should be part of the initial decommissioning plan and should include information about the waste management approach to be applied. This approach may be the same as the one used during operation of the nuclear installation, see the descriptions in ~~Chapter~~ Section 8.

7.14. Experiences from decommissioning projects indicate that a lack of attention to documentation and record keeping could result in safety problems and in a costly misallocation of resources. Records are essential when preparing decommissioning plans. Records from all the phases of the nuclear installations' lifecycle, including siting, design, construction, commissioning, operation and decommissioning, which are of importance for decommissioning planning and conduct, should be identified, preserved and made available when needed. The process of initial and final planning should use pertinent records to ensure safety and optimize efficiency in the decommissioning of the nuclear installation. These records should include:

(a) Records of the history of the nuclear installation, including:

- Design specification and information from the siting and construction, including as-built drawings, photographs, piping diagrams, cable penetrations, and other details helpful for decommissioning purposes;
- Fuel failures, fuel and special nuclear material accountability records;
- Criticality safety records [30];
- Use of chemicals and their inventories;
- Incidents leading to spillage or inadvertent release of radioactive material, including information about actions, corrective measures and close out of the events;
- Radiation and contamination survey data (radionuclide inventory and its distribution throughout the installation, particularly for areas of the nuclear installation that are rarely accessed or especially difficult to access;
- Releases and leaks that could have potentially affected surface water, groundwater soil and sediment; and
- Waste storage locations.

(b) Records of modifications to the installation and experiences from maintenance works, including:

- Updated ‘as built’ drawings, videos and photographs, including details of the materials used;
- “As built” drawings and background samples for added buildings:
- Special repair or maintenance actions and techniques (e.g., effective temporary shielding arrangements or techniques for the removal of large components);
- Details of the design, material composition, and the history and location of all temporary experiments and devices.

7.15. During installation operation, records should be retained as appropriate to meet the needs of future decommissioning and as dictated by national requirements. In case of deferred dismantling, where long periods of storage of records are anticipated prior to final dismantlement and site remediation, records should be periodically checked to confirm they are being preserved in a safe and retrievable media and format.

~~7.16. During decommissioning, records should be maintained of key decommissioning actions. For example, accurate and complete information concerning the quantities and types of radionuclides remaining at the installation, their locations and distributions, and the volume of radioactive waste generated. These records could be used to demonstrate that all radioactive materials, that were present at the beginning of decommissioning, have been properly accounted for and that their final dispositions (e.g. restricted reuse or disposal) have been identified and confirmed. Documentation should also account for materials, structures and land that have been removed from regulatory control.~~

~~7.17. If restrictions are placed on a site, the restrictions should be documented and established as part of the institutional controls, so future uses of the site are not contrary to the restrictions. An example of such documentation is a land deed restriction.~~

~~7.18. The regulatory body should ensure that relevant plans, records and reports (addressing decontamination, demolition and dismantling actions, as well as surface, groundwater, soil and sediment remediation, and the final radiological survey) are prepared by the licensee, and retained for an appropriate timeframe.~~

~~7.19.~~7.16. During the operation of the nuclear installation, operational radioactive waste should be properly managed and ~~promptly~~ removed from the premises of the nuclear installation to the dedicated disposal facilities, to the extent practicable, ~~from the premises of the nuclear installation~~ to simplify transitioning to decommissioning.

~~7.20.~~7.17. The transition from operation to decommissioning starts after the permanent shutdown of the nuclear installation. The transition period should be as short as practicable. The end of the transition period is defined by the date of granting the ~~decommissioning~~ license for decommissioning (or any other authorisation for decommissioning) or by the date of approval of the final decommissioning plan.

~~7.21.~~7.18. During the transition period, the nuclear installation is subject to the operational license. All applicable operational requirements to the nuclear installation remain in place, unless the regulatory body has agreed to reductions of the requirements on the basis of a reduction of the hazards, such as the removal of radioactive waste or spent nuclear fuel from the installation.

~~7.22.~~7.19. Some activities preparatory to decommissioning may be carried out after permanent shutdown of the nuclear installation under the operational license, such as management of operational waste and residual materials (including drainage of systems and removal of combustible materials to reduce the fire loads), characterization of the nuclear installation, fuel removal, modification or the installation and preparation of systems to support decommissioning, and preliminary system decontamination.

Requirement 11 of GSR Part6 [1]: Final decommissioning plan

Prior to the conduct of decommissioning actions, a final decommissioning plan[8] shall be prepared and shall be submitted to the regulatory body for approval. [1]

7.23.7.20. Before the permanent shutdown of a nuclear installation the licensee must inform the regulatory body (or the government, if so required) about its plans to cease the operations. Additionally, at this time or at the latest during transition from operation to decommissioning, the licensee should initiate studies to support development of the final decommissioning plan. These studies should identify the systems, equipment and infrastructure from the operational phase that will need to be maintained for use during decommissioning, and the new systems, equipment and infrastructure that will need to be installed to support decommissioning.

7.24.7.21. When large or complex decommissioning projects are considered, the final decommissioning plan may be supported by additional documents (such as waste management plan, safety assessment, emergency plan, etc.). For small or simple decommissioning projects, the final decommissioning plan could be a standalone document, which incorporates most of the supporting information. Notwithstanding this, an emergency plan and a security plan isare usually requested as a separate documents even for simple projects. Graded approach should be applied with regard to the content of the final decommissioning plan and its supporting documents, so the information provided is adequate to document and demonstrate safety of the proposed decommissioning actions.

7.25.7.22. Safety assessment is a key supporting document to the final decommissioning plan. The licensee is responsible for preparing this document and submitting it for review to the regulatory body, in accordance with national regulatory framework. The scope of the safety assessment, its content and the degree of detail may vary depending on the complexity and hazard potential of the nuclear installation.

7.26.7.23. It is a good practice if, bBefore submission of the final decommissioning plan and the safety assessment to the regulatory body, these and other selected supporting documents are should be subject to an internal independent review performed under the responsibility ofby the licensee. The purpose of this independent peer review is to provide confidence to all stakeholders that the proposed tasks are feasible and that suitable and sufficient safety controls have been identified.

[8] The final decommissioning plan is that version of the decommissioning plan submitted for approval to the regulatory body prior to implementation of the plan. During implementation of this final plan, revisions or amendments may subsequently be needed as the activity progresses.

~~7.27.~~7.24. Characterization surveys should be performed by the licensee to support the development of the final decommissioning plan. Outcomes of these characterization surveys should be expressed in terms of radiation and contamination maps of the SSCs, rooms, buildings and land areas around the nuclear installation, as applicable.

~~7.28.~~7.25. Some of these results and maps may be available from surveys performed during the operational period of the nuclear installation. However, such maps may need to be updated to account for radioactive decay, the in-growth of daughter products, and migration of radionuclides. Furthermore, they should show any results of special surveys to determine the penetration depth in concrete structures, soil and sediments and the extent of contamination. For completeness, contamination in shielded or self-shielded components, such as inside pipes and other equipment, should be determined to the extent possible.

~~7.29.~~7.26. Radiological characterization data should include ~~zone~~ site area description (e.g., premises of the nuclear installation, environment ground and surface water, soil, and sediments), contamination and dose rate levels, and chemical and physical forms of materials. Characterization surveys should also identify adjacent uncontaminated zones. During planning of decommissioning actions, special attention should be given to prevent cross contamination of such zones. Radiological characterization of the nuclear installation should comprehensively describe contamination and activation levels.

~~7.30.~~7.27. If radioactive material or operational waste remains at the nuclear installation (including subsurface soils and groundwater), this radioactive material must be included in the characterization survey. Special attention should be given to the inventory of used radioactive sources and storage of packages with unknown and uncharacterized radioactive material. Existing storages of liquid radioactive waste are also of importance for decommissioning, as removal and processing may require considering also the physical and chemical status, as well as the design life of related storage tanks. Additional characterization of the site to evaluate potential migration should be considered.

~~7.31.~~7.28. Experience of the Member States shows that it is common practice to manage a complex decommissioning project adopting a phased approach (multi-phase approach). In this case, the final decommissioning plan should be a living document, which is updated to reflect the current status of the nuclear installation and the on-going progress of the project. This final decommissioning plan should be supported by an overarching safety assessment, which covers all the project phases. When using a phased approach, it is important to keep a global overview of the entire project in order to build confidence in the capability of the licensee to achieve the defined final ~~end state~~end state of the decommissioning project.

~~7.32.~~7.29. As an example, a decommissioning project based on an immediate dismantling strategy could consist of the following phases:

Phase 1: Removal of radioactive waste and dangerous substances used and produced during the operating life of the nuclear installation (when this has not been completed during the transition phase);

Phase 2: Preliminary operations to prepare for the dismantling work (e.g. establishing new working areas, supporting facilities, interim storage of waste, etc.);

Phase 3: Dismantling and decontamination actions and removal of the radioactive waste from the area which is subject to decommissioning;

Phase 4: Final on-site radiological remediation activities; and

Phase 5: ~~Conventional~~ Final conventional removal activities (e.g. demolition of radiologically clean buildings).

Termination of the decommissioning license could occur after Phase 4 or Phase 5, depending on national practice.

7.30. Some phases could be conducted in parallel, according to the final decommissioning plan. The success of the implementation of a phased approach is linked to the definition of clear objectives for specific phases. The final decommissioning plan should define the starting and ending points of each phase.

~~7.33.~~7.31. Where decommissioning of a nuclear installation is to take place in discrete phases, an interim end state report should be prepared when each planned interim end state is achieved. The report should describe the physical condition of the nuclear installation, as well as the remaining hazards.

~~7.34.~~7.32. In some decommissioning projects it may be advantageous to ~~ship~~ remove large components, e.g. steam generators from nuclear power plants, as a whole outside the nuclear installation's building or to ship them to another facility away from the site for further segmentation and treatment. In such cases this should be reflected in the decommissioning plan and the relevant safety issues should be addressed, e.g. transport safety.

~~7.35.~~7.33. Decisions regarding which techniques or tools are to be applied in individual project phases may be kept open in the entire project, subject to additional appropriate ~~safety~~ justifications of the safety of particular techniques. Such an approach should be discussed in advance with the regulatory body and should take into account the risks and hazards of the dismantling actions, in order

to optimize the resources both the licensee and the regulatory body in the update, development and regulatory review of the final decommissioning plan and the required supporting documentation.

~~7.36.~~7.34. General experience shows that it is possible to utilize dismantling techniques which are commercially available "on the shelf". In this case, time does not need to be dedicated to research studies for development of new tools and techniques.

~~7.37.~~7.35. Introduction of "new" techniques may require specific analysis to assess suitability and the safety of the new technique or equipment and to implement adequate controls, and also may require additional training of the personnel. This training should start during planning for the use of the new technique, to provide feedback to the planning process. It should be used to confirm basics assumption and inputs to the safety assessment, the identification of related components and equipment important for safety and to develop working procedure and administrative and engineering controls as well.

~~7.38.~~7.36. ~~If disposal capacity is available, d~~Decommissioning waste should be disposed of in the appropriate waste disposal facilities, subject to their availability. Large and complex decommissioning projects will require radioactive waste management facilities for processing, ~~interim~~ storage and transport of decommissioning waste. These facilities should be planned as part of the decommissioning plan and should be commissioned under the decommissioning license or under separate authorizations issued by the regulatory body.

~~7.39.~~7.37. While the bulk of the radioactive waste from nuclear power plants will be low level radioactive waste, a small percentage will be intermediate level waste with very high contact dose rate, requiring shielded packages for safe storage. This may not be the case for nuclear fuel cycle facilities, depending on their operational usage.

~~7.40.~~7.38. Nuclear fuel cycle facilities and facilities for management of spent nuclear fuel must consider criticality safety in the plans for decommissioning, in the assessment of safety of planned actions, and in the design of waste packages and interim waste storage facilities.

~~7.41.~~7.39. A ~~deferred dismantling~~ decommissioning project based on a deferred dismantling strategy could be considered a multi-phase project, consisting of the following phases:

Phase 1: Removal of radioactive waste and dangerous substances used and produced during the operating life of the nuclear installation (when this has not been completed during the transition phase);

Phase 2: Preparation for safe enclosure (possibly including initial dismantling works);

Phase 3 Safe enclosure period;

Phase 4: Operations to prepare for the final dismantling work (e.g. establishing new working areas, supporting facilities, interim storage of wastes, etc.);

Phase 5: Dismantling and decontamination actions and removal of the radioactive waste from the area which is subject to decommissioning;

Phase 6: Final radiological remediation activities (e.g. on-site remediation);

Phase 7: ~~Conventional~~ Final conventional removal activities (e.g. demolition of radiologically clean buildings).

~~7.42.~~7.40. Preparation for safe enclosure requires an identification of the safe enclosure area, which will be preserved for the deferral period, by defining the boundaries of the buildings, premises and equipment concerned, the physical and radiological status to be reached before commencing the safe enclosure mode, and the safety systems (passive systems should be preferred, but sometime also active systems are appropriate) which remain in operation to ensure safe preservation.

~~7.43.~~7.41. Preparatory actions for safe enclosure should be supported by characterization surveys and by a safety assessment to demonstrate that the work to be done (removal of waste, removal from service and/or dismantling of unnecessary SSCs, decontamination, etc.) can be performed safely. The deferral period (safe enclosure period) should, furthermore, be supported by a safety assessment to demonstrate that the barriers of the safe enclosure area can withstand internal and external events which may occur during the period of safe enclosure.

~~7.44.~~7.42. A surveillance and maintenance plan for the safe enclosure period ~~is~~ should be based on the outcomes of the safety assessment. It should consider ageing and obsolescence aspects of the SSCs. The safety assessment for the deferred dismantling strategy should be the basis for establishing the safety parameters (e.g. temperature, humidity, containment, and discharges to the environment,) which should be maintained by means described in the surveillance and maintenance plan. Corrosion and brittle fracture of materials, as well as ageing and obsolescence of materials (spare parts) are typical issues to be considered carefully. During the safe enclosure period the licensee should perform at regular intervals a review of the safety of the nuclear installation as a whole, to demonstrate the compliance with its expected condition.

~~7.45.~~7.43. Near the end of the safe enclosure period, the final decommissioning plan should be updated, and supported by an appropriate safety assessment for the final dismantling phase. This safety assessment should be equivalent to the one for a decommissioning project based on an immediate dismantling strategy. The update should consider additional preparatory actions, which will be necessary to “re-open” the installation in order to implement dismantling actions.

~~7.46.~~7.44. As the decommissioning project is undertaken, there may be modifications to the decommissioning actions based on new data, unexpected events, experience feedback and other factors. The final decommissioning plan and the related supporting documentation may subsequently need to be updated during its implementation as the decommissioning activities progress. These updates may or may not require further approvals by the regulatory body. For complex decommissioning projects, the final decommissioning plan may describe a change control process to allow minor changes to actions described in the final decommissioning plan without approval by the regulatory body. The impact of updates to the final decommissioning plan on the environmental impact assessment should also be considered. The environmental impact assessment should be updated when a previously unconsidered potential environmental impact is identified.

PUBLIC INVOLVEMENT

~~7.47.~~7.45. According to national requirements, interested parties may be involved in the licensing process for decommissioning, as well as in the process for termination of decommissioning license by providing comments before decisions are taken by the regulatory body and prior to granting or terminating a decommissioning license.

~~7.48.~~7.46. Experience shows that interested parties focus their attention mainly on the selected decommissioning strategy and its justification, the nature and extent of planned dismantling works, the management and long term storage of radioactive waste on-site, the installation ~~end-state~~end state, especially in the case of restricted reuse, and on the socio-economic impacts.

~~7.49.~~7.47. Public inquiries or consultations should be organized by the regulatory body with participation of the licensee to provide to the interested parties an opportunity to give comments on the final decommissioning plan and appropriate supporting documents, in accordance with national regulations. These inquiries should be held primarily with the local communities from the area of the nuclear installation to be decommissioned. It is considered a good practice if the licensee establishes and supports public outreach programmes, independent of the regulatory body, to provide opportunities for community involvement and enhancing public understanding and trust of the decommissioning approach and process.

~~7.50.~~7.48. The results of the public inquiries and consultations of interested parties should be made public to show how the comments have been addressed by the regulatory body during the licensing process for decommissioning, if and when applicable.

UNANTICIPATED PERMANENT SHUTDOWN

~~7.51.~~7.49. If the permanent shutdown of a nuclear installation is unanticipated, due to political, economic, or social demands, or due to an accident, the installation should be kept safe or brought to a

safe condition by the licensee under an appropriate authorization, until an approved final decommissioning plan can be implemented.

~~7.52.~~7.50. The selection of the decommissioning strategy should be reviewed in light of the cause and consequences of the event, which resulted in premature permanent shutdown, especially the effect of the event on the condition of the nuclear installation. If any actions are required to place an installation into a safe condition as a result of the unanticipated permanent shutdown, they should preferably be done under the operating license or under an amended operating license which covers these actions.

~~7.53.~~7.51. An unanticipated shutdown may occur during operation when a final decommissioning plan and its supporting documents are not available yet. In such case, the final decommissioning plan and supporting documents must be prepared as soon as possible.

~~7.54.~~7.52. In case of an unanticipated shutdown due to an accident, the nuclear installation should be brought to a safe condition by applying emergency measures and recovery (stabilization) actions. After the emergency phase is over, information should be collected as soon as possible about the radiological and physical status of the nuclear installation and the final decommissioning plan should be developed, addressing decommissioning of the nuclear installation damaged by the accident.

~~7.55.~~7.53. Planning of the decommissioning of an accident damaged nuclear installation will involve an extensive update of the characterization surveys carried out previously. If accessibility to the parts of the nuclear installation has deteriorated as a result of the accident, increased use of remote handling equipment for the decommissioning may be foreseen. Special attention should be paid to the removal of emergency provisions which may have been implemented to mitigate the consequences of the accident. Records and data of the nature and extent of such existing safety provisions should be considered during planning for decommissioning.

~~7.56.~~7.54. The decommissioning process for an accident damaged nuclear installation should follow the same principles and main steps as for planned decommissioning. Technical challenges are expected to be ~~possible~~ possibly larger, due to high dose rates and contamination levels, higher uncertainties of information about the physical and radiological status of the installation, possible new categories of waste, and especially due to large amount of unstructured material and waste, which may lead to a selection of a deferred dismantling strategy. Nevertheless, decommissioning of such installation should be planned and considered as an authorized activity which should, in principle, comply with the same set of safety criteria as decommissioning after normal operation and planned shutdown. In case of severe accident, the decommissioning plan of such installation should be consistent and coordinated with overall strategy including off-site remediation.

8. CONDUCT OF DECOMMISSIONING ACTIONS

Requirement 12 of GSR Part6 [1]: Conduct of decommissioning actions

The licensee shall implement the final decommissioning plan, including management of radioactive waste, in compliance with national regulations. [1]

8.1. Conduct of decommissioning involves implementation of the decommissioning strategy and related actions, as described in the final decommissioning plan. The final decommissioning plan is the version of the decommissioning plan submitted for approval to the regulatory body prior to its implementation.

8.2. Modifications of the existing infrastructure of the nuclear installation may be needed to facilitate immediate dismantling or, in some cases, to prepare the installation for a safe enclosure period. The main modifications may involve:

- Modification or substitution of SSCs that are important for ensuring safety during decommissioning, such as ventilation and containment systems;
- Isolation and removal of SSCs which are not needed for decommissioning, such as criticality detection systems;
- Establishment of new access and transport routes for personnel, equipment and waste to and from the nuclear installation;
- Installation of additional equipment, such as remote size reduction and waste handling equipment;
- Establishment of an interim waste storage area within the installationon-site.

8.3. Preliminary decontamination of process equipment should be carried out as early as possible. It is advantageous in reducing the radiological risks posed, because a significant amount of radioactive contamination or nuclear material, in case of some nuclear fuel cycle facilities, may remain in the process equipment of the nuclear installation after its permanent shutdown. If this is carried out successfully, the hazard (such as criticality, high dose rates) can be removed or reduced as a consideration from the safety assessment for the decommissioning actions. This allows more flexibility on how the decommissioning of the nuclear installation will be undertaken, e.g., allows reduction of the amount of liquid used for decontamination, allows removal of the operational SSCs associated with the hazard (i.e., criticality monitoring) or minimizes the potential to cross contaminate redundant equipment.

8.4. Consideration should be given to an early removal, containment or immobilization of any remaining loose contamination, where practicable, as this reduces the challenge posed to the

ventilation system (possibility of its contamination) and the workers undertaking the decommissioning actions. Records of such activities should be kept, including the level of residual contamination.

8.5. If the licensee adopts a deferred dismantling strategy, safe configuration of the nuclear installation must be maintained and records should be periodically checked to confirm they are being preserved in a safe and retrievable media format. For deferred dismantling, the main installation modifications may involve:

- Establishment of physical protection measures;
- Establishment of barriers to isolate the safe enclosure area;
- Isolation and removal of SSCs which are not needed;
- Establishment of alternative SSCs (preferably passive); and
- Creation of storage areas for equipment, materials and waste.

8.6. At the end of the preparatory phase for safe enclosure the regulatory body should perform inspection to verify that the nuclear installation is in the state as planned and approved, i.e. that it is ready for the passive safe enclosure phase.

8.7. If activities for decontamination and dismantling are deferred in part or in whole, the licensee should ensure safety of the nuclear installation ~~should be ensured~~ through an approved monitoring, surveillance and maintenance programme. When reviewing the required systems to support the deferred decommissioning strategy, it is vital to identify SSCs that are not required, so that the surveillance and maintenance carried out on these systems can be reduced or terminated.

8.8. A surveillance and maintenance programme for the safe enclosure period should be prepared prior to commencement of this phase and should be approved by the regulatory body. It should contain type and periodicity of the surveillance and maintenance actions, and should reference the procedures to be used.

8.9. There are many techniques and methods available for decommissioning. It is preferable to select proven techniques that are commercially available and technically mature. As detailed within the final decommissioning plan, the available techniques to be deployed to carry out the decommissioning actions are evaluated to confirm feasibility and suitability. The following factors may influence the choice of the decommissioning techniques to be deployed:

- Potential impact on the workers and the environment, for example giving preference to techniques that do not generate high airborne radioactivity;
- Cost–benefit analysis comparing the radiological benefits and waste management benefits of the decommissioning technique with the expected overall costs;

- Availability of suitable waste containers, routes and facilities for storage and disposalition facilities;
- Types and physical properties (e.g., size, shape and accessibility) of the redundant equipment and structures to be dismantled;
- Maturity of the technology that will be deployed for the decommissioning actions and the development timeframe;
- Reliability of the dismantling equipment and tools and its simplicity to operate, decontaminate and maintain;
- Impact on adjacent systems and structures and on other work in progress within the nuclear installation;
- Time and schedule constraints, such as availability of waste treatment processing facilities; and
- Specialist resource and training requirements, such as for the use of remotely operated equipment; and
- Generation of secondary radioactive waste.

8.10. However, in some cases special tools and equipment may be needed, and they should be tested in simulated conditions before their use, from both a safe operability and maintainability aspect. Benefits can be taken from computer-based simulations, given the necessary benchmarking being performed, as well as physical mock-ups to select decommissioning techniques, to evaluate options, to aid in the design and to train workers.

8.11. SSCs, for which little attention has been given or for which access has been limited during the operational phase of the nuclear installation, may have suffered degradation. Such systems should be given special consideration when decommissioning techniques are considered. Examples of this include liquid storage tanks and remote handling systems within unmanned cells.

8.12. Decommissioning of a nuclear installation may be aided in certain instances by partial or total decontamination of the components, equipment and structures to be dismantled. Decontamination may be applied to internal or external surfaces and covers a broad range of actions directed at the removal or reduction of radioactive contamination in or on components, equipment and structures of the installation. Given this, the process of decontamination associated with the decommissioning actions can be conducted before, during or after dismantling. Before any decontamination technique is selected, an evaluation of its effectiveness and of the potential for reducing total exposure should be performed. The decontamination process should also be evaluated to ensure it is compatible with waste processing systems and disposal options. The main objectives of decontamination include:

- Reducing workers' internal and external exposure during decommissioning actions;
- Minimizing the volume and reduce the categorization of the radioactive waste; and

- Increase the opportunities for recycling and reuse of components, equipment or structures of the nuclear installation.

8.13. As the decommissioning actions progress new hazards may occur. The decommissioning workers should highlight any such new hazards as part of the daily briefs and feedback sessions. An example of this is during size reduction ~~of redundant ventilation ducting~~ using a diamond wire system, sharp edges are generated and a number of additional control measure should be adopted, such as application of protection covers. It is vital that the new hazards are addressed properly, so to maintain overall safety of the decommissioning actions undertaken.

8.14. A primary output from the decommissioning safety assessment is the identification of SSCs important to safety in accordance with a graded approach. The SSCs provide a means for the prevention, detection, control and limitation of events and mitigation of the potential consequences.

8.15. The development and update of the list of SSCs important to safety is based on the design of the existing nuclear installation, the installation of the infrastructure to enable decommissioning and the safety assessment concerning the decommissioning actions. The SSCs from the operational phase of the nuclear installation may be required to facilitate decommissioning, but the condition of these should be evaluated in-line with the safety assessment for decommissioning. For example, the level and extent of the evaluation depends on:

- Condition of the SSCs;
- Extent of inspection, monitoring and maintenance of SSCs;
- Safety function requirements of SSCs during decommissioning; and
- Expected duration of the decommissioning actions.

8.16. Assessment areas which should be covered include:

- Evaluation of the existing structures of the nuclear installation for stability structural capability;
- Evaluation of the confinement integrity of the existing installation infrastructure, including tanks, vessels, piping, and ventilation ducting;
- Adequacy and integrity of the existing installation infrastructure required for decommissioning, including electrical distribution systems;
- Availability and adequacy of the existing SSCs support systems, including alarm systems and ventilation systems; and
- Processes and infrastructure interfaces with other facilities, in the case of a multi-facility site.

8.17. Decommissioning actions may involve the deliberate removal of SSCs that had fulfilled specific safety functions during operation of the nuclear installation (e.g., containment, shielding, ventilation, and cooling). This should be recorded and aligned with the on-going phases, work packages and tasks identified in the final decommissioning plan.

8.18. Removal from service of such SSCs is a key issue during decommissioning, and a decision making process to remove SSCs from services should be carefully assessed and implemented by the licensee. A good practice is to establish a list of SSCs important for safety during decommissioning and to update this list in-line with the on-going decommissioning actions. This information can be used to update the installation's inspection and surveillance and maintenance programmes.

8.19. During decommissioning, radioactive and non-radioactive effluents will be generated. Discharge of effluents requires authorization from the regulatory body and control in compliance with appropriate national regulations. In general, the expected discharges of effluents should be less than during operation of the nuclear installation but may be in a different form and with a different radionuclide composition. It is typical for effluent discharges to vary through the different phases of decommissioning. For example, as decommissioning leads to a progressive removal of radiological hazards, the radioactive discharges may be reduced.

8.20. In some instances, decommissioning actions might result in elevated discharges for a limited period of time. Hence, the discharge authorization for decommissioning should be revised as appropriate. An example of this is, when a reactor undergoing decommissioning is part of a site with other operating facilities, then the discharge authorizations for the reactor and for the entire site should be reviewed and revised as appropriate in light of the decommissioning activities to be undertaken. Guidance for developing and implementing an environmental monitoring programme can be found in the IAEA Safety Standards Series publications [~~29~~31].

8.21. Depending on the end state of the decommissioning ~~final end state~~ project, demolition of the remaining structures of the former nuclear installation may be required. In many cases, the decommissioning actions are aimed at making the demolition of the building structure a non-radiological action. Where demolition of the buildings involves radioactively contaminated structures, radiological safety considerations need to be addressed. In such a case, specific techniques such as water spraying and use of local containment systems should be implemented to reduce the impact on the environment. Care should be exercised during demolition to ensure that contaminated material is segregated from the non-contaminated material and from non-radiological hazardous materials.

8.22. -During decommissioning, records should be maintained of key decommissioning actions. For example, accurate and complete information concerning the quantities and types of radionuclides remaining at the installation, their locations and distributions, and the volume of radioactive waste

generated. These records could be used to demonstrate that all radioactive materials, that were present at the beginning of decommissioning, have been properly accounted for and that their final dispositions (e.g. restricted reuse or disposal) have been identified and confirmed. Documentation should also account for materials, structures and land that have been removed from regulatory control.

~~8.21.~~

REGULATORY OVERSIGHT DURING CONDUCT OF DECOMMISSIONING ACTIONS

~~8.22.~~8.23. The regulatory body's inspection programme for a nuclear installation in decommissioning should follow a graded approach. The decommissioning inspection programme should be commensurate with the decommissioning actions and associated hazards. Guidance on the regulatory inspection of nuclear facilities and enforcement by the regulatory body is provided in the IAEA Safety Standards Series publications [~~30~~32].

~~8.23.~~8.24. During periods of intensive decommissioning actions, inspections should be increased and coordinated to coincide with actions taking place that have a high potential safety impact, such as movement of large components and size reduction activities. Inspections during this period might focus on topics such as: exposures to workers, contamination control, nuclear material flow control, industrial safety, transportation of radioactive waste, and radiological condition of areas that may not be easily accessible at a later time during decommissioning.

~~8.24.~~8.25. If a deferred dismantling strategy is chosen, the frequency and scope of inspections should be reduced when an installation is in safe enclosure. These inspections should focus on surveillance and preservation of the nuclear installation (e.g., preventing degradation that may result in loss of control of material and the spread of contamination), adequacy of record keeping, site monitoring and surveillance and radiation protection.

EMERGENCY RESPONSE ARRANGEMENTS

Requirement 13 of GSR Part6 [1]: Emergency response arrangements for decommissioning

Emergency arrangements for decommissioning, commensurate with the hazards, shall be established and maintained and events significant to safety shall be reported to the regulatory body in a timely manner. ~~[1]~~

~~8.25.~~8.26. Prior to decommissioning of a nuclear installation, an emergency plan ~~must~~ should already exist for the installation or for the whole site where the nuclear installation is located [~~22~~23]. A review and revision of this emergency plan should be made before commencement of decommissioning actions, to ensure it is adequate for decommissioning.

~~8.26.~~8.27. Hazards should be reassessed to identify those which will be applicable during decommissioning and emergency arrangements should be revised accordingly to face such hazards. This will mean identifying range of postulated emergency scenarios and developing emergency plans and procedures to deal with them in accordance with [~~22~~23]. ~~An e~~Examples of this could be loss of containment or ~~the~~ a recovery from a dropped waste package either within the nuclear installation or on transfer to the ~~interim~~ storage facility or disposal site.

~~8.27.~~8.28. The licensee should ensure that adequate staff, equipment, means for communication, logistical support, emergency response facilities, etc., are available and procedures, coordination and organization are in place in accordance with the approved emergency plan. Personnel should be qualified, trained in emergency procedures and fit for the duty, and consideration should be made for regular testing and updating of these procedures by conducting exercises periodically.

~~8.28.~~8.29. The emergency plan and related procedures should cover on-site and, where necessary, off-site responses, including the timely notification of appropriate off-site authorities (government, regulatory bodies and support organizations) and the public. In cases when emergency and security plans from operation are intended to be used during decommissioning, the licensee should perform their review and ensure they are adequate in the new circumstances (in some cases new organizations may be involved, and new possible emergency situations and/or security threats may become relevant). Guidance for emergency preparedness and response has been covered in the IAEA Safety Standards Series publication [~~31~~33,~~32~~34].

RADIOACTIVE WASTE MANAGEMENT

Requirement 14 of GSR Part6 [1]: Radioactive waste management ~~for~~ in decommissioning

Radioactive waste shall be managed for all waste streams in decommissioning. ~~[1]~~

~~8.29.~~8.30. Decommissioning invariably involves generation of large amounts of material and waste in forms that may be different from materials and categories routinely handled during the operational phase of the nuclear installation. A waste management plan that covers all the anticipated decommissioning waste streams and categories should be developed. The waste management plan should define the manner in which material and radioactive waste will be removed from the nuclear installation and the manner for segregating radiological from non-radiological and hazardous waste.

~~8.30.~~8.31. If existing waste processing systems cannot cope with the waste generated during decommissioning in the volumes or types of waste expected, the construction of new facilities or the use of existing facilities for ~~interim~~ storage should be considered. Such considerations should take place in the framework of updating the initial decommissioning plan. Consideration should also be given to minimizing cross-contamination of waste and materials, and the generation of secondary

waste, which may require additional ~~interim~~ storage or processing capacities on-site. A separate authorization of such activities may be required from the regulatory body.

~~8.31.~~8.32. In general, an update of the existing waste management plan from the operational phase of the nuclear installation should be performed with consideration for additional waste materials and categories associated with the decommissioning actions. The waste management plan should anticipate periods requiring the processing of high volumes of waste and the manner to minimize any impacts upon the decommissioning actions or the operations of other facilities at a multi-facility site. Licensees should ensure that the waste management plan, which is part of the decommissioning plan or stand-alone supporting document, is implemented and maintained.

8.33. During conduct of decommissioning, a waste management plan that covers all the anticipated decommissioning waste streams and categories should be implemented. Waste generated during decommissioning should be segregated into different categories (radiological, non-radiological, hazardous and non-hazardous) based on accepted procedures and criteria. Specific plans for the re-use, recycling, storage, or disposal of that waste should be required.~~Waste generated during decommissioning should be segregated in accordance with applicable handling, processing, re-use and disposal options.~~ This is undertaken to minimize the volume of waste to be disposed as radioactive, facilitate future downstream process of the waste and reduce overall costs. A proper determination and documentation of the characteristics of waste form, waste container and/or waste package should be ensured to provide data required for future management e.g. disposal.

~~8.32.~~8.34. Decisions on the processing of radioactive waste generated during decommissioning should consider existing or anticipated options for waste disposal.

~~8.33.~~8.35. Verification of the waste characteristics and waste packages should be based on procedures that may include direct measurements on the material, laboratory measurements of representative samples, use of properly derived radionuclide vectors ("scaling factors", correlation between "difficult to measure nuclides" and "easy to measure nuclides") and adequate identification of the waste origin.

~~8.34.~~8.36. Transport of radioactive waste from the nuclear installation to the processing, storage or disposal facilities should conform to national transport regulations. The requirements for the transport of radioactive material and the associated guidance are provided in the IAEA Safety Standards Series publications [8, 9]. Precautions should be taken to prevent the external contamination of disposal containers that could spread contaminants during transport.

~~8.35.~~8.37. The licensee should ensure that each ~~maintain waste management related records using a specific database of the~~ waste ~~and~~ package~~s~~ generated during decommissioning is provided with a durable label carrying an identification number and relevant information, and that proper

records of each waste package and all the unpackaged waste are kept as part of the integrated management system. All records should be securely stored, easily accessible and be able to be retrieved over an extended period of time after completion of decommissioning using a specific database. The data recorded for each individual waste package should include as a minimum:

- Origin of waste (material/ item/components the waste package contains);
- Identification number of the package;
- Type of waste package~~s~~;
- Volume or weight of the package;
- Radioactive inventory (total activity, nuclide composition or spectrum and activities of main radionuclides);
- Results of surface contamination measurement;
- Maximum dose rate at contact and 1 m distance (transport index) and date of measurement ~~Contact dose rate~~; and
- Corresponding classification of the radioactive waste [~~33~~35].

~~8.36.~~8.38. Management of operational waste, spent fuel and process materials should be done under the operational license during the transition from operation to decommissioning. ~~Provisions for timely management of the operational waste should be elaborated prior to the permanent shutdown, and discussed with the regulatory body and other interested parties in accordance with national requirements.~~ This should ensure that delays in removal of operational waste and a costly extended shutdown mode of the nuclear installation at the end of its operation are avoided, and the nuclear installation is efficiently brought to a condition when decommissioning could begin.

~~8.37.~~8.39. Removal of spent fuel elements and operational waste before implementing any decommissioning actions may be difficult when the related waste management facilities are not available or when these issues are included as part of the decommissioning programme. In such cases, the removal of the remaining waste and materials should be addressed in the final decommissioning plan and associated waste management plan. Planning of decommissioning during operation should help to identify any milestones and tasks that have to be completed to facilitate decommissioning, including timely arrangements for management of radioactive waste from both operation and decommissioning.

~~8.38.~~8.40. Implementing a phased approach to decommissioning of a nuclear installation could allow the licensee to dedicate the first phase to the management of the remaining operational waste and materials that have to be removed prior to the beginning of the next decommissioning phase.

9. COMPLETION OF DECOMMISSIONING ACTIONS AND TERMINATION OF AUTHORIZATION FOR DECOMMISSIONING

Requirement 15 of GSR Part6 [1]: Completion of decommissioning actions and termination of the authorization for decommissioning

On the completion of decommissioning actions, the licensee shall demonstrate that the end state criteria as specified in the final decommissioning plan and any additional regulatory requirements have been met. The regulatory body shall verify the compliance with the end state criteria and shall decide on termination of the authorization for decommissioning. [1]

9.1. On completion of decommissioning, a final decommissioning report must be prepared by the licensee and retained as specified by the national requirements. The final decommissioning report should include key decommissioning reporting documents, such as the final radiological survey report.

9.2. The final decommissioning report should summarize the final status of the former nuclear installation. The final physical and radiological status of the remaining structures of the nuclear installation, if any, and/or the site at the time of release from nuclear regulatory control or at the time of conversion to other (nuclear) use should be described. A summary or reference to the results of the radiological survey report should be provided. Furthermore, it should address any remaining restrictions on the site, if they exist. A review of the environmental impact assessment may be necessary considering the final radiological status of the former installation, as required by national requirements. The final decommissioning report should summarize the activities performed during decommissioning, and should also provide additional project information, as appropriate.

9.3. After completion of decommissioning works, the final decommissioning report should be submitted by the licensee in a timely manner to the regulatory body. Additionally, the licensee may prepare more specific documentation of the decommissioning project for its own use, e.g. providing details about methods and tools applied for conducting decommissioning actions and summarizing decommissioning lessons learned to be utilized in similar decommissioning projects in the future.

9.4. The final decommissioning report must be reviewed by the regulatory body to ensure that the final decommissioning end stateend state, both for the physical and radiological status, has been reached in compliance with the final decommissioning plan and the related requirements of the license for decommissioning. The results of the review of the decommissioning report should be made available by the regulatory body in a timely manner to allow further works to be performed, if deemed necessary by the regulatory body, when non-compliance with criteria is identified.

9.5. A final radiological survey of the nuclear installation needs to be performed to demonstrate that the decommissioning objectives, as described in the final decommissioning plan and in the

decommissioning license, have been fulfilled, and that the residual radioactivity meets the regulatory criteria for restricted or unrestricted release.

9.6. The final survey plan is part of the final decommissioning plan (as described in the Annex I) and has been, as such, approved by the regulatory body. Any changes to the design and implementation of the final survey plan should be discussed with the regulatory body during the planning period for the survey, and should be submitted to the regulatory body for review and approval. The survey may be carried out in phases, as portions of decommissioning work are completed, to enable parts of the nuclear installation or site to be released from regulatory control. If the surveys are completed in phases, the licensee should have procedures to ensure that the surveyed areas are not impacted by the ongoing decommissioning actions on other parts of the site.

9.7. The criteria for release of the nuclear installation from regulatory control, established by the regulatory body, should be convertible into terms of measurable quantities that can readily be compared with the results of the field measurements. Sampling methods should be implemented as defined and justified in the final survey plan. The radionuclides present will influence the survey and sample methods adopted. The final survey plan and procedures should provide sufficient data and detail to produce a final radiological survey report and should be approved by the regulatory body. The final radiological survey report, as a part of the final decommissioning report, is submitted to the regulatory body for approval. The results of the survey will be a major portion of the final decommissioning report.

9.8. The regulatory body should perform inspections during the final survey implementation to verify survey procedures are being properly implemented and are compliant with requirements. The regulatory body should perform independent confirmatory radiological surveys and sampling to ensure compliance with the end state criteria for the site or the implementation of restrictions at the site. These surveys should be conducted by experts with special training in this field.

~~9.9. The regulatory body should use both in-process surveys and confirmatory surveys. In-process surveys are typically done side-by-side with the licensee, and serve to confirm the validity of their final survey process. Confirmatory surveys are done after the licensee has completed survey work and submitted a final radiological survey report. In doing confirmatory surveys, it is not necessary to repeat every survey sample, as the purpose is to provide additional assurance that the site end state condition is not inconsistent with the final decommissioning plan. These surveys should be conducted by experts with special training in this field.~~

9.9. The regulatory body should verify or validate that the site meets the end state criteria [7]. In the event that the site or remaining structures of the former nuclear installation do not comply with the

initially approved release criteria, a reassessment of the situation should be performed by the licensee and presented to the regulatory body for review and potential approval.

9.10. The regulatory body should ensure that relevant plans, records and reports (addressing decontamination, demolition and dismantling actions, as well as surface, groundwater, soil and sediment remediation, and the final radiological survey) are prepared by the licensee, and retained for an appropriate timeframe.

9.11. When deviations from the ~~end-state~~end state are considered unacceptable or not properly justified, the regulatory body may require the licensee to resume decommissioning actions to reach the ~~end-state~~end state as foreseen in the final decommissioning plan.

9.12. If the end state approved in the final decommissioning plan cannot be achieved, ~~Any~~ deviations from th~~at~~e ~~end-state~~ end state~~,~~ ~~as described in the final decommissioning plan,~~ should be clearly identified, their consequences should be assessed, and a new end state should be described and approved by the regulatory body. Such deviation should be addressed in the final decommissioning report. Sometimes an update of the final decommissioning plan would also be needed, if additional decommissioning actions are needed to achieve the new end state. ~~(for example, when waste storage facilities remain on a part of the site under a new license, with possible transfer of responsibilities to a separate licensee). This update should be approved by the regulatory body.~~

9.13. In order to achieve termination of the decommissioning license for some or all the facilities on a multi-facility site, partial or restricted release may be sought. Restrictions would become necessary to ensure protection of human health and the environment.

9.14. If restrictions are necessary for access to or for the use of the remaining parts of the nuclear installation or site, the regulatory body needs to ensure that an appropriate mechanism is in place to demonstrate compliance with these restrictions ~~for radiological control~~.

9.15. For sites released with restrictions, appropriate arrangements for continuous control are needed to ensure the protection of human health and the environment. The restrictions should be documented and established as part of the institutional controls, so future uses of the site are not contrary to the restrictions. An example of such documentation is a land deed restriction. The responsibility for implementing and maintaining these controls has to be clearly assigned to an organization or institution. The implementation of controls has to comply with regulatory requirements and the monitoring and surveillance for compliance has to be in place, as approved by the regulatory body.

9.16. A long term surveillance and maintenance plan for the area released with restrictions should be prepared by the licensee, and should be submitted for approval by the regulatory body. Interested parties should be informed of any site restrictions and of the results of monitoring and surveillance.

Legal and financial arrangements should be made for implementation of a long term surveillance and maintenance plan.

9.17. The regulatory body should conduct periodic inspections to ensure compliance with the long term monitoring and surveillance requirements and ensure that maintenance is being performed to meet site restrictions and institutional control requirements.

9.18. If the decommissioning waste has to be stored on-site for a longer period of time after completion of decommissioning, an application for ~~creation~~ construction of a new storage facility for radioactive waste must be prepared by the licensee and submitted to the regulatory body for review, approval and authorization. Requirements and guidance concerning radioactive waste storage are provided in [11-13]. If spent fuel remains on-site, guidance found in [10] should be applied. ~~In that case, the licensee of the waste storage facility should periodically report to the regulatory body detailing the radioactive waste inventory, monitoring, transportation and disposal. Moreover, information such as radiological surveys, effluent and environmental monitoring and personnel exposure monitoring data should be reported to the regulatory body, as required.~~ A decommissioning plan for the ~~new~~ waste storage or spent fuel storage facility that remains on the site ~~must~~ should be prepared.

~~9.19. The regulatory body should perform periodic inspections of the waste storage facility to ensure compliance with regulatory requirements and to ensure that material condition of the facility and waste is being maintained.~~

~~9.20.~~9.19. It is permissible to progressively release buildings and land areas from radiological controls that are described in the license for decommissioning. A discussion between the licensee and the regulatory body should be initiated as soon as possible to address such situation.

~~9.21.~~9.20. If a partial site release and reduction in the authorization is the objective, this should be reflected in the final decommissioning plan, survey plan and procedures to demonstrate compliance with the national requirements for site release. The request for release from regulatory control of a particular part of the nuclear installation or part of its site must consider the radiological criteria for the final release of the entire site and its future use. For example, the partial site release should not use an industrial re-use scenario (“brownfield”) to determine the residual radioactivity criteria for that part of the site, if the licensee’s plans for the entire site are to re-use it without restrictions (~~according to the residential farmer scenario (~~“greenfield”) after completion of decommissioning on the entire site.

~~9.22.~~9.21. Comments from interested parties, e.g. the public, must be obtained and addressed before the license for decommissioning is terminated. Appropriate consideration should be given to the communication with the public, especially if the end state is release from regulatory controls with restrictions.

~~9.23.~~9.22. Prior to terminating the decommissioning license, the regulatory body should communicate relevant issues and coordinate its decision with other regulatory bodies that have authority or responsibilities for other issues or aspects related to the site.

~~9.24.~~9.23. When the criteria for the site release have been met according to the defined final decommissioning end state, the regulatory body should formally notify the licensee, other relevant competent authorities and interested parties of the decision to release the site from regulatory control. In the event of a decision for restricted release, the notification should specify the restrictions, associated measures to be applied and the time frames for the application of these measures, as well as the entities responsible for the implementation, monitoring and regulatory control of the restrictions.

~~9.25.~~9.24. The regulatory body should specify a period for which the documents associated with decommissioning are to be maintained and retained. The documents retained should be consistent with national requirements.

~~9.26.~~9.25. An adequate record management system should be applied to the records related to the site release after completion of decommissioning. It should cover some records produced before the termination of the decommissioning license, such as description of the nature and level of residual radioactivity, then the decisions related to the site release, made prior to and after decommissioning of the site and their rationale, and information which verifies that the site end state criteria have been met. Record keeping is particularly important where restrictions are imposed on the future use of sites.

~~9.27.~~9.26. If specific restrictions are required to be imposed upon future owners or users of the decommissioned nuclear installation and its site, these restrictions should be included in a legal document and should be enforceable.

~~9.28.~~9.27. The nature and extent of the decommissioning records, to be preserved after termination of the decommissioning license, should be viewed in the light of a possible transfer of ownership of the site after the final release from regulatory controls. Long term management of the knowledge base of the former nuclear installation should be in place. Any caretaker responsibility, including keeping relevant records for potential litigation or for other purposes, is then likely to be transferred to other institutions, as required by the national laws and regulations.

~~9.29.~~9.28. Records may be required to identify and justify actions that were taken when a later review of the end state or project performance because of, among other things, new regulatory positions (e.g. on clearance levels) or the development of more advanced, higher resolution detection equipment may occur. The former actions may be in conflict with these new developments and the information will provide a history and bases for these past actions. Typically the national regulatory body or another national authority would take over keeping the records from the decommissioning licensee. The duration of records control is usually determined by the national regulations for records

for, for example, occupational exposures and potential future liability. Other records may need to be kept for institutional purposes or other ad hoc reasons.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Facilities, IAEA Safety Standards Series No. GSR Part 6, IAEA, Vienna (2014).

[2] EUROPEAN ATOMIC ENERGY COMMUNITY, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Fundamental Safety Principles, IAEA Safety Standards Series No. SF-1, IAEA, Vienna (2006).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Medical, Industrial and Research Facilities, IAEA Safety Standards Series No. WS-G-2.2, IAEA, Vienna (1999) (under revision, DS403).

[4] EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulatory Control of Radioactive Discharges to the Environment, IAEA Safety Standards Series No. WS-G-2.3, IAEA, Vienna (2000) – under revision, DS442 – replace when published.

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Concepts of Exclusion, Exemption and Clearance, IAEA Safety Standards Series No. RS-G-1.7, IAEA, Vienna (2004).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Release of Site from Regulatory Control Upon Termination of Practices, IAEA Safety Standards Series No. WS-G-5.1, IAEA, Vienna (2006).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 2012 Edition, IAEA Safety Standards Series No. SSR-6, IAEA, Vienna (2012).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2012 Edition), IAEA Safety Standards Series No. SSG-26, IAEA, Vienna (2014).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Storage of Spent Nuclear Fuel, IAEA Safety Standards Series No. SSG-15, IAEA, Vienna (2012).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Radioactive Waste, IAEA Safety Standards Series No. GSR Part 5, IAEA, Vienna (2009).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Low and Intermediate Level Radioactive Waste, IAEA Safety Standards Series No. WS-G-2.5, IAEA, Vienna (2003).

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of High Level Radioactive Waste, IAEA Safety Standards Series No. WS-G-2.6, IAEA, Vienna (2003).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Radioactive Waste from the Mining and Milling of Ores, IAEA Safety Series No. WS-G-1.2, IAEA, Vienna, (2002) – under revision DS459.

[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Disposal of Radioactive Waste, IAEA Safety Standards Series No. SSR-5, IAEA, Vienna (2011).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Borehole Disposal Facilities for Radioactive Waste, IAEA Safety Standards Series No. SSG-1, IAEA, Vienna (2009).

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Geological Disposal Facilities for Radioactive Waste, IAEA Safety Standards Series No. SSG-14, IAEA, Vienna (2011).

[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Near Surface Disposal Facilities for Radioactive Waste, IAEA Safety Standards Series No. SSG-29, IAEA, Vienna (2014).

[19] INTERNATIONAL ATOMIC ENERGY AGENCY, Remediation Process for Areas Affected by Past Activities and Accidents, IAEA Safety Standards Series No. WS-G-3.1, IAEA, Vienna (2007).

[20] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Rev. 5), IAEA Nuclear Security Series No. 13, IAEA, Vienna (2011).

[21] INTERNATIONAL ATOMIC ENERGY AGENCY, Governmental, Legal and Regulatory Framework for Safety, IAEA Safety Standards Series No. GSR Part 1, IAEA, Vienna (2010).

~~[21]~~[22] INTERNATIONAL ATOMIC ENERGY AGENCY, Occupational Radiation Protection, IAEA Safety Standards Series No. xxx (DS453), IAEA, Vienna (in preparation)

~~[22]~~[23] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GS-R-2, IAEA, Vienna (2002). [under revision, GSR Part 7 (2015)]

~~[23]~~[24] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for Facilities and Activities, IAEA Safety Standards Series No. GSR Part 4, IAEA, Vienna (2009).

~~[24]~~[25] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for the Decommissioning of Facilities Using Radioactive Material, IAEA Safety Standards Series WS-G-5.2, IAEA, Vienna (2008).

~~[25]~~[26] INTERNATIONAL ATOMIC ENERGY AGENCY, Licensing Process for Nuclear Installations, IAEA Safety Standards Series No. SSG-12, IAEA, Vienna (2012).

~~[26]~~[27] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-R-3, IAEA, Vienna (2006).

~~[27]~~[28] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-G-3.1, IAEA, Vienna (2006).

[29] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System For Nuclear Installations, IAEA Safety Standards Series No. GS-G-3.5, IAEA, Vienna (2008).

~~[28]~~[30] INTERNATIONAL ATOMIC ENER-GY AGENCY, Criticality Safety in the Handling of Fissile Material, IAEA Safety Standards Series No. SSG-27, IAEA, Vienna (2014).

~~[29]~~[31] INTERNATIONAL ATOMIC ENERGY AGENCY, Environmental Source Monitoring for Purposes of Radiation Protection, IAEA Safety Standards Series No. RS-G-1.8, IAEA, Vienna (2005).

[30][32] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulatory Inspection of Nuclear Facilities and Enforcement by the Regulatory Body, IAEA Safety Standard Series Requirements No. GS-G-1.3, IAEA, Vienna (2002).

[31][33] INTERNATIONAL ATOMIC ENERGY AGENCY, Arrangements for Preparedness for a Nuclear or Radiological Emergency, IAEA Safety Standard Series No. GS-G-2.1, IAEA, Vienna (2007).

[32][34] INTERNATIONAL ATOMIC ENERGY AGENCY, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011).

[33][35] INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, IAEA Safety Standards Series No. GSG-1, IAEA, Vienna (2009).

CONTRIBUTORS TO DRAFTING AND REVIEW

Auffray, P. Electricité de France, France

Baecker, A. Energiewerke Nord GmbH, Germany

Batandjieva, B. International Atomic Energy Agency

Francois, P. Institut de Radioprotection et de Sûreté Nucléaire, France

Hayes, J. US Nuclear Regulatory Commission, United States of America

Kaulard, J. TÜV Industrie Service GmbH, Germany

Lauridsen, K. Consultant, Denmark

Ljubenov V. International Atomic Energy Agency

Pennington, M. Sellafield Ltd, United Kingdom

Reisenweaver, D. Enercon Federal Services, United States of America

Rowat, J. International Atomic Energy Agency

Smith, T. US Nuclear Regulatory Commission, United States of America

Versemann, R. RWE Power AG, Germany

Visagie, A. South African Nuclear Energy Corporation, South Africa

Watson, B. U.S. Nuclear Regulatory Commission, United States of America

Wong, M. International Atomic Energy Agency

Annex I

EXAMPLE OF THE CONTENT OF A FINAL DECOMMISSIONING PLAN AND SUPPORTING DOCUMENTS

The final decommissioning plan is the key document in the entire decommissioning process. It contains the information on which the regulatory body will base its decision regarding the safety of the decommissioning project as proposed by the licensee. There is a range of supporting documentation to the final decommissioning plan that will be referenced and summarized in the final decommissioning plan. This is particularly likely for large and complex decommissioning projects. For smaller facilities, these supporting documents are integrated into the final decommissioning plan itself.

This Annex provides an example of the possible content of a final decommissioning plan for a nuclear installation. Following the graded approach, the level of detail will depend on the complexity of the decommissioning actions.

The content of the final decommissioning plan should be specified by the regulatory body.

0. SUMMARY

1. INTRODUCTION

    1.1. Scope and context of the decommissioning project

    1.2. General information of the licensee and existing licenses

2. SITE AND INSTALLATION DESCRIPTION

    2.1. Site location and description

    2.2. Description of the installation, including related SSCs

    2.3. Installation's operational history, including modifications and events

    2.4. Installation's radiological characterization, including surface and subsurface soils and water

    2.5. Interdependencies with other facilities on the site (in case of multi-facility site)

3. DECOMMISSIONING STRATEGY

    3.1. Description of overall site decommissioning strategy (in case of multi-facility site)

    3.2. Selected Decommissioning strategy including ~~end state~~end state

3.3. Justification of the selected strategy

4. INTEGRATED MANAGEMENT SYSTEM FOR DECOMMISSIONING

4.1. Safety management policy including safety culture

4.2. Organizational structure including responsibilities and authorities

4.3. Staffing and qualification including training

4.4. Stakeholder engagement including regulatory interfaces

4.5. Documentation and record keeping

4.6. Project management approach, including contractors involvement

5. CONDUCT OF DECOMMISSIONING ACTIONS

5.1. Work Breakdown Structure (WBS) including related phases and schedule

5.2. Decontamination and dismantling methods and techniques

5.3. Surveillance and maintenance

6. WASTE AND MATERIAL MANAGEMENT

6.1. Identification of radioactive waste and material

6.2. Waste classification and streams, waste acceptance criteria and clearance

6.3. Solid and liquid radioactive waste pre-disposal management including supporting facilities

7. FINANCIAL RESOURCES

7.1. Financial resources availability including cost estimates

7.2. Financial resources allocation

7.3. Review and update of financial resources

8. RADIATION PROTECTION

8.1. Radiation protection principles and objectives

8.2. Radiation protection programme

8.3. Monitoring, control and surveillance during decommissioning

9. SAFETY ASSESSMENT

9.1. Safety assessment framework including criteria

9.2. Safety assessment methodology

9.3. Identification of normal and abnormal situations (internal and external events)

9.4. Safety assessment results

9.5. Implementation of safety assessment results including limits and conditions

9.6. Surveillance and maintenance of safety measures

10. ENVIRONMENTAL IMPACT ASSESSMENT

10.1. Identification of the discharges in the environment during decommissioning actions

10.2. Identification of sources for direct exposure to the public and environment

10.3. Radiological impact assessment to the public and the environment during decommissioning actions

10.4. Non-radiological impact assessment

10.5. Protection and control measures

11. EMERGENCY ARRANGEMENTS [1]

11.1. Emergency planning basis including scenarios

11.2. Organization and responsibilities

11.3. Emergency response process

11.4. Emergency preparedness process

12. PHYSICAL SECURITY AND SAFEGUARDS

12.1. Legal and regulatory framework

12.2. Organization and responsibilities

12.3. Physical security programme and measures

12.4. Safeguards programme and measures

13. FINAL RADIOLOGICAL SURVEY

13.1. Objectives of the final radiological survey

13.2. Methodology for conducting survey

13.3. Definition of sampling parameters and background/baseline levels

13.4. Types of equipment, instruments, techniques and procedures

13.5. Methodology for evaluating the survey results

REFERENCES TO ANNEX I

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Standard Format and Content for Safety Related Decommissioning Documents, IAEA Safety Reports Series No. 45, IAEA, Vienna (2005).

~~[1]~~[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Method for Developing Arrangements for Response to a Nuclear or Radiological Emergency, EPR-METHOD (2003), IAEA, Vienna (2003).

Annex II

EXAMPLE OF THE CONTENTS OF THE FINAL DECOMMISSIONING REPORT

The final decommissioning report is prepared by the licensee as a basis for regulatory decision to terminate the decommissioning license. This report should:

1. Summarize the final decommissioning plan, its updates and any related authorizations;
2. Include the final radiological survey report(s);
3. Describe remaining restrictions on-site or restrictions related to the existence of remaining facilities on-site after completion of decommissioning, if any, describe controls needed and plans for their removal in the future;
4. Provide information on radiation exposures to workers;
5. Provide information on radioactive discharges to the environment;
6. Provide information on radioactive waste and material management.

In addition, the licensee may include additional information in the final decommissioning report for its own use. In order to improve the conduct of decommissioning projects in the future, within the final decommissioning report the licensee may summarize and share project experiences and lessons learned, or to provide details about methods and tools applied for conducting decommissioning actions.

Annex III

EXAMPLE OF THE CONTENTS OF THE FINAL RADIOLOGICAL SURVEY REPORT

The final radiological survey report presents the final conditions at the facility and the site at the conclusion of the physical decommissioning actions. This report is usually a part of the final decommissioning report.

The final radiological survey report includes the following information:

1. Conduct of the final radiological survey and the survey results

    a. Summary of the survey, including changes from the final radiological survey plan and comparison with the initial (baseline) radiological survey

    b. Sampling performed (e.g., maps indicating sampling/measurements points, type and number of measurements and analyses performed)

    c. Measured data and analytical results

    d. Data evaluation, comparison with established guidelines, and reporting consistent with national regulatory framework

    e. Quality management aspects related to the final radiological survey

2. Summary and Conclusion

    a. Concise description of the final radiological situation at the facility, including any areas that were not surveyed

    b. Identification of all site areas, structures, systems and components that can be released for unrestricted use

    c. Description of any institutional controls that will be required for any areas that have not been released, including overview drawings and maps.

Annex IV

EXAMPLE OF DECOMMISSIONING RELATED DOCUMENTS

In practice, the final decommissioning plan, as described in the Annex 1, is supported by a set of documents (depending on national regulatory requirements) which provide additional information explaining aspects of the decommissioning plan. Typical example is the safety assessment report, which for decommissioning of nuclear installations is usually a stand-alone document, providing more detail on the safety aspects of decommissioning, than presented in chapter ~~10~~ 9 of the final decommissioning plan (according to the content presented in the Annex 1).

The supporting documents may elaborate on the following:

- Historical Site Assessment
- Characterization Survey Report
- Safety Assessment report
- Decommissioning limits and conditions
- Environmental Impact Assessment
- Radiation Protection Programme
- Industrial Health and Safety Plan
- Waste Management Plan
- Quality Management Plan (as part of the Integrated Management System)
- Emergency Response Plan
- Security and Safeguards Plan
- Funding Provisions and Cost Estimate
- Public Relations Plan

Annex V

CONSIDERATION FOR SAFETY ASSESSMENT FOR DECOMMISSIONING OF NUCLEAR INSTALLATIONS

GENERAL CONSIDERATION FOR SAFETY ASSESSMENT

V-1. The aim of the safety assessment for decommissioning is to determine the safety functions needed during decommissioning and related structures, systems and components (SSCs) which will deliver these safety functions, as well as the administrative procedures important to safety, in accordance with a graded approach. The SSCs important to safety provide means for the safe conduct of decommissioning actions, for prevention of the occurrence of postulated initiating events leading to abnormal events, for the control and limitation of accident scenarios and mitigation of the potential consequences. In addition, the requirements for maintenance or replacement of systems for mechanical handling, ventilation, power supply and waste handling should be considered in the safety and engineering assessment.

V-2. The safety assessment must employ a systematic methodology to demonstrate compliance with safety requirements and criteria for decommissioning, including the release of material, buildings and sites from regulatory control. [1-5].

V-3. The safety assessment should be commensurate with the complexity and potential hazard of the nuclear installation and, in case of deferred dismantling, should take into account the safety of the nuclear installation during the period leading up to final dismantling.

V-4. Analyses of accident scenarios should be performed and protective measures for preventing accidents or minimizing the likelihood of their occurrence and for mitigating their potential consequences proposed. The protective measures may require changes to the existing safety systems that were used during the operational phase. The acceptability of such changes should be clearly justified in the safety assessment. Protective measures are either engineered or administratively controlled to provide the necessary radiological protection.

V-5. Postulated initiating events that could lead to elevated radiation levels or to a release of radioactive material and associated hazardous chemical substances should be identified. The resulting set of identified postulated initiating events should be confirmed to be comprehensive and defined in such a way that the events cover credible failures of the SSCs of the nuclear installation, as well as human errors that could occur during decommissioning activities. The set of postulated initiating events should consider both internal and external events.

V-6. Human factors are an important aspect of the safety of nuclear installations, as the state of the nuclear installation changes frequently with decommissioning actions. The safety assessment should

consider the human errors according to the complexity and hazard potential of the nuclear installation concerned (e.g., large numbers of equipment, tanks, pipes and valves with unexpected remaining radioactive materials and contaminated liquid).

V-7. The likelihood of bounding external events should be assessed, taking into account the decommissioning strategy and the site characteristics (e.g., seismic ~~risks~~hazards, flooding, extreme temperatures, influence from or dependence on any neighbouring facilities) and the likelihood of potential initiating events for incident/accident scenarios. (e.g., human error, fire, flood, dropped loads, building/structure collapse/failure, and chemicals). A systematic safety approach should be implemented in order to minimize human errors (built-in controls and procedural and equipment protective measures to workers to avoid the risk of contamination).

V-8. The implementation of the safety assessment results should lead to the definition of decommissioning limits and conditions, which are the set of rules that establish parameter limits, the functional capability and the performance levels of equipment and personnel for the safe decommissioning of a nuclear installation. The decommissioning limits and conditions should also define the required intervals for periodic testing and inspection of SSCs important to safety.

V-9. Dismantling may involve the deliberate destruction and removal of engineered SSCs that had fulfilled specified safety functions during operation of the nuclear installation (e.g., containment, shielding, ventilation, and cooling). If these safety functions are still required, they should be provided by suitable alternative means or SSCs (e.g., tents, temporary systems or structures, fire systems, electrical systems, and administrative procedures) for as long as is required on the basis of the safety assessment. The appropriateness of alternative means of fulfilling these functions should be demonstrated. Procedures for changing safety functions during decommissioning should be justified and demonstrated in advance before their implementation.

V-10. An overarching safety assessment should address the main safety issues and objectives of the final decommissioning plan and related phases. Based on the outcomes from the overarching safety assessment, developed for the entire decommissioning project and covering all phases, the licensee should develop detailed safety assessments for each phase, where relevant, to demonstrate safety of actions foreseen in a given phase.

V-11. A given phase can be subdivided into discrete work packages or tasks for which specific safety assessments can be performed. Detailed safety assessments for the first phase should be performed during the transition period, while detailed safety assessment for the others phases may be performed later, but prior to the beginning of such phases.

V-12. In all phases of decommissioning of a nuclear installation, the workers, the public and the environment have to be properly protected from hazards resulting from the decommissioning actions

for both normal and abnormal situations. Safety assessments contain an analysis of radiological hazards associated with decommissioning actions and demonstrate compliance with the regulatory requirements and criteria. Non-radiological hazards should also be evaluated. In decommissioning a number of "industrial" occupational health hazards will play a larger role than during operation of a nuclear installation, for instance in connection with the dismantling and demolition of large components and structures. The risk arising from these hazards should be addressed, but is outside the scope of this Safety Guide.

V-13. The licensee should consider the following when assessing the radiological and non-radiological hazards during decommissioning of a nuclear installation:

- Presence and nature of all types of contamination;
- Hazards associated with the possible in-growth of radionuclides (such as americium);
- Potential for criticality hazards associated with the possible accumulation of fissile material during operation in the process equipment or during decommissioning actions (such as decontamination);
- Complexity of strategies for waste management due to the diversity of waste streams;
- For multi-facility sites, hazards associated with facilities that are not under decommissioning;
- Inaccessible areas and buried pipes;
- Separation and concentration of material stored in tanks;
- Hazardous chemicals located in SSCs, in the buildings, soil, sediment, surface and groundwater;
- Changes in chemical and physical forms;
- Non-radiological hazards, such as fire or explosion, associated with decommissioning actions.

V-14. In the planning stage for decommissioning, the degree and extent of contamination in a nuclear installation should be clearly determined, characterized, evaluated and classified. Surveys should be conducted to determine the inventories and locations of radioactive and other hazardous materials. An accurate characterization of the facility will provide the input for the decommissioning safety assessment.

V-15. During decommissioning, safety issues such as radiation exposures, for example, external exposure from direct radiation, potential criticality, internal exposure due to inhalation, ingestion or cuts and abrasions, and loss of containment leading to the uncontrolled release of radionuclides have to be considered in the safety assessment.

V-16. For nuclear installations which have been inoperable for a long period of time before decontamination or dismantling begins, a survey of equipment and buildings should be made to assess

hazards associated with the deterioration of SSCs. In addition, considerations should be given to the materials of physical barriers and process equipment for which mechanical properties may have changed during operation due to factors such as fatigue (e.g., from cyclic mechanical or thermal loadings), stress corrosion, erosion, chemical corrosion or the induction of changes by irradiation. Decontamination actions implemented during decommissioning should consider the risk coming from the ageing of physical barriers and process equipment.

V-17. If suitable alternative means (e.g., mobile tents and administrative procedures) are necessary when dismantling process equipment and physical barriers, the nature and number of the alternative means and their performance should be commensurate with the degree of the potential contamination hazards. Special attention should be paid to specific aspects such as the potential dispersion of residual alpha emitters. In many situations, mobile tents may become the first confinement barrier during decommissioning. The design of this first confinement barrier should be described in the safety assessment and justified (e.g., static confinement, ventilation, filtration systems, fire and mechanical resistance). The associated SSCs should be defined within the safety assessment and taken into account in the decommissioning limit and conditions.

V-18. The operator should make design considerations for fire safety on the basis of a fire safety analysis. Special attention should be given to the use of thermal cutting techniques (e.g., plasma cutting) and non-thermal cutting techniques (e.g., using grinder and saw) and the associated risk of outbreak of fire during dismantling especially when mobile confinement tents and personnel protective equipment are used.

V-19. During decommissioning, additional emphasis should be placed on mitigating the following:

- Closer proximity of radiation sources to personnel (due to the removal of shielding or interlocks to gain access to sources), and hence the greater potential for radiation exposure;
- Greater potential for the creation of airborne radionuclides, due to removal of containment or barriers during dismantling;

V-20. The safety assessment for decommissioning may identify a number of potentially significant non-radiological hazards, which may have radiological consequences during the decommissioning of the nuclear installation. These non-radiological hazards might not have been normally encountered during the operational phase. These may include the lifting and handling of heavy loads, drop of loads, outbreaks of a fire or explosion, collapse of structures and the generation of hazardous materials during the actions for decontamination and dismantling. Although the method for dealing with most of the non-radiological hazards should be managed according to national regulations, a strong safety culture will help to ensure that such hazards are identified and adequately controlled.

Specific issues to consider in the safety assessment for nuclear power plants and research reactors

V-21. Decommissioning of nuclear power plants and research reactors will include handling of both activated and contaminated materials. Management of components located in the reactor core and its vicinity, which have been activated during operation, may benefit from natural radioactive decay.

V-22. Work performed during the transition period ~~are~~ is often done under the operational license and in accordance with the safety assessment developed for the operational phase of the nuclear installation. In such a way, operational experience and safety assessment developed for operation are essential when implementing transition from operation to decommissioning. This is especially true for research reactors, where modifications of systems, removal of past experiments, partial dismantling works of experimental devices and equipment such as glove boxes, are performed periodically during operation.

V-23. For existing research reactors with a long operational history, information of past experiments and incidents is often not available, due to either missing records or retirement of the experienced personnel. In such cases more extensive characterization may be needed for carrying out the safety analysis, possibly supplemented by interviews with retired personnel.

Specific issues to consider in the safety assessment for nuclear fuel cycle facilities

V-24. For uranium enrichment facilities, fuel fabrication facilities and reprocessing plants, special attention should be given to the actions which could increase the criticality risk, such as decontamination, waste treatment, conditioning and storage of waste packages.

V-25. The generation of heat by radioactive decay, if not adequately controlled, may result in the release of radioactive material. Heat generation should be taken into account during decommissioning due to the presence of highly active material (solid or liquid) in the facility.

V-26. Radiolysis, if not adequately controlled, may result in the release of hydrogen with the risk of explosion. Radiolysis ~~shall~~ should be taken into account as appropriate in planning for decommissioning actions and assessing safety. Possible accumulation of hydrogen in the waste due to radiolysis should also be considered in the design of waste treatment process and waste packaging. This may affect the design and the operation of the storage facilities and the transport conditions of waste packages.

REFERENCES TO ANNEX V

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Facilities, IAEA Safety Standards Series No. GSR Part 6, IAEA, Vienna (2014).

~~[2]~~[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for the Decommissioning of Facilities Using Radioactive Material, IAEA Safety Standards Series WS-G-5.2, IAEA, Vienna (2009).

~~[3]~~[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Release of Site from Regulatory Control Upon Termination of Practices, IAEA Safety Standards Series No. WS-G-5.1, IAEA, Vienna (2006).

~~[4]~~[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for the Decommissioning, IAEA Safety Reports Series 77, IAEA, Vienna (2013).

~~[5]~~[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Monitoring for Compliance with Exemption and Clearance Levels, IAEA Safety Reports Series No. 67, IAEA, Vienna (2012).

Annex VI

BIBLIOGRAPHY

CONTENT OF THE DECOMMISSIONING PLAN

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Standard Format and Content for Safety Related Decommissioning Documents, IAEA Safety Reports Series No. 45, IAEA, Vienna (2005).

[2] NUCLEAR ENERGY AGENCY, Achieving the Goals of the Decommissioning Safety Case, Working Party on Decommissioning and Dismantling (WPDD) 3, NEA No. 5417, OECD (2005).

TRANSITION FROM OPERATION TO DECOMMISSIONING

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

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

DECOMMISSIONING STRATEGIES

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Safe Enclosure of Nuclear Facilities During Deferred Dismantling, IAEA Safety Reports Series No. 26, IAEA, Vienna (2002).

~~[6]~~[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning Strategies for Facilities Using Radioactive Materials, IAEA Safety Reports Series No. 50, IAEA, Vienna (2007).

~~[7]~~[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Policies and Strategies for the Decommissioning of Nuclear and Radiological Facilities, IAEA Nuclear Energy Series No. NW-G-2.1, IAEA, Vienna (2011).

RADIOLOGICAL CHARACTERIZATION

~~[8]~~[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiological Characterization of Shutdown Nuclear Reactors for Decommissioning Purposes, IAEA Technical Reports Series No. 389, IAEA, Vienna (1998).

~~[9]~~[10] NUCLEAR ENERGY AGENCY, Radiological Characterization for Decommissioning of Nuclear Installations, Working Party on Decommissioning and Dismantling (WPDD), NEA/RWM/WPDD(2013)2, OECD (2013).

SAFETY ASSESSMENT

~~[10]~~[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for the Decommissioning, IAEA Safety Reports Series 77, IAEA, Vienna (2013).

DECOMMISSIONING TECHNOLOGIES

~~[11]~~[12] INTERNATIONAL ATOMIC ENERGY AGENCY, State-of-the-art Technology for Decontamination and Dismantling of Nuclear Facilities, IAEA Technical Reports Series No. 395, IAEA, Vienna (1999).

~~[12]~~[13] NUCLEAR ENERGY AGENCY, R&D and Innovation Needs for Decommissioning of Nuclear Facilities, NEA No. 7191, OECD (2014).

MANAGEMENT OF MATERIAL AND WASTE FROM DECOMMISSIONING

~~[13]~~[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Derivation of Activity Concentration Values for Exclusion, Exemption and Clearance, IAEA Safety Reports Series No. 44, IAEA, Vienna (2005).

~~[14]~~[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Monitoring for Compliance with Exemption and Clearance Levels, IAEA Safety Reports Series No. 67, IAEA, Vienna (2012).

~~[15]~~[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Monitoring for Compliance with Remediation Criteria for Sites, IAEA Safety Reports Series No. 72, IAEA, Vienna (2012).

~~[16]~~[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Problematic Waste and Material Generated During the Decommissioning of Nuclear Facilities, IAEA Technical Reports Series No. 441, IAEA, Vienna (2006).

~~[17]~~[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Managing Low Radioactivity Material from the Decommissioning of Nuclear Facilities, IAEA Technical Reports Series No. 462, IAEA, Vienna (2008).

RECORD MANAGEMENT

~~[18]~~[19] INTERNATIONAL ATOMIC ENERGY AGENCY, Record keeping for the Decommissioning of Nuclear Facilities: Guidelines and Experience, IAEA Technical Reports Series No. 411, IAEA, Vienna (2002).

~~[19]~~[20] INTERNATIONAL ATOMIC ENERGY AGENCY, Long Term Preservation of Information for Decommissioning Projects, IAEA Technical Reports Series No. 467, IAEA, Vienna (2008).

TRAINING

~~[20]~~[21] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Facilities: Training and Human Resources Considerations, IAEA Nuclear Energy Series NG-T-2.3, IAEA, Vienna (2008).

INVOLVEMENT OF INTERESTED PARTIES

~~[21]~~[22] INTERNATIONAL ATOMIC ENERGY AGENCY, An Overview of Stakeholder Involvement in Decommissioning, IAEA Nuclear Energy Series NW-T-2.5, IAEA, Vienna (2009).

~~[22]~~[23] INTERNATIONAL ATOMIC ENERGY AGENCY, Managing the Socioeconomic Impact of the Decommissioning of Nuclear Facilities, IAEA Technical Reports Series No. 464, IAEA, Vienna (2008).

DECOMMISSIONING COSTING

[24] NUCLEAR ENERGY AGENCY, International Structure for Decommissioning Costing (ISDC) of Nuclear Installations, IAEA/OECD NEA Report ISBN 978-92-64-99173-6, NEA No. 7088, OECD (2012).

~~[23]~~[25] INTERNATIONAL ATOMIC ENERGY AGENCY, Cost Estimation for Research Reactor Decommissioning, IAEA Nuclear Energy Series NW-T-2.4, IAEA, Vienna (2014).

RESEARCH REACTORS

~~[24]~~[26] INTERNATIONAL ATOMIC ENERGY AGENCY, The Decommissioning of Research Reactors; Evolution, State-of-the-art, Open Issues, IAEA Technical Reports Series No. 446, IAEA, Vienna (2006).

[27] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Research Reactors and Other Small Nuclear Facilities by Making Optimal Use of Available Resources, IAEA Technical Reports Series No. 463, IAEA, Vienna (2008).

CONTRIBUTORS TO DRAFTING AND REVIEW

Auffray, P.	Electricité de France, France
Baecker, A.	Energiewerke Nord GmbH, Germany
Batandjieva, B.	International Atomic Energy Agency
Francois, P.	Institut de Radioprotection et de Sûreté Nucléaire, France
Hayes, J.	US Nuclear Regulatory Commission, United States of America
Kaulard, J.	TÜV Industrie Service GmbH, Germany
Lauridsen, K.	Consultant, Denmark
Ljubenov V.	International Atomic Energy Agency
Pennington, M.	Sellafield Ltd, United Kingdom
Reisenweaver, D.	Enercon Federal Services, United States of America
Rowat, J.	International Atomic Energy Agency
Smith, T.	US Nuclear Regulatory Commission, United States of America
Versemann, R.	RWE Power AG, Germany
Visagie, A.	South African Nuclear Energy Corporation, South Africa
Watson, B.	U.S. Nuclear Regulatory Commission, United States of America
Wong, M.	International Atomic Energy Agency