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**Decommissioning of Nuclear Power Plants,  
Research Reactors and Other Nuclear Fuel  
Cycle Facilities**

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



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# 1. INTRODUCTION

## BACKGROUND

1.1. With the maturing of the nuclear industry in the past decades, many Member States have constructed and commissioned facilities<sup>1</sup> that use nuclear and radioactive material or radioactive sources in a variety of applications. Many of them are reaching the end of their operating lifetimes and will be facing permanent shutdown<sup>2</sup> in the near future. Other factors, such as national energy policies, changing energy markets or unforeseen conditions (i.e., major accidents) may result in facilities permanently shutting down earlier than planned. These facilities will need to be decommissioned after permanent shutdown. This Safety Guide provides a consistent approach to the decommissioning of both new and existing facilities, as incorporates lessons learned from previous decommissioning projects.

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 the lifetime of a facility, aspects of decommissioning, such as designing for the minimization of radioactive waste (especially long-lived), decommissioning planning, and record keeping, are required to be considered throughout the lifetime of a facility, beginning with the initial planning and design of the facility.

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 characterization 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 the workers, the public and the environment, and to demonstrate that the facility achieves 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<sup>3</sup> period. As

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<sup>1</sup> The term “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. In this Safety Guide the term “facility” or “facilities” is used in a limited scope, to cover the types of facilities considered in this Safety Guide.

<sup>2</sup> The term “permanent shutdown”, as used in this publication, means that the facility has ceased operations and operation will not be recommenced.

<sup>3</sup> The term “Safe enclosure” is the period during the deferred dismantling strategy where the facility is placed and maintained in a safe, long term storage condition until decontamination and dismantling actions are performed.

a consequence, the time period for the conduct of decommissioning actions may typically range from a few months, for simple and small facilities undergoing immediate dismantling, to decades (for example, to allow for radioactive decay), for large and complex facilities using the deferred dismantling strategy. Decommissioning may include a phased release of parts of the facility from regulatory control during the conduct of decommissioning actions. On completion of all planned decommissioning actions and on reaching the planned end state, the licence for decommissioning can be terminated. The site and remaining structures of the former facilities, if any, will be available for unrestricted or restricted re-use depending on the end state.

1.5. Depending on the national regulatory system, decommissioning of facilities might be subject to the granting of a licence for decommissioning or an authorization to perform decommissioning actions in the framework of a licence granted for the whole lifetime of the facility until the facility is released from regulatory control. In this Safety Guide, the term “licence for decommissioning” is used for both regulatory concepts.

1.6. Decommissioning of facilities 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 a facility. A decommissioning project usually starts when preparation of the final decommissioning plan is initiated or, in some cases, when a decommissioning licence is granted.

1.7. Adequate planning and implementation of decommissioning actions are required to ensure the protection of the workers, the public and the environment. With the expansion of the nuclear industry worldwide and with many nuclear facilities nearing the end of their operating lifetimes, experience has shown the importance of considering planning aspects of decommissioning for new facilities during their 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 required prior to the commencement of decommissioning actions. However, there are still some existing facilities close to the end of their operating life or already permanently shutdown, which do not have a decommissioning plan in place, so for such facilities a final decommissioning plan is required to be developed as soon as possible.

1.8. This Safety Guide supersedes Decommissioning of Nuclear Power Plants and Research Reactors, issued in 1999<sup>4</sup>, and Decommissioning of Nuclear Fuel Cycle Facilities, issued in 2001<sup>5</sup>.

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<sup>4</sup> INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Power Plants and Research Reactors, IAEA Safety Standard Series No. WS-G-2.1, IAEA, Vienna (1999).

<sup>5</sup> INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Fuel Cycle Facilities, IAEA Safety Standard Series No. WS-G-2.4, IAEA, Vienna (2001).

Guidance concerning the decommissioning of medical, industrial and research facilities can be found in Ref. [2].

1.9. 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 Refs [3, 4].

1.10. Requirements and guidance on radiological criteria for the removal of regulatory control from materials, equipment and sites are provided in Refs [3, 5, 6].

1.11. Requirements and guidance on transport of radioactive material and the associated safety and environmental aspects are covered in Refs [7, 8].

## OBJECTIVE

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

## SCOPE

1.13. This Safety Guide provides guidance on how to comply with the IAEA Safety Requirements applicable to decommissioning, primarily those given in GSR Part 6 [1], but also in other General Safety Requirements publications and in the applicable Specific Safety Requirements publications. This Safety Guide addresses decommissioning considerations and actions for safe decommissioning of nuclear power plants, research reactors and other nuclear fuel cycle facilities. The following types of nuclear facilities are included in the scope of this Safety Guide: uranium conversion plants, uranium enrichment plants, nuclear fuel fabrication plants, research reactors including subcritical and critical assemblies, nuclear power plants, facilities for storage of spent fuel, reprocessing facilities and facilities for predisposal management of radioactive waste. Uranium and thorium mines and facilities for disposal of radioactive waste are out of the scope, as they are subject of closure and not of decommissioning. Surface processing facilities for mining and milling of uranium and thorium are subject to decommissioning, and all the considerations in this Safety Guide are applicable to facilities of this type. For radioactive waste disposal facilities this Safety Guide provides information relevant for decommissioning of support infrastructure, i.e. parts of the facilities other than the disposal section itself, which is subject to closure.

1.14. The guidance provided in this Safety Guide is applicable to decommissioning of nuclear fuel

cycle research and development facilities conducting research and development activities on processes and equipment envisaged for use on an industrial scale (e.g. ‘pilot plants’ or ‘demonstration plants’). This Safety Guide does not address decommissioning of medical and industrial facilities, and non-reactor research facilities, which conduct laboratory scale experiments and fundamental research studies on specific nuclear materials like prototype nuclear fuels (before and after irradiation in a reactor) or investigations of nuclear materials or wastes arising from new processes. Decommissioning of these types of facilities is addressed in [2]. This Safety Guide does not address decommissioning of facilities for processing naturally occurring radioactive material (NORM). Although the general guidance on the decommissioning process is fully applicable to these types of facilities, this Safety Guide does not provide specific guidance. Additional guidance is provided in other Safety Guides [2, 9].

1.15. Decommissioning considerations and actions addressed in this Safety Guide take place from siting and design of a facility until termination of the licence for decommissioning. On the basis of general considerations regarding safety, radiation protection, protection of human health and protection of the environment, as well as related regulatory aspects, this Safety Guide provides guidance on the selection of a decommissioning strategy, development of decommissioning plans and implementation of the final decommissioning plan. This Safety Guide discusses application of the graded approach in decommissioning of facilities, key decommissioning considerations during the facility’s lifetime, 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 licence for decommissioning.

1.16. Decommissioning of facilities 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 facility, 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 facility’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 end state.

1.17. This Safety Guide addresses the radiological risks, resulting from actions associated with decommissioning of facilities, and the management of waste and material, arising from the decommissioning actions. It is developed primarily for facilities with a normal operational history (i.e., without a severe accident), which was followed by a planned permanent shutdown. However, many of the considerations are also applicable to decommissioning after an accident that has resulted in serious damage or extensive contamination of the facility’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 material used during operation, and the management of radioactive waste generated during the operational phase are actions which are repeatedly or continuously performed during operation of a facility under the operating licence. Thus, these actions should not be 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 licence for decommissioning or under a separate operating licence for processing or storage of operational waste and spent fuel. Other IAEA publications address these aspects [10-14].

1.19. The hazards associated with facilities often involve chemical, biological and industrial hazards, in addition to the radiological hazards, and consideration should 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 should be given due consideration in all aspects of decommissioning including planning, management, financing, conduct and completion.

1.20. In the case when only a part of a facility is being decommissioned, this Safety Guide only applies to decommissioning actions associated with the part of the facility being decommissioned. However, the potential safety implications with respect to interaction between any decommissioning actions and any continuing facility's operations need to be addressed. An example might be the decommissioning of a laboratory facility associated with an operating research reactor.

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 [9]. While this Safety Guide covers facilities associated with processing and storage of radioactive waste, it does not address disposal of radioactive waste and closure of disposal facilities. Those issues are considered in other IAEA publications [15-18].

1.22. This Safety Guide applies to planned authorized activities. Although some reference is made to remediation in the context of facility's decommissioning, this Safety Guide does not apply to remediation situations, as these are considered in other IAEA Safety Standards [3, 19].

1.23. Security aspects have to be considered during decommissioning, but they are outside the scope of this publication. The IAEA issues fundamentals and recommendations on nuclear security in the

IAEA Nuclear Security Series [20-22]<sup>6</sup>. Requirements pertaining to interfaces of safety with nuclear security are established in Ref. [23]. Aspects relating to accounting for and control of nuclear material may continue to exist during decommissioning (as stated in paragraph 4.32), especially for nuclear fuel cycle facilities, but are outside the scope of this publication. They are addressed in Ref. [24].

## STRUCTURE

1.24. Sections 2 through 9 of this Safety Guide provide guidance on how the requirements of IAEA General Safety Requirements Part 6 [1] can be implemented by the various organizations associated with decommissioning.

1.25. 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. Section 3 describes responsibilities of the major parties involved in decommissioning. Management of decommissioning is discussed in Section 4, while Section 5 discusses the selection of a decommissioning strategy. Section 6 addresses financing of decommissioning. Planning for decommissioning during all stages of facility's lifetime is discussed in Section 7. Section 8 describes conduct of decommissioning of facilities. Section 9 discusses completion of decommissioning, including surveys and reporting to support termination of the decommissioning licence.

1.26. The Appendix provides examples of considerations for safety assessment during decommissioning of facilities. Annex I provides an outline of a final decommissioning plan. Annex II provides an example of the content of a final decommissioning report. Annex III provides an example of the content of a final radiological survey report. Annex IV provides a list of typical supporting documents to the final decommissioning plan. Annex V provides a list of publications, which contain additional information on specific organizational, financial, technical and safety issues related to decommissioning.

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<sup>6</sup> Draft nuclear security guidance on physical protection of nuclear facilities (NST023) and on security during the lifetime of a nuclear facility (NST051) is in preparation.

## 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.**

2.1. The principles of radiation protection and safety for radiation sources are provided in Refs [3, 25]. During decommissioning, proper protection of workers, the public and the environment against radiological risks is required.

2.2. Arrangements for radiation protection during decommissioning are required to be addressed in the decommissioning plan and have to be based on the national requirements for radiation protection. Optimization has to 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 facility 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 emergency 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 is required to be given to the protection of workers, the public and the environment against consequences of incidents that may occur during decommissioning. When appropriate, 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. Further definition is provided in ref [26, 27].

2.5. An example where special attention should be given to the protection of workers 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 which 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 facility 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 or adapted to the risks present during decommissioning actions. In case of on-site or off-site contamination, actions may be necessary to remediate the contaminated areas or to prevent further spread of radioactive substances, for instance contaminated water. Such issues are not addressed in this Safety Guide, as they are addressed in other IAEA Safety Standards [3, 19, 28].

2.7. Remedial actions for the immediate area surrounding a facility, which is covered by the operating licence, may be part of the decommissioning project when a facility has been permanently shut down after an accident. Decommissioning does not include remediation actions outside the area included in the operating licence. For contaminated areas outside the licenced area due to a severe accident, remediation actions should be implemented separate from the licenced decommissioning actions. This is important because decommissioning funds are not collected to remediate areas outside the licenced site. This remediation should be considered as a separate project. For contamination that was due to small leakages during normal operation that caused contamination to extend outside the licenced boundary, the remediation of these small areas would be part of decommissioning. 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 emergency provisions should be considered during planning for decommissioning.

2.8. In addition to protection of workers and the public, licensees are required to consider and plan for protection of the environment during decommissioning implementation (paragraph 2.3 of [1]). An environmental impact assessment<sup>7</sup> 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. Adequate controls should be defined by the licences and approved by the regulatory body to ensure mitigation of significant impacts to the environment, both on-site and to the surrounding area. Specific provisions required by the regulatory body based on the environmental impact assessment should be overseen to ensure their implementation by the licensee, depending on the end state described in the final decommissioning plan.

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<sup>7</sup> The term ‘environmental impact assessment’ is not defined in the IAEA safety standards, although such assessments are included in many international instruments and national legislations and regulations. In the context of a draft Safety Guide on radiological environmental impact assessment for facilities and activities, which is currently in preparation, 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.

2.9. The licensee should indicate in the environmental impact assessment for decommissioning, which supports 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**

**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.**

2.10. As defined in the IAEA Safety Glossary, the graded approach is an application of safety requirements that is commensurate with the characteristics of the facilities and activities or the source and with the magnitude and likelihood of the exposures. The graded approach should be applied during all aspects of decommissioning in a way that does not compromise safety and environmental issues, 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 and environmental protection requirements. Depth of the analyses and level of details in the documentation should be commensurate with national regulatory requirements. The factors taken into account when applying graded approach should include, but are not limited to the following:

- Stage in the lifetime of the facility (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;
- The complexity and the operational history of the facility;
- Physical state of the facility, specifically the integrity of the SSCs. In particular, the extent to which ageing or abandoned building structures may have been compromised due to the lack of adequate maintenance;
- Radiological (source term), biological and chemical inventories and hazards associated with the decommissioning of the facility;
- Scope of the project (e.g., for a part of a facility, a whole facility, a single facility 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 facility) 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; and
- Complexity and risks associated with the decommissioning actions.

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

- Radiological 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 facility, and should be consistent with national regulatory requirements;
- Licensing process;
- Identification of SSCs (already present or new ones), which are needed for the safe decommissioning of the facility, definition of the associated safety criteria and associated control requirements;
- Control of decommissioning actions;
- Monitoring programme;
- Overall cost estimate;
- Management of the decommissioning project (e.g., organizational structure); specific guidance on management of decommissioning is presented in Section 4;
- Staffing and training;
- Regulatory oversight; and
- Involvement of interested parties.

### **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.**

2.13. Decommissioning of facilities is associated with numerous radiological and non-radiological hazards. In addition to existing radiological hazards associated with a permanently shutdown facility, decommissioning actions might create new hazards that need to be considered, for example use of

cutting tools or generation of airborne contamination and secondary radioactive waste<sup>8</sup>. Therefore, decommissioning planning should adequately assess and manage those hazards.

2.14. Safety assessment is required to 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.

2.15. According to the complexity of decommissioning actions and the duration of the decommissioning project, the final decommissioning plan may be supported by a single overall safety assessment for the entire project, or by a summarized safety assessment, which covers the entire project and provides input and links to a set of more detailed safety assessments that may be developed separately for each decommissioning phase or work package, with due account taken of the interdependences between the different phases.

2.16. The safety assessment should be conducted to define protective measures, implementing an optimization approach for radiation protection, with due regard to industrial safety, taking into account the organizational and human factors, in accordance with the requirements [26] and recommendations of the Safety Guide [27].

2.17. 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 or accepted and implemented by the licensee, in accordance with the integrated management system. The results should also be reviewed and approved by the regulatory body to ensure overall safety during decommissioning.

2.18. The results of safety assessments will determine which safety functions and related SSCs used during the operational phase will no longer be needed after operation permanently ended. 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 and commissioning of associated SSCs. The safety assessment should demonstrate consistency of the safety measures during the entire decommissioning, and should be updated when necessary to reflect the ongoing changes in the status of the facility, as decommissioning actions progress.

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<sup>8</sup>A form and quality of radioactive waste that results as a by-product from processing of the primary radioactive waste.

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



### 3. RESPONSIBILITIES ASSOCIATED WITH DECOMMISSIONING

3.1. The decommissioning process for facilities involves several organizations, the key ones being the government, regulatory bodies and licensees. This part of the Safety Guide addresses the responsibilities of these three organizations during planning, conduct and completion of decommissioning of facilities.

#### **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.**

3.2. In preparing and implementing the national ~~policy framework~~ for decommissioning, ~~which may be part of the national policy for management of radioactive waste~~, the government should approve the overall objectives of decommissioning as part of its obligation to establish and maintain a governmental legal and regulatory framework for all aspects of decommissioning, including management of the resulting radioactive waste. 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 is required to 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.

3.4. Although it is preferable to have regulatory responsibilities for decommissioning within a single regulatory body, such responsibilities are 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, radiation, transport and waste, industrial and environmental safety are 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 between different regulatory bodies having responsibilities for decommissioning..

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 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 or regulatory bodies having responsibility for nuclear, radiation, transport, waste, 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.**

3.7. When developing regulations, the regulatory body should identify clearly the facilities and actions to which regulatory requirements are to be applied. The regulatory body is required to establish safety criteria and regulations for all aspects of decommissioning, including management of radioactive waste. The regulatory body should oversee the implementation of the criteria and regulations 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 licence for decommissioning.

3.8. The regulatory body should supplement 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. Interested parties should be involved in the process. 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 licence 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. According to IAEA GSR Part 6 [1], para 7.16, "interested parties shall be given an opportunity to examine the final decommissioning plan and, as appropriate and subject to national regulations, supporting documents, and to provide comments prior to approval."

3.12. 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 an implication to safety of the decommissioning or to the 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 should review this assessment according to national arrangements and consider an amendment to, or a renewal of the decommissioning licence.

3.13. In order for decommissioning to be performed in a safe and efficient manner, the regulatory body should contribute to the definition of funding mechanisms that can be used to ensure that appropriate funds will be available when needed<sup>9</sup>. It should verify or check the existence of such mechanisms. The amount of funds needed and the timeline for the expenditure of the funds should be based on a decommissioning cost estimate prepared by the licensee.

3.14. On-site inspection is one of the elements of the regulatory regime and the regulatory body should allocate adequate resources to this task. The regulatory body should develop an inspection programme based on a graded approach, 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. The inspection programme could also make reference to the industrial safety programme.

3.15. The regulatory body shall perform inspections during decommissioning, as stated in the paragraph 8.5 of the [1]. For that purpose the regulatory body should establish inspection procedures. It should especially ensure that the selected key decommissioning actions are inspected (e.g., dismantling of activated components, 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). 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 licence and decommissioning limits and conditions.

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<sup>9</sup>The definition of the funding mechanism may be the responsibility of other governmental organizations.

3.16. 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 develop and use procedures for determining and exercising enforcement actions.

3.17. 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. The regulatory body should inform the public and other interested parties about the key decisions with regard to decommissioning of facilities 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 [29]. In addition, the regulatory body should get involved in public consultation in order to answer public's questions and concerns [30].

3.19. As stated in para. 3.19 of [1], the regulatory body is required to establish the requirements for ensuring that records important for the planning and implementation of the decommissioning actions 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 facility's licence has been terminated. These records should be identified and preserved, and the responsibility for their retention should be allocated clearly.

3.20. 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 under such conditions, and it is the responsibility of the regulatory body to coordinate with the licensee in order 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 be 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.**

3.21. Prior to permanent shutdown of a facility, the licensee should discuss and agree with the regulatory body on the timing of decommissioning, proposed decommissioning actions, applicable regulations and guidance and relevant requests of the regulatory body. It has been demonstrated that

early cooperation 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. In preparing for decommissioning, the licensee may perform activities such as removal of spent fuel and operational waste stored on-site during operation. Such activities should be bounded by the current operating licence of the facility to ensure the facility is maintained in a safe configuration during transition from operation to decommissioning, until the final decommissioning plan is approved for implementation and the decommissioning licence is granted.

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

3.24. The responsibilities of the licensee for decommissioning end with the termination of the licence for decommissioning by the regulatory body when the end state of decommissioning is achieved. However, for sites released with restrictions, the responsibility for institutional controls should be assigned to the licensee or other organization.

3.25. More details on how the licensee fulfils its responsibilities for decommissioning are provided in the 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.**

4.1. 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, including decommissioning planning and preparatory actions performed during normal operation.

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 actions and defining training 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 are provided in other IAEA Safety Standards Series publications [31-33]. A description or reference to the integrated 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 if applicable.

4.5. 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.

4.6. Good project management divides projects into various phases to allow development of cost estimates, waste management actions and other major actions (such as document development, preparation, characterization survey, decontamination and dismantling of systems, etc.). This common practice should not be confused with using a phased-approach in decommissioning where a project for multi-facility sites may be divided into phases that allows the detailed planning to be done for major actions, but does not provide the detailed planning for the entire project. In this case there is an overall

summary decommissioning plan with supporting documents (i.e., safety assessment, environmental impact report), but the specifics are only developed for the next phase that will be implemented, versus the planning for the entire project. When using this phased approach, a global overview of the entire project should be kept in order to build confidence in the capability of the licensee to achieve the defined end state of the decommissioning project. In case of the second approach, special care should be taken to ensure all the phases and the interfaces between different phases are coordinated properly.

4.7. Safety management refers to those aspects of the integrated management system that are put in place to ensure that an acceptable level of safety is maintained; including radiation protection and safety during decommissioning.

4.8. The licensee should develop a safety and environmental 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.

4.9. 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. The safety policy of the licensee and the behaviour and attitudes of experienced managers should be committed to safety and should be visible to the organization at every level and extend to other organizations that perform delegated tasks.

4.10. There should be no complacency at any level about the need for continuous attention to safety. It is particularly important in decommissioning, where the facility's 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.

4.11. 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.

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

4.13. 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 should be established, agreed by all involved organizations and recorded.

4.14. Based on an evaluation of the skills and knowledge needed to decommission a facility, 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;
- Environmental protection;
- Industrial safety;
- Security and safeguards for radioactive material;
- Emergency preparedness;
- Regulatory/licensing expertise;
- Decontamination, dismantling and demolition;
- Robotics and remote handling;
- Predisposal waste management (i.e. processing, storage and transportation)
- Site remediation and landscaping.

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

4.15. As decommissioning involves many new actions which may have new hazards associated with them and were never performed during operation of the facility, the licensee should develop and implement a comprehensive training programme for all personnel involved in the decommissioning project, no matter if former operation personnel are involved or the actions are performed by



contractors. The training programme should ensure that a sufficient number of trained and qualified workers are available to safely conduct planned decommissioning actions. The training may be in the form of oral briefings, practical exercises, training lectures or comprehensive training courses.

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

4.17. In some cases, contractors may be used to perform all or some aspects of decommissioning (planning, conduct, completion of 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 or should prove their knowledge. Additionally, depending on the actions to be performed, relevant personnel should receive specific training in:

- Facility's design and layout;
- Technical characteristics of the facility and its operational history;
- Decommissioning actions 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; and
- Emergency preparedness and response.

4.18. 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 contractor's personnel are adequately trained.

4.19. There are different approaches that can be used when planning decommissioning actions that will have an impact on training activities. One example is to work from "low hazard" areas to "higher

hazard” areas of the facility. This approach might be beneficial if inexperienced staff or new techniques or equipment may be used. From a training point of view, such an approach allows 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. This approach may be optimal when well-tested equipment or experienced staff are performing the actions.

4.20. 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 performed 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.

4.21. 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 actions, should be incorporated into the working procedures. Experience from the operation of the facility, e.g., from the planning of maintenance or annual outages, may be useful when planning decommissioning.

4.22. Each work procedure should be sufficiently detailed, so a qualified individual is able to perform the required actions. Consideration should be given to the area layout, the general design of the facility, staffing requirements and decommissioning experience at the facility concerned. Procedures should be developed in accordance with established requirements and recommendations related to the integrated management system.

4.23. To ensure consistency in format and content, working procedures are required to 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).

4.24. The approval process for the working procedures should be commensurate with licence requirements. Persons with appropriate competence and experience should be designated to prepare, review and approve the procedures. Human factors should be taken into account to develop safe, reliable and effective working procedures.

4.25. Administrative procedures used during the operational phase of the facility 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.

4.26. The administrative procedures should identify the decommissioning permanent and temporary records and identify 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: facility's logbooks and video footage and photographs to aid future decommissioning of the facility and to aid future training. Preferably, more than one copy of the key records should be kept in different locations.

4.27. Periodic 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 supervisor 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 periodical reviews of the actions helps to identify key learning and to discuss relevant experiences from conduct of similar actions in other projects or facilities.

4.28. Should the licensee change after permanent shutdown or during decommissioning, procedures are required to 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 licence conditions [31-33]. 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 facility.

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

4.30. At the completion of decommissioning, the final decommissioning report is prepared, which should document the end state of decommissioning of the facility, and should provide 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.

4.31. Reporting documentation during the implementation of decommissioning should be submitted to the regulatory body in accordance with national policy and specified in the final decommissioning plan or in the decommissioning licence.

4.32. Security and safeguard requirements will normally be reduced during decommissioning due to nuclear and radioactive material being removed from the facility. The site access and nuclear security requirements should be in accordance with the approved site conditions [20-22]. During deferred dismantling, security requirements will remain in effect through the entire project including the safe enclosure period.

## 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.**

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.

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]. Generally, the immediate dismantling is the preferred strategy, as it avoids 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. There may be situations in which immediate dismantling is not a practicable strategy when all relevant factors are considered and the deferred dismantling option would be the most practical option. An example might be when one unit at a multi-unit plant ceases operation and decommissioning has to wait for other unit to cease operations before decommissioning of the first unit can start, because of common systems used by multiple units. Release from regulatory control without restrictions should be the preferred end state and ultimate objective of decommissioning. The “No action” (leaving the facility after operation as it is, and waiting for decay of radioactive inventory) and entombment (all or part of the facility encased in a structurally long lived material) should not be regarded as acceptable decommissioning strategies.

5.3. The selection of a decommissioning strategy follows an iterative process. The selection of the decommissioning strategy should be based on an analysis of various options, which may lead to selecting a combined strategy, which consists of some degree of immediate dismantling actions, followed by a preservation of the remaining parts of the facility, which are then dismantled after a period of safe enclosure. Such combined strategy can include an early dismantling of some parts of the facility, usually externally accessible areas and auxiliary systems, while placing others, e.g., the reactor core, into a safe enclosure mode. A “preferred decommissioning strategy” for a particular facility should be proposed when developing the initial decommissioning plan, in coordination with the regulatory body. It should be reviewed and updated during the lifetime of the facility and confirmed when the decision for permanent shutdown is taken by the licensee.

5.4. The selection of a decommissioning strategy should take account of the fundamental principles of radiation protection, namely justification, optimization and application of dose limits. A

justification for selection of a particular strategy is required to demonstrate the advantages of the selection made and the reasons for its choice, especially if deferred dismantling is selected, as it implies to some extent transfer of responsibilities for decommissioning to future generations. Any strategy which involves waiting periods should be justified in terms of safety, management of decommissioning waste and radiation protection issues.

5.5. 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.

5.6. 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 operating licence. Some preparatory actions for decommissioning may begin during the transition period. However, care should be taken to ensure that decommissioning funds are not used to perform tasks which have not been considered in the decommissioning plan and in the related cost estimate (typical examples are removal of operational waste, removal of spent fuel, or disposition of excess experimental equipment around a research reactor).

5.7. Main factors influencing the selection of the decommissioning strategy include:

- National policies and regulatory framework;
- Safety aspects;
- Physical (for example, ageing components and structures) and radiological status of the facility;
- Type of facility, interdependencies with other facilities or infrastructure located at the same site;
- Proposed reuse and desired end state;
- Availability of expertise (knowledge, skills, experience), technologies and infrastructure (tools, equipment, supporting facilities and services);
- Environmental 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.

More detailed considerations related to the above-mentioned factors are provided later in paragraphs 5.19-5.44.

5.8. As discussed in the Section 6 of this Safety Guide, the financial arrangements for decommissioning should be established early during the lifetime of the facility to enable safe decommissioning in a timely and efficient manner. Thus, for facilities that have performed proper and early planning for decommissioning, a deferred dismantling strategy should not be justified on the basis of poor financial planning and a lack of financial resources. For existing facilities, the lack of financial resources may be a real concern if the economic situation has changed significantly due to manifold reasons, including decisions on a high political level, or if proper financial planning was not performed. In this case deferred dismantling should be considered until funds can be accumulated or obtained.

5.9. When updating the decommissioning plan, the licensee should check if the decommissioning strategy is still appropriate. Relevant 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 management and removal of the generated waste and the evolution of radiological and physical status of the facility, 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.

5.10. 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 as required or upon request.

5.11. A site strategy for decommissioning, reflected in the individual decommissioning plans for each facility on-site, should identify opportunities and synergies between individual decommissioning projects, in order to optimize resources and efforts, 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 facility 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 subcontractors 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 facility;
- Establishing common facilities providing support for the predisposal management of radioactive waste (i.e. processing, storage and removal from the site) and coordinating their use for different decommissioning projects on the site; this may require revised facility's 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 licence approved by the regulatory body for the entire site;
- Need to use consistent approaches for final remediation actions and consistent criteria for release of the site from regulatory control across the entire site, regardless of whether 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.

5.12. Licensees in charge of several decommissioning projects for different facilities at different sites in the same Member 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.

5.13. Unforeseen permanent shutdown could occur during operation of a facility based on economical, technical or political reasons. In such cases, the timing of the decision to permanently shut down a facility may not have been anticipated by the licensee. Consequently, a review of the preferred decommissioning strategy may be necessary on the basis of the situation that initiated the unforeseen shutdown, in order to evaluate whether a revision of the strategy is required.

5.14. An unforeseen permanent shutdown of a facility may also be result of an accident. In this case, the first objective is to bring the facility into a safe 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 consequences of the recovery actions should be addressed in the final decommissioning plan. Recovery actions should preferably be chosen taking into account their consequences on decommissioning.



5.15. After a safe state of the facility involved in an accident is achieved, a comprehensive survey of the physical and radiological conditions of the facility should 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.

5.16. Incidents or accidents may lead to a spread of contamination outside of the buildings of the facility, implying the need to implement remedial actions on the site where the facility is located. Such actions within the licenced site are usually considered a part of the overall decommissioning of the facility. The extent of the on-site contamination may require change of the previously selected strategy and the end state, as well as establishment of long term decommissioning and remediation plans. Contamination outside the licenced site, as a consequence of an accident, is out of the scope of this Safety Guide, and is addressed in Safety Guide [19].

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

5.18. Even if it may be the only appropriate alternative, the choice of entombment may lead to technical and regulatory difficulties due to a lack of specific regulations and guidance in Member States and a lack of an international consensus. Additionally, the 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 facility 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. If entombment is selected, it will cause a burden to future generations due to long term monitoring of the site and due to possible future actions needed to reinforce barriers or mitigate leakages of radioactive material.

## FACTORS INFLUENCING THE SELECTION OF A DECOMMISSIONING STRATEGY

### **National policies and regulatory framework**

5.19. The adopted national ~~policies-policy~~ on ~~decommissioning and on~~ management of radioactive waste, which should include decommissioning aspects, 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 facility types, and may not apply universally to all the different types of facilities, e.g. nuclear power plants, research reactors, nuclear fuel cycle facilities.

### **Type of facility, interdependencies with other facilities or infrastructure located at the same site**

5.20. There may be different considerations related to the selection of a decommissioning strategy for a facility, based on its type, size and complexity, actions performed during operation of the facility, residual inventory of radionuclides, or the location of the facility and its relations and interdependencies with other facilities on the same site.

5.21. The type of the facility 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. The decommissioning strategy for a particular facility should also take into account the characteristics of the site where the facility 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. Additionally, the location of the facility may pose unique challenges to decommissioning. For example, a facility 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.

5.22. When selecting a decommissioning strategy where more than one facility is located on a site, it may be beneficial to define an overall site decommissioning strategy. This might include selection of deferred dismantling for facilities already permanently shut down until the remaining facilities are permanently shut down. Then the decommissioning of all facilities could be performed in a single campaign, avoiding any negative impact to the operating facilities and allowing better utilization of personnel.

### **Proposed reuse and desired end state**

5.23. 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 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 may influence the choice of the decommissioning strategy giving preference to immediate dismantling in order to start decommissioning actions as soon as possible after permanent shutdown.

5.24. In case of decommissioning of research reactors, very often the desired objective 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

within several years. Taking into account only this aspect, the preferred decommissioning strategy will be immediate dismantling.

5.25. There may be other reasons which simplify the selection of a decommissioning strategy for a facility or eliminating some strategies from consideration. For example, the unavailability of waste management routes or the public opinion and expectations to decommission a facility in a short period of time and to release the site from regulatory controls may also give a priority to the immediate dismantling strategy.

### **Physical and radiological status of the facility**

5.26. The diversity of types of nuclear facilities makes characterization of the facility 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.

5.27. The physical and the radiological status of the facility at the end of its operational phase should be considered when selecting the decommissioning strategy.

5.28. The extent of contamination will depend greatly on past operational practices, the age and type of the facility. The age and generation of a facility will have influenced the types of material used in construction, which in turn results in different levels and types of radioactivity.

5.29. The integrity and conditions of the buildings and SSCs should be assessed at the end of the operational period 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 and further re-strengthening of the facility or SSC is not possible, immediate dismantling actions should be undertaken. Additionally, safety systems may be required depending on the outcome of the safety assessment process, as well as the use of best available techniques not entailing excessive costs.

5.30. In the case of deferred dismantling, it should be verified that after ending the safe enclosure period it will be possible to assess the radiological situation through measurements prior to starting decontamination and dismantling actions.

5.31. Depending on the activation and contamination levels within a facility and the related composition of radionuclides, the selection of the decommissioning strategy may have an impact on radiation exposure to the workers, public and environment. High radiation levels may make 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 in a reasonable time, immediate dismantling is the preferred strategy.

## **Safety aspects**

5.32. When selecting a decommissioning strategy, the licensee should consider the results of the safety reviews performed during the operation of the facility. These safety reviews should be part of the regulatory bodies oversight function. 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 facility 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.

5.33. 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 and in the case of deferred dismantling, considering the state of the facility at the end of the safe enclosure period. In the case of deferred dismantling, safety will be maintained during the entire safe enclosure period.

## **Availability of expertise, technologies and infrastructure**

5.34. 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 (institutional) memory. Availability of staff with operational knowledge is beneficial, in particular for planning of dismantling actions, and therefore this may be an argument for immediate dismantling.

5.35. 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**

5.36. 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.

5.37. For most facilities, the number of employees (both directly employed at the facility and employed in the local community providing services to the facility and to its employees) will generally be lower during decommissioning than during operation of the facility. 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.

5.38. The environment around the facility may have changed since the building was constructed. An example might be the change in environmental conditions such as the increasing of population distribution surrounding the facility making deferred dismantling unfeasible.

### **Availability of infrastructure for radioactive waste management**

5.39. 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) National waste management policy (e.g., one that prefers clearance);
- (b) Types, categories and amount of waste (e.g., including remaining operational waste);
- (c) Waste 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 disposal capacity.

5.40. If on-site or external waste processing and storage facilities are available, then either immediate dismantling or deferred dismantling is a viable decommissioning strategy. If the waste management infrastructure is available, including waste disposal capacities, then immediate dismantling would be the preferred strategy. In the absence of facilities and infrastructure for processing of radioactive waste, or when the storage or disposal capacities are not available, the preferred decommissioning strategy may include a waiting period until waste management infrastructure is available..

5.41. If a waste management infrastructure is not available when decommissioning is anticipated, efforts should be made to synchronize the timing of the development of the waste management infrastructure with the anticipated timing of decommissioning. Where this is not possible, licensees should consider alternative options in order to facilitate implementation of their preferred decommissioning strategy.

5.42. The discussion above on the individual factors affecting the choice of decommissioning strategy sometimes includes statements about the preferred decommissioning strategy for a particular factor, in order to provide examples. However, the selection of a preferred strategy will have to consider and balance all the factors together, rather than consider each factor in isolation.



## 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.**

6.1. Responsibilities for financing of decommissioning and a mechanism to provide adequate financial resources for the safe decommissioning of facilities should be in place prior to the start of the facility's operation.

6.2. Financial resources for decommissioning should be consistent with the chosen decommissioning strategy and with decommissioning actions described in the decommissioning plan. Necessary financial resources should be determined on the basis of a cost estimate for decommissioning.

6.3. Typical costs associated with decommissioning aspects include costs of the following:

- (a) Decommissioning planning, including initial decommissioning planning prior to starting facility's operation, periodic updating of the plan and then preparation of the final decommissioning plan during transition from operation to decommissioning, licence application and approval, and detailed planning needed during conduct of decommissioning actions;
- (b) Pre-decommissioning actions (including actions performed during the transition phase), e.g., radiological characterization, post-operational decontamination of the systems, training of personnel for decommissioning including setting up of mock-up facilities;
- (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 licence, e.g. monitoring in case of release of the facility with restrictions, preparation of the final decommissioning documentation and archival storage of decommissioning records, ongoing handling and processing of waste after completion of decommissioning, temporary storage of waste and its subsequent disposal.

6.4. The decommissioning cost estimate is one of the key supporting documents to the decommissioning plan and should be performed by the licensee or by a specialized contractor. The

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first cost estimate should be performed in support to the initial decommissioning plan, and should be revised and updated together with the revisions and updates of the decommissioning plan.

6.5. The cost estimate for decommissioning should cover 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.

6.6. The decommissioning cost estimate should distinguish between operating expenses and decommissioning expenses. A clear distinction should be made between actions for which the decommissioning fund can be used and the actions which are paid from other funds, especially during transition.

6.7. The development of a cost estimate and its updates should be 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 stage in the lifetime of the facility, and depending on the level of detail provided in the initial and final decommissioning plans.

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

- Order of magnitude – this type of cost estimate can be utilized prior to receiving the operating licence 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).

6.9. Responsibility for preparing the cost estimate and its updates should reside 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 to provide a third party or independent perspective of the approach and reasonableness of the estimate, in accordance with the national regulatory framework.

6.10. 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, waste management costs or regulatory changes, especially in case of deferred dismantling where the decommissioning process may take decades with long safe enclosure period. The



occurrence of incidents leading to spillage or inadvertent release of radioactive material, or accidents should also prompt the updating of the cost estimate.

6.11. Mechanisms to provide 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 are required to be in place prior to approval of the issuance of a licence, licence renewal or licence extension for the operation of the facility.

6.12. The mechanism by which financial assurance is guaranteed should be sufficiently robust, so that it will withstand changes in government (for government owned and financed facilities), 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).

6.13. In the case of post-accident decommissioning, after completion of the recovery actions when the facility 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.

6.14. If the end state of a decommissioning project is the release of the facility or site 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.

6.15. If spent fuel or radioactive waste storage facilities remain on site after the end of decommissioning, they should be licensed as new operating facilities. The operational costs of such new facilities for waste or spent fuel management should not be covered by the decommissioning fund.

## 7. PLANNING OF DECOMMISSIONING DURING THE LIFETIME OF THE FACILITY

### **Requirement 10 of GSR Part6 [1]: Planning 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.**

7.1. As stated in paragraph 7.3 of [1], planning of decommissioning shall start at the design stage and continue throughout the lifetime of a facility. This should facilitate conduct of decommissioning; to optimize protection of decommissioning workers, the public and the environment; to minimize radioactive waste generation and to properly 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 facility, 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 to the regulatory body for approval, in accordance with the national regulatory framework.

7.3. Decommissioning should be facilitated by planning and preparatory work undertaken during the entire lifetime of the facility. Figure 1 illustrates the relations between the lifetime of the facility and the decommissioning plans required. Decommissioning plans should be periodically reviewed and updated. Aspects to be considered during the lifetime of the facility, as well as aspects related to unforeseen shutdown, are dealt with in later parts of this Section.

7.4. For many older existing facilities, decommissioning may not have been considered at the design stage or during construction and subsequent operation. For these facilities, planning for decommissioning should start as early as possible once the deficiency has been recognized. Furthermore, in addition to planning for decommissioning, possible modifications to buildings and systems during the remaining operating life 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.

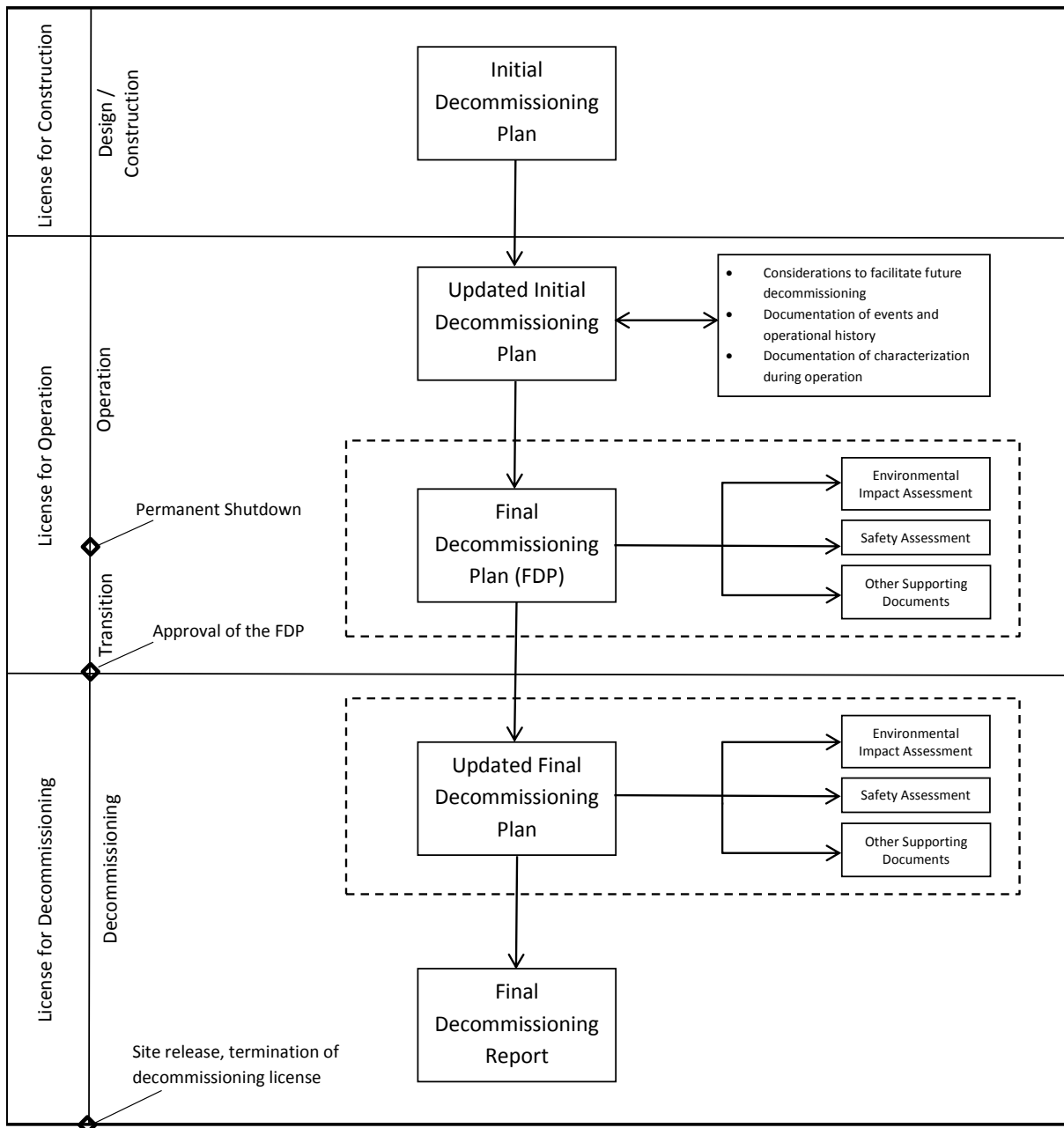


FIG. 1. An example of decommissioning plans during the lifetime of a facility

## CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

7.5. At the design stage of a new facility, the designer or the licensee should warrant that decommissioning considerations are taken into account prior to application to the regulatory body for a design certification or for a construction license. The initial decommissioning plan should be prepared during the design/construction stage and be part of the operation licence submittal package.

7.6. Relevant features and aspects, which should be considered during the design stage of a facility to facilitate decommissioning, and which should not reduce but may enhance the safe operation and maintenance of the facility, include the following:

- (a) Minimize the number and size of contaminated areas to facilitate decontamination during decommissioning;
- (b) Facilitate access to SSCs, 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 SSCs;
- (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 facility to avoid undesired accumulations of chemical or radioactive material, 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;
- (k) Minimize the use of hazardous substances which could result in mixed hazardous and radioactive waste;
- (l) Consider providing defence-in-depth measures to reduce the risk of inadvertent releases;
- (m) Identify and reserve space where new facilities that might support decommissioning (i.e., new waste management facilities) may be located, and
- (n) Consider provisions for installation of coupons to facilitate radiological characterization of SSCs.

7.7. During construction or at latest before commencement of the initial operation of the facility, 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 facility and its surrounding area to establish background concentration levels of radionuclides of natural and artificial origin for use in assessing the future impact of the facility. 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 facility to the site and the surrounding area due to its operation; and
- (b) Establishing end state criteria and demonstrating compliance with proposed end state.

If a site did not have a pre-construction background survey performed, survey data from an undisturbed area with similar characteristics or a survey of similar building material should be used.

7.9. The background data should be updated prior to commissioning of any new facility 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 licence 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 facility. 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 paragraphs 7.11 – 7.19). This initial decommissioning plan is required to be submitted by the licensee to the regulatory body in support of the licence application or authorization for operating the facility. This plan should:

- (a) Preferably be based on the immediate dismantling strategy; however, deferred dismantling of individual facilities may be considered, for example, in the case of a multi-facility site or in case of a premature shutdown;
- (b) 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 (preferably release without restrictions), related key decommissioning actions and basic safety issues;

- (c) Include a schedule for major decommissioning actions;
- (d) Include the approach for management of radioactive waste, providing initial identification of waste classes and initial estimate of waste quantities;
- (e) Provide a basis for a preliminary cost estimate of the decommissioning project and identify the means to obtain financial provisions for the decommissioning; and
- (f) Should demonstrate that the decommissioning can be performed in a safe manner.

#### INITIAL DECOMMISSIONING PLAN UPDATING

7.11. As stated in the paragraph 7.5 of [1], the initial decommissioning plan shall be updated by the licensee and shall be reviewed by the regulatory body periodically (typically every five years or as prescribed by the regulatory body), or when specific circumstances warrant. 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, environmental protection standards;
- (d) Change of the selected decommissioning strategy and/or planned end state;
- (e) Commissioning of a radioactive waste disposal facility and availability of waste acceptance requirements or criteria for disposal;
- (f) Operational and decommissioning experience feedback, including technological developments;
- (g) Extension of facility's operating period;
- (h) Changes in contractors and/or suppliers management; and
- (i) 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 facility approaches the end of its operating life.

7.13. Waste management should be addressed by the initial decommissioning plan either as a part of the decommissioning plan or as a stand-alone document and referenced and summarized in the decommissioning plan. Information about the waste management approach that will be applied should be included. This approach may be the same as the one used during operation of the facility, see the descriptions in 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 from all the stages of the lifetime of the facility, 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 facility. These records should include:

(a) Records of the history of the facility, 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 [34];
- 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 facility, particularly for areas of the facility 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 and/or disposal locations.

(b) Records of modifications to the facility 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 facility’s 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 the operation of the facility, operational radioactive waste should be properly managed and removed from the premises of the facility to the dedicated disposal facilities, to the extent practicable, to simplify transitioning to decommissioning. If this is not the case, the updates of the initial decommissioning plan should take into account management of operational waste as part of decommissioning.

7.17. The transition from operation to decommissioning starts after the permanent shutdown of the facility. The transition period should be as short as practicable. The end of the transition period is defined by the date of granting the licence for decommissioning or by the date of approval of the final decommissioning plan.

7.18. During the transition period, the facility is subject to the operating licence. All applicable operational requirements to the facility 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 facility.

7.19. Some activities preparatory to decommissioning may be carried out after permanent shutdown of the facility under the operating licence, such as management of operational waste and residual material (including drainage of systems and removal of combustible materials to reduce the fire loads), characterization of the facility, fuel removal, modification of the facility and preparation of systems to support decommissioning, and preliminary decontamination of the facility’s systems (part of the post operational clean-up).



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

**Prior to the conduct of decommissioning actions, a final decommissioning plan<sup>10</sup> shall be prepared and shall be submitted to the regulatory body for approval.**

7.20. As stated in the paragraph 7.9 of [1], the licensee shall inform the regulatory body (or the government, if so required) prior to shutting down a facility permanently. The licensee should also inform the regulatory body about its intention to decommission the facility. 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 identify, and if necessary research, any new systems, equipment and infrastructure that will need to be installed to support decommissioning.

7.21. When large or complex decommissioning projects are considered, the final decommissioning plan may be supported by additional documents (such as a 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 are usually requested as separate documents even for simple projects. A 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.

7.22. 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 facility.

7.23. Before submission of the final decommissioning plan and the safety assessment to the regulatory body, these and other selected supporting documents (see Annexes I – IV for examples) should be subject to an internal independent review performed by the licensee. The purpose of this independent review is to provide confidence that the proposed tasks are feasible and that suitable and sufficient safety controls have been identified.

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<sup>10</sup> The final decommissioning plan is that version of the decommissioning plan submitted for approval to the regulatory body prior to conduct of decommissioning actions. During implementation of this final plan, revisions or amendments may subsequently be needed as the activity progresses.

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 facility, as applicable.

7.25. Some information from activities in older facilities may not have been documented, particularly concerning unusual events. It may be useful to interview senior staff or even staff who have already retired, to access the experience and knowledge that they may have concerning past radiological occurrences. This will be valuable to supplement the characterization of the facility.

7.26. Some of these results and maps may be available from surveys performed during the operational period of the facility. However, such maps may need to be updated to account for radioactive decay, the in-growth of daughter products and previous decontamination actions. Furthermore, they should show any results of special surveys to determine the penetration depth of contamination or activation in structures, soil and sediments and the extent of radioactivity. For completeness, contamination in shielded or self-shielded components, such as inside pipes and other equipment, should be determined to the extent possible.

7.27. Radiological characterization data should include site area description (e.g., premises of the facility, environment, ground and surface water, soil and sediments), contamination and dose rate levels, and chemical and physical forms of material. 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 facility should comprehensively describe contamination and activation levels.

7.28. If radioactive material or operational waste remains at the facility (including subsurface soils and groundwater), this radioactive material will have to 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 storage areas for liquid radioactive waste are also of importance for decommissioning, as removal and processing of this type of waste 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.

7.29. When preparing decommissioning plans, experiences from ongoing or completed decommissioning projects of similar facilities should be utilized.

7.30. The final decommissioning plan should be a living document, which is updated to reflect the current status of the facility and the on-going progress of the project. This final decommissioning plan should be supported by a safety assessment, which covers all the project phases.

7.31. 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.

7.32. Where decommissioning of a facility is to take place in discrete phases, an interim phase completion report should be prepared when each planned phase completion is achieved. The report should describe the physical condition of the facility, as well as the remaining hazards.

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

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

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 basic assumptions and the inputs to the safety assessment, the identification of related components and equipment important for safety and to develop working, administrative and engineering procedures. Specialist training on a particular SSC may be necessary. There may also be a need to use mock-ups for practice if there will be first time, high dose and difficult actions to be performed.

7.36. Decommissioning waste is required to 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, storage and transport of decommissioning waste. These temporary facilities should be planned as part of the decommissioning planning effort and can be commissioned under the decommissioning licence or under separate licences issued by the regulatory body.

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 some nuclear fuel cycle facilities, depending on their operational usage.

7.38. Criticality safety is required to be considered a) in the plans for decommissioning nuclear power plants and research reactors, if spent fuel assemblies are still located in the facility, b) in the plans for decommissioning of nuclear fuel cycle facilities and facilities for management of spent nuclear fuel, c) in the assessment of the safety of planned actions involving fissile material, and d) in the design of waste packages and waste storage facilities for fissile material.

7.39. In case of deferred dismantling strategy, 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.

7.40. 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.

7.41. A surveillance and maintenance plan for the safe enclosure period should be based on the outcomes of the safety assessment. 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 facility as a whole, to demonstrate the compliance with its expected condition.

7.42. 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 facility in order to implement dismantling actions.

7.43. 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 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

7.44. According to the paragraphs 7.16 and 9.6 of [1], interested parties shall be involved in the licensing process for decommissioning, as well as in the process for termination of decommissioning licence by providing comments before decisions are taken by the regulatory body and prior to granting or terminating a decommissioning licence.

7.45. Experience shows that interested parties focus their attention mainly on the selected decommissioning strategy and its justification, the nature and extent of planned dismantling actions, the management and long term storage of radioactive waste on-site, the facility's end state especially in the case of restricted reuse, the financial management of the decommissioning fund and on the socio-economic impacts.

7.46. Public inquiries or consultations should be organized by the regulatory body with participation of the licensee to provide an opportunity for interested parties 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 facility to be decommissioned. A good practice for the licensee is to establish and support 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 [30].

7.47. 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

7.48. If the permanent shutdown of a facility is unanticipated, due to political, economic, or social demands, or due to an accident, the facility should be kept safe or brought to a safe condition by the licensee under an appropriate licence, until an approved final decommissioning plan can be implemented.

7.49. 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 facility. If any actions are required to place a facility into a safe condition as a result of the unanticipated permanent shutdown, they should preferably be done under the operating licence or under an amended operating licence which covers these actions.

7.50. 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 are required to be prepared as soon as possible. This task should normally be performed by the licensee, but in case of unplanned shutdown due to an accident it may be transferred to another organization, which takes over the responsibility for decommissioning.

7.51. In case of an unanticipated shutdown due to an accident, the facility 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 facility and the final decommissioning plan should be developed, addressing decommissioning of the facility damaged by the accident.

7.52. Planning of the decommissioning of an accident damaged facility will involve an extensive update of the characterization surveys previously performed. If accessibility to the parts of the facility has deteriorated as a result of the accident, an 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.

7.53. The decommissioning process for an accident damaged facility should follow the same principles and main steps as for planned decommissioning. Technical challenges are expected to be possibly larger, due to high dose rates and contamination levels, higher uncertainties of information about the physical and radiological status of the facility, 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 a facility 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 a severe accident, the decommissioning plan of such a facility should be consistent and coordinated with the 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.**

8.1. Conduct of decommissioning involves implementation of the decommissioning strategy and related actions, as described in the final decommissioning plan.

8.2. Modifications of the existing infrastructure of the facility may be needed to facilitate immediate dismantling or, in some cases, to prepare the facility 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 provided the facility has been verified to be free of fissile material;
- Establishment of new access and transport routes for personnel, equipment and waste to and from the facility;
- Installation of additional equipment, such as remote size reduction and waste handling equipment; and
- Establishment of an on-site waste storage area.

8.3. Preliminary removal of excess radioactive material and 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 facility after its permanent shutdown. If this is performed 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 facility 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 detection and alarm systems) 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 actions should be kept, including the level of residual contamination.

8.5. If the licensee adopts a deferred dismantling strategy, safe configuration of the facility is required to 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 facility's 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 facility is in the state as planned and approved, i.e. ready for the passive safe enclosure phase.

8.7. If actions for decontamination and dismantling are deferred in part or in whole, the licensee is required to ensure safety of the facility 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 or techniques to avoid exposing workers to high dose rates through the use of remote handling or robotics;
- 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 disposal;



- 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 facility;
- Time and schedule constraints, such as availability of waste processing facilities;
- Specialist resource and training requirements, such as for the use of remotely operated equipment;
- Generation of secondary radioactive waste from decontamination actions;
- Potential impact on the workers and the environment arising from the presence of hazardous and non-radioactive contaminants.

8.10. However, in some cases special tools and equipment as well as standard tools and equipment that would be used in special conditions may be needed. The equipment 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, to which little attention has been given or to which access has been limited during the operational phase of the facility, may have suffered degradation. Such systems should be given special consideration when decommissioning techniques are considered. Examples of this include storage tanks for liquid radioactive waste and remote handling systems within unmanned cells.

8.12. Decommissioning of a facility may be aided in certain instances by partial or total decontamination of the equipment and SSCs 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 equipment and SSCs of the facility. 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, of the potential for reducing total exposure, and of the benefit in terms of generation of waste and effluents should be performed. The decontamination process should also be evaluated to ensure it is compatible with waste processing systems as well as storage and/or disposal options. The main objectives of decontamination include:

- Reduce workers' internal and external exposure during decommissioning actions;
- Minimize 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 facility.

8.13. As the decommissioning actions progress new hazards may emerge. 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 using a diamond wire system, sharp edges are generated and a number of additional control measures 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 facility, the installation of the infrastructure of the facility to enable decommissioning and the safety assessment concerning the decommissioning actions. The SSCs from the operational phase of the facility 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 facility for stability and structural capability;
- Evaluation of the confinement integrity of the existing facility's infrastructure, including tanks, vessels, piping and ventilation ducting;
- Adequacy and integrity of the existing facility's infrastructure required for decommissioning, including electrical distribution systems;
- Availability and adequacy of the existing SSCs support systems, including alarm systems (especially related to fire, radiation and contamination), lighting 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 facility (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 facility's inspection and surveillance and maintenance programmes.

8.19. During decommissioning, radioactive and non-radioactive effluents will be generated. Discharge of radioactive effluents requires authorization from the regulatory body and control in compliance with appropriate national regulations. The expected discharges of effluents during decommissioning may be in a different form and with a different radionuclide composition than the discharges during operation. 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, radioactive discharges may reduce.

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, and 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 [35].

8.21. Depending on the end state of the decommissioning project, demolition of the remaining structures of the former facility 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 should 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, information concerning the quantities and types of radionuclides remaining at the facility, their locations and distributions, and the volume of radioactive waste generated. These records could be used to demonstrate that all radioactive material, 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 material, structures and land that have been removed from regulatory control. Such documentation should be prepared by the licensee and provided to the regulatory body as part of the final decommissioning report.

## REGULATORY OVERSIGHT DURING CONDUCT OF DECOMMISSIONING ACTIONS

8.23. The regulatory body's inspection programme for a facility 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 [36].

8.24. During periods of intensive decommissioning actions, regulatory oversight should be performed with appropriate competence and with focus on safety and potential risks, and should be coordinated to coincide with conduct of actions that have a high potential safety implications, such as movement of large components and size reduction actions. Inspections during this period might focus on topics such as: exposures to workers, environmental protection, contamination control, control of movement of nuclear material, industrial safety, transportation of radioactive waste, and radiological condition of areas that may not be easily accessible at a later time during decommissioning.

8.25. If a deferred dismantling strategy is chosen, the frequency and scope of inspections may be reduced when a facility is in safe enclosure. These inspections should focus on surveillance and preservation of the facility (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.

8.26. Regulatory oversight is required to be performed by the regulatory body during the total lifetime of the facility including the actual decommissioning conduct phase. The frequency and scope of inspections should be established to be consistent with associated risks and hazards, and the operator's ability to deal with the tasks involved in the relevant decommissioning phase. In some cases, regulatory oversight may continue after the completion of decommissioning and termination of the licence for decommissioning, for example in case of restricted release of the site.

8.27. Depending on the nature and extent of the decommissioning actions to be performed, regulatory oversight should focus on the preparation and conduct of actions having a significant impact on safety and being of public concern.

8.28. During conduct of decommissioning, the licensee may implement internal procedures to allow minor modifications of decontamination and dismantling techniques, which do not have an adverse effect on safety. Such procedures should be approved by those parts of the licensee responsible for ensuring safety. These procedures should be subject to oversight by the regulatory body prior to and during their implementation, according to national requirements.

## EMERGENCY ARRANGEMENTS

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

**Emergency response 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.**

8.29. Prior to decommissioning of a facility, there is usually an emergency plan for the facility during its operation, or for the whole site where the facility is located [28]. A review and revision of this emergency plan should be made before commencement of decommissioning actions, to ensure it is adequate for decommissioning. If an emergency plan does not exist, an emergency plan should be developed commensurate with the potential risks posed by the facility.

8.30. 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 the range of postulated emergency scenarios and developing emergency plans and procedures to deal with them in accordance with Ref. [28]. Examples of this could be loss of containment or a recovery from a dropped waste package either within the facility or on transfer to the storage facility or disposal site.

8.31. The licensee is required to 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.

8.32. 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.

8.33. In cases when emergency plans from the operational period are intended to be used during decommissioning, the licensee should perform a review to confirm they are adequate in the new circumstances (in some cases new organizations may be involved, and new possible emergency

situations and/or security threats and vulnerabilities may become relevant). Guidance for emergency preparedness and response is provided in the IAEA Safety Standards Series publications [37, 38].

## RADIOACTIVE WASTE MANAGEMENT

### **Requirement 14 of GSR Part6 [1]: Radioactive waste management in decommissioning**

#### **Radioactive waste shall be managed for all waste streams in decommissioning.**

8.34. Decommissioning of nuclear power plants, research reactors and other nuclear fuel cycle facilities invariably involves the generation of large amounts of material and waste in forms that may be different from material and categories routinely handled during the operational phase of the facility. 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 facility and the manner for segregating radiological from non-radiological and hazardous waste. The waste management plan should be part of the decommissioning plan.

8.35. 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 (e.g., for storage or waste processing) or the use of existing facilities for 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 storage or processing capacities on-site. A separate authorization of such activities may be required from the regulatory body.

8.36. In general, an update of the existing waste management plan from the operational phase of the facility 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.

8.37. 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. 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).

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

8.39. 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.

8.40. Transport of radioactive waste from the facility to the processing, storage or disposal facilities has to 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 [7, 8]. Precautions should be taken to prevent the external contamination of disposal containers that could spread contaminants during transport.

8.41. The licensee should ensure that each waste package 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;
- 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 ;  
and
- Corresponding classification of the radioactive waste in accordance with the national classification system or the IAEA classification system [39].

8.42. Management of operational waste, spent fuel and process material should be done under the operating licence during the transition from operation to decommissioning. This should ensure that

delays in removal of operational waste and a costly extended shutdown mode of the facility at the end of its operation are avoided, and the facility is efficiently brought to a condition when decommissioning can begin.

8.43. Removal of spent fuel assemblies 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 spent fuel assemblies and the remaining waste and material will have to 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.



## **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.**

9.1. On completion of decommissioning, the licensee is required to prepare a final decommissioning report and to retain it 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 facility. The final physical and radiological status of the remaining structures of the facility, 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 final 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 facility, 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 actions, 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, 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 is required to be reviewed by the regulatory body to ensure that the decommissioning end state, both for the physical and radiological status, has been reached in compliance with the final decommissioning plan and the related requirements of the licence 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 facility is required to be performed to demonstrate that the decommissioning objectives or criteria, as described in the final decommissioning plan, in the

decommissioning licence or in the national regulations, have been fulfilled, and that the residual radioactivity meets the regulatory criteria for restricted or unrestricted release.

9.6. The final decommissioning plan should include a plan for the final survey (as described in the Annex I), which, as such, is approved by the regulatory body. The final survey plan should be reviewed and revised, if needed, based on additional radiological survey information obtained during the decommissioning process. Any changes to the design and implementation of the plan for the final survey 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 before the final survey is conducted. The survey may be carried out in phases, as portions of decommissioning actions are completed, to enable parts of the facility 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 facility from some or all 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 verify that the site meets the end state criteria [6]. In the event that the site or remaining structures of the former facility 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 are considered unacceptable or not properly justified, the regulatory body may require the licensee to resume decommissioning actions to reach the end state as foreseen in the final decommissioning plan.

9.12. If the end state approved in the final decommissioning plan cannot be achieved, deviations from that end state 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.

9.13. In order to achieve termination of the decommissioning licence 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 facility or site, the regulatory body should ensure that an appropriate mechanism is in place to demonstrate compliance with these restrictions.

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 should clearly be assigned to an organization or institution. The implementation of controls has to comply with regulatory requirements and the monitoring and surveillance for compliance is required to be put in place, as approved by the regulatory body.

9.16. A long term surveillance and maintenance plan for the area released with restrictions is required to be prepared by the licensee, and 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. The regulatory body should conduct regulatory oversight 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.

9.17. If the decommissioning waste has to be stored on-site for a longer period of time after completion of decommissioning, an application for construction of a new storage facility for radioactive waste is required to be prepared by the licensee and submitted to the regulatory body for review, approval and issuance of a licence. Requirements and guidance concerning radioactive waste storage are provided in [11-14]. If spent fuel remains on-site, guidance found in [10] should be

applied. A decommissioning plan for the waste storage or spent fuel storage facility that remains on the site is required to be prepared. On-site disposal of decommissioning waste is not a recommended practice in case of decommissioning after a normal operation, and is not addressed in this Safety Guide.

9.18. It is permissible to progressively release buildings and land areas from regulatory control. A discussion between the licensee and the regulatory body should be initiated as soon as possible to address such situation.

9.19. If a partial site release and reduction of the licenced part of the site is an 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 facility or part of its site has to 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 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 after completion of decommissioning on the entire site.

9.20. Comments from interested parties, e.g. the public, are required to be obtained and addressed before the licence 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.

9.21. Prior to terminating the decommissioning licence, 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.

9.22. When the criteria for the site release have been met according to the defined 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.

9.23. 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.

9.24. 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 licence, 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 of particular importance where restrictions are imposed on the future use of sites.

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

9.26. The nature and extent of the decommissioning records, to be preserved after termination of the decommissioning licence, 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 facility should be in place. The responsibility of keeping relevant records for potential litigation or other purposes should be transferred to other institutions, as required by the national laws and regulations.

9.27. Records may be required to identify and justify actions that were taken when a later review of the end state or project performance may occur because of, among other things, new regulatory positions (e.g. on clearance levels) or the development of more advanced, higher resolution detection equipment. The former actions may be in conflict with these new developments, especially for decommissioning with restricted release as an end state, and such 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 (e.g., for records of occupational exposures, for records of importance for potential future liabilities). Other records may need to be kept for institutional purposes or other ad hoc reasons.

## Appendix

### CONSIDERATION FOR SAFETY ASSESSMENT FOR DECOMMISSIONING OF FACILITIES

#### GENERAL CONSIDERATION FOR SAFETY ASSESSMENT

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 relevant procedures, in accordance with a graded approach. The SSCs important to safety provide the 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.
2. The safety assessment should employ a systematic methodology to demonstrate compliance with safety requirements for decommissioning, including the release of material, buildings and sites from regulatory control.
3. The safety assessment should be commensurate with the complexity and potential hazard of the facility and, in case of deferred dismantling, should take into account the safety of the facility during the period leading up to final dismantling.
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 should be 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.
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 facility, as well as human errors that could occur during decommissioning activities. The set of postulated initiating events should consider both internal and external events.
6. Human factors are an important aspect of the safety of facilities, as the state of the facility changes frequently with decommissioning actions. The safety assessment should consider the human errors according to the complexity and hazard potential of the facility concerned (e.g., large numbers

of equipment, tanks, pipes and valves with unexpected remaining radioactive material and contaminated liquid). Ergonomic factors in dismantlement should be analysed and planned for to avoid injury or prolonged exposure.

7. The likelihood and consequences of external events should be assessed, taking into account the decommissioning strategy and the site characteristics (e.g., seismic hazards, flooding, extreme temperatures, influence from or dependence on any neighbouring facilities, and accidental aircraft crash) and the likelihood and consequences of potential initiating events for incident/accident scenarios. (e.g., human error, fire, flood, dropped loads, building/structure collapse/failure, and the release of hazardous 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).

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 facility. The decommissioning limits and conditions should also define the required intervals for periodic testing and inspection of SSCs important to safety.

9. Dismantling may involve the deliberate destruction and removal of engineered SSCs that had fulfilled specified safety functions during operation of the facility (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/or 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.

10. A safety assessment should address the main safety issues and objectives of the final decommissioning plan. Based on the outcomes from the 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.

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 other phases may be performed later, but prior to the beginning of such phases.

12. In all phases of decommissioning of a facility, 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 facility, 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.

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

- 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.

14. In the planning stage for decommissioning, the degree and extent of contamination in a facility 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.

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.

16. For facilities 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.

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.

18. The licensee 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.

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; and
- Greater potential for the creation of airborne radionuclides, due to removal of containment or barriers during dismantling.

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 facility. 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**

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

22. Work performed during the transition period is often done under the operating licence and in accordance with the safety assessment developed for the operational phase of the facility. 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 actions of experimental devices and equipment such as glove boxes, are performed periodically during operation.

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**

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 using liquids, waste treatment, conditioning and storage of waste packages.

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.

26. Radiolysis, if not adequately controlled, may result in the release of hydrogen with the risk of explosion. Radiolysis 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.

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## Annex I

### **SUGGESTED STRUCTURE OF THE CONTENT OF A FINAL DECOMMISSIONING PLAN AND SUPPORTING DOCUMENTS**

I-1. 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. The final decommissioning plan is of great importance for the licensee and all organizations involved in the decommissioning process as it establishes the strategy and objectives of decommissioning. 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 may be integrated into the final decommissioning plan itself, where appropriate (some supporting documents could contain restricted information, for example security related plans). See also Ref. [I-1].

I-2. This Annex provides an example of the possible content of a final decommissioning plan for a facility. Following the graded approach, the level of detail will depend on the complexity of the decommissioning actions.

I-3. The content of the final decommissioning plan is 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 licences

#### 2. SITE AND FACILITY DESCRIPTION

2.1. Site location and description

2.2. Description of the facility, including related SSCs

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

2.4. Facility'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
- 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
- 6.4. Identification of non-radioactive waste and material
- 6.5. Disposition of all waste streams

### 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 both onsite and offsite 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 [I-2]

11.1. Emergency planning basis including scenarios

11.2. Organization and responsibilities

11.3. Emergency response process

11.4. Emergency preparedness process

## 12. PHYSICAL PROTECTION AND ARRANGEMENTS FOR ACCOUNTING FOR AND CONTROL OF NUCLEAR MATERIAL<sup>11</sup>

12.1. Legal and regulatory policy and framework

12.2. Organization and responsibilities

12.3. Physical protection programme and measures

12.4. Programme and measures for nuclear material accounting and control

## 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**

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<sup>11</sup> 'Public' information on arrangements for physical protection and accounting and control of nuclear material that is included in the decommissioning plan does not contain sensitive security information.

## **Annex II**

### **SUGGESTED STRUCTURE OF THE CONTENTS OF THE FINAL DECOMMISSIONING REPORT**

II-1. The final decommissioning report is prepared by the licensee as a basis for regulatory decision to terminate the decommissioning licence. This report:

1. Summarizes the final decommissioning plan, its updates and any related licences;
2. Includes the final radiological survey report(s);
3. Describes 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. Provides information on radiation exposures to workers;
5. Provides information on radioactive discharges to the environment;
6. Provides information on radioactive waste and material management.

II-2. 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

### SUGGESTED STRUCTURE OF THE CONTENTS OF THE FINAL RADIOLOGICAL SURVEY REPORT

III-1. 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.

III-2. 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**

### **SUGGESTED STRUCTURE OF DECOMMISSIONING RELATED DOCUMENTS**

IV-1. In practice, the final decommissioning plan, as described in the Annex I, 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 facilities is usually a stand-alone document, providing more detail on the safety aspects of decommissioning, than presented in chapter 9 of the final decommissioning plan (according to the content presented in the Annex I).

IV-2. 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 plan and plan for accounting for and control of nuclear material
- Funding provisions and cost estimate
- Public relations plan

## Annex V

### RELEVANT LITERATURE

#### CONTENT OF THE DECOMMISSIONING PLAN

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