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Acronyms and Abbreviations

AGR	Advanced Gas-cooled Reactor
ANDRA	Agence Nationale pour la Gestion des Déchets Radioactifs – French National Radioactive Waste Management Agency
ASN	Autorité de Sûreté Nucléaire – French Nuclear Safety Authority
BWR	Boiling Water Reactor
CEA	Commissariat à l'Énergie Atomique – French Atomic Energy Commission
CNSC	Canadian Nuclear Safety Commission
DECON	Immediate (Prompt) Dismantling
DOE	Department of Energy (United States)
EC	European Commission
FBR	Fast Breeder Reactor
HLW	High Level Waste
HTGCR	High Temperature Gas Cooled Reactor
HTGR	High Temperature Graphite Reactor
IAEA	International Atomic Energy Agency
ILW	Intermediate Level Waste
ISFSI	Independent Spent Fuel Storage Facility
LL-	Long-Lived
LLW	Low Level Waste
LILW	Low and Intermediate Level Waste
NEA	Nuclear Energy Agency
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission (United States)
NS	Nuclear Ship
NWMO	Nuclear Waste Management Organization (Canada)
OECD	Organization for Economic Co-operation and Development
PSDAR	Post-Shutdown Decommissioning Activities Report
PWR	Pressurized Water Reactor
SAFSTOR	Safe Storage (equivalent to Deferred Dismantling)
SGHWR	Steam Generating Heavy Water Reactor
SL-	Short-Lived
SSM	Strålsäkerhetsmyndigheten – Swedish Radiation Safety Authority
VSL-	Very-Short-Lived

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Executive Summary


Candesco - Division of Kinectrics was retained to conduct literature research on international decommissioning strategies, regulatory requirements and lessons learned from decommissioning nuclear facilities and provide a gap analysis between the current Canadian and International regulatory framework. Seven countries were included in this review: Finland, France, Germany, Italy, Sweden, the United Kingdom and the United States. International requirements and recommendations of the International Atomic Energy Agency (IAEA) and the European Commission (EC) were also considered.

The Canadian regulatory approach to the planning for decommissioning, decommissioning cost estimating and provision of funds for decommissioning is similar to the approach adopted in most of the other countries considered in this review. Canadian regulators address these matters through a combination of the use of statutory authority granted to the CNSC (financial guarantees), regulations (the requirement to include plans for decommissioning in an application for a Class I nuclear facility licence), regulatory documents (G-206 & G-219), licence conditions and code and standards (CSA N294-09 & CSA N286). Other countries also address these issues through a combination of statutes (Italy), regulations (Italy & the United States), regulatory documents (Finland, Sweden & the United States), licence conditions (United Kingdom), government policy or the policies of national decommissioning agencies (France, Italy & the United Kingdom).


Some gaps were noted when Canadian regulatory practice was compared to the relevant IAEA Safety Requirements and regulatory practice in the other seven countries that were reviewed. The notable inter-country differences were between regulatory practices in Canada and the United States. The American regulatory system governing decommissioning (both NRC and DOE) is more highly developed than the system in any of the other countries considered in this review probably due to the number and variety of decommissioning projects that have already been completed in the United States.

Based on the results of this review it is recommended that:

1. Licensees should be provided with guidance on the preferred or acceptable strategic approaches to decommissioning. It is recommended that this guidance should be consistent with the IAEA recommendation that “The preferred decommissioning strategy shall be immediate dismantling. There may, however, be situations where immediate dismantling is not a practical strategy when all relevant factors are considered.”
2. Licensees should be provided with clear guidance on if (or when) it would be acceptable to base decommissioning plans on an ‘In-Situ Confinement’ decommissioning strategy.
3. Licensees should be required to give formal notice of permanent shutdown in advance of, or within a reasonable time after permanent shut down for decommissioning.

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4. The power of the CNSC to order a facility to decommission and the responsibility for decommissioning in the event that the owner/operator is unwilling or unable to perform the work should be clarified.
5. A definition of the activities that may be performed under a Licence to Operate in anticipation of decommissioning should be provided.
6. The schedule for submission of a Detailed Decommissioning Plan should be clarified.
7. Guidance on the acceptable duration of decommissioning should be provided.
8. Guidance on the Stabilization Activities and Storage and Surveillance Activities given in RD/GD-360 should be consistent with the guidance given in the CSA N294 standard. This may require revision of RD/GD-360, CSA N294-09 or both.
9. Guidance on the content of a Storage with Surveillance Plan should be provided. This guidance could also be included in an amendment of the CSA N294 standard.
10. Guidance on the content of an Interim End State Report (and a Characterization Report if that will be a separate document) should be provided. This guidance could also be included in an amendment of the CSA N294 standard.
11. The acceptability of institutional control or restricted release following issuance of a License to Abandon and the procedures for implementing them should be clarified.

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1. Introduction

The Canadian Nuclear Safety Commission (CNSC) has contracted Candesco - Division of Kinectrics to conduct literature research on International decommissioning strategies, regulatory requirements and lessons learned from decommissioning nuclear facilities and provide a gap analysis between the current Canadian and International regulatory framework. In addition to Canada, seven countries have been identified as the focus of this review: the United States, France, Germany, Finland, Italy, Sweden, and the United Kingdom. International requirements and recommendations of the International Atomic Energy Agency (IAEA) and the European Commission (EC) are also to be considered.

Decommissioning regulations, strategies, waste disposal/storage options and lessons learned were researched online searching primarily for information provided by the regulator authorities in each country, by other national agencies (such as the Nuclear Decommissioning Authority in the United Kingdom or SOGIN in Italy) and by international organizations such as the IAEA and the OECD/NEA. The information considered in this report was gathered between January 6, 2014 and May 31, 2014.

The regulatory framework and practices relevant to decommissioning were identified for each of the 8 countries considered and summaries were prepared for each country which describe:

- Types and status of the nuclear facilities in the country;
- Decommissioning regulatory framework;
- Responsibilities for decommissioning;
- Decommissioning strategies mandated by the government or adopted by licenses;
- Waste management strategies and practices relevant to decommissioning; and
- Any lessons learned for decommissioning work that has been completed.

Canadian practice was then compared with the requirements of IAEA Safety Requirements WS-R-5 (Decommissioning of Facilities Using Radioactive Material) and the practices observed in the other seven countries. A gap analysis was conducted to assess for potential gaps in the Canadian regulatory framework and decommissioning practice.

With the exception of nuclear reactors (particularly power reactors) or uranium mines and mills which may present unique issues or hazards, it was noted that it was not common practice in any of the countries reviewed to tailor regulations or guidance to specific types of nuclear facilities. In general, other countries followed the Canadian practice of producing regulations or guidance that are applicable to all types of nuclear facilities and supplementing this for nuclear reactors or uranium mines and mills where required.

For ease of comparison, the information in the some of the tables in this report are categorized following the CNSC Categories (classes) and sub classified by the facility types as listed in



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Table 1. Note: Uranium Mines and Mills are facilities involved in the mining, ore processing and milling of uranium are out of scope for this report.

Table 1 CNSC Facility Categories (Classes)

CNSC Category (Class)	Sub-Category	Facility Type
Class IA		Nuclear fission or fusion reactor or subcritical nuclear assembly
Class IB	A	Facility that includes a particle accelerator, other than a particle accelerator that is capable of producing nuclear energy and has a beam energy of: less than 50 MeV for beams of particles with a mass equal to or less than 4 atomic mass units; or no more than 15 MeV per atomic mass unit for beams of particles with a mass greater than 4 atomic mass units.
	B	Plant for processing, reprocessing or separation of an isotope of uranium, thorium or plutonium
	C	Plant for the manufacture of a product from uranium, thorium or plutonium
	D	Plant for processing or use, in a quantity greater than 10^{15} Bq per calendar year, of nuclear substances other than uranium, thorium or plutonium
	E	Facility for the disposal of a nuclear substance generated at another nuclear facility, and includes where applicable, the land on which the facility is located, a building that forms part of, or equipment used in conjunction with, the facility and any system for the management, storage or disposal of a nuclear substance

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CNSC Category (Class)	Sub-Category	Facility Type
Class II	F	<p>Class II Prescribed Equipment includes:</p> <p>(a) an irradiator that uses more than 10^{15} Bq of a nuclear substance;</p> <p>(b) an irradiator that requires shielding which is not part of the irradiator and that is designed to deliver a dose of radiation at a rate exceeding 1 cGy/min at a distance of 1 m;</p> <p>(c) a radioactive source teletherapy machine;</p> <p>(d) a particle accelerator that is capable of producing nuclear energy and has a beam energy of less than 50 MeV for beams of particles with a mass equal to or less than 4 atomic mass units;</p> <p>(e) a particle accelerator that is capable of producing nuclear energy and has a beam energy of no more than 15 MeV per atomic mass unit for beams of particles with a mass greater than 4 atomic mass units; or</p> <p>(f) a brachytherapy remote afterloader.</p>

This report provides comparisons between the decommissioning strategies and decommissioning regulatory framework, discussion of international good practice, analysis of possible gaps in the Canadian system and recommendations on possible ways to address them.


2. Summary of International Decommissioning Strategies

2.1. Decommissioning Strategies

Neither the CSA nor the IAEA formally define the term ‘decommissioning strategy’. For this review, decommissioning strategy is taken to mean a statement of the approach to the decommissioning with particular emphasis on the relative timing of different phases of the decommissioning project.

The IAEA and other international (e.g.: NEA) and national (e.g.: CSA) organizations recognize three general decommissioning strategies. Clause 6.1.2 of CSA N294-09 [6] defines these three strategies as:

- a) *prompt decommissioning — to decontaminate and dismantle the facility without any planned delays;*
- b) *deferred decommissioning*

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- (i) *to place the facility in a period of storage-with-surveillance followed by decontamination and dismantlement; or*
- (ii) *to conduct activities directed at placing certain buildings or facilities in a safe, secure interim end state, followed by a period of storage-with-surveillance, and ultimately decontamination and dismantlement; and*
- c) *in-situ confinement — to place the facility in a safe and secure condition with the intention to abandon in-place.*

Prompt decommissioning is also called ‘immediate dismantling’ by the IAEA and some other international organizations. IAEA Safety Report Series No 50 (Decommissioning Strategies for Facilities Using Radioactive Material) [1] defines prompt (immediate) dismantling as:


“Immediate dismantling is the strategy in which the equipment, structures, components and parts of a facility containing radioactive material are removed or decontaminated to a level that permits the facility to be released for unrestricted use as soon as possible after permanent shutdown. In some cases, where unrestricted release is not feasible, the facility may be released from regulatory control with restrictions imposed by the regulatory body. The implementation of the decommissioning strategy begins shortly after permanent termination of operational activities for which the facility was intended, normally within two years. Immediate dismantling involves the prompt removal and processing of all radioactive material from the facility for either long term storage or disposal. Non-radioactive structures may remain on-site. Immediate dismantling is the preferred decommissioning strategy.”

The advantages of immediate decommissioning include:

- Availability of personnel familiar with the operation of the facility (facility knowledge retained, resulting in improved safety in activities);
- Financial obligations and potential liabilities are reduced by reducing the duration of site responsibility;
- Retention of on-site staffing (loss of operational staff, increase in decommissioning staff);
- Being able to take advantage of land reuse options sooner; and
- Shorter period of regulatory oversight (less regulatory staff turnover, possibility of regulatory continuity).

Deferred decommissioning is also called ‘deferred dismantling’ and some other international organizations. IAEA WS-R-5 (Decommissioning of Facilities Using Radioactive Material) [3] defines deferred dismantling as:

“Deferred dismantling (sometimes called safe storage, safe store or safe enclosure) is the strategy in which parts of a facility containing radioactive contaminants are either processed or placed in such a condition that they can be safely stored and maintained until they can

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subsequently be decontaminated and/or dismantled to levels that permit the facility to be released for unrestricted use or with restrictions imposed by the regulatory body.”

This document also advises:

If the deferred dismantling strategy has been selected, it shall be demonstrated in the decommissioning plan that such an option will be implemented safely and will require minimum active safety systems, radiological monitoring and human intervention and that future requirements for information, technology and funds have been taken into consideration. The potential aging and deterioration of any safety related equipment and systems shall also be considered.

The advantages of deferred decommissioning include:


- Lower dose rates;
- Longer planning period for disposal facilities;
- More time for accumulation of OPEX and for implementing appropriate additions to regulatory input and oversight;
- More time to develop land re-use options; and
- Longer period for accumulation and maturing of decommissioning funds.

In-situ confinement is also called ‘entombment’. In-situ confinement has not been widely used except at some Department of Energy in the United States (see Table 2).

2.2. International Guidance

Clause 4.2 of IAEA Safety Requirements No WS-R-5 [3] states:

“The preferred decommissioning strategy shall be immediate dismantling. There may, however, be situations where immediate dismantling is not a practical strategy when all relevant factors are considered. These factors may include: the availability of waste disposal or long term storage capacity for decommissioning waste; the availability of a trained workforce; the availability of funds; co-location of other facilities on the same site requiring decommissioning; technical feasibility; and optimization of the radiation protection of workers, the public and the environment. If the deferred dismantling or entombment strategy is chosen, the operating organization shall provide a justification for the selection. The operating organization shall also demonstrate that, for the selected strategy, the facility will be maintained in a safe configuration at all times and will be adequately decommissioned in the future and that no undue burdens will be imposed on future generations.”


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2.3. Practice in Other Countries


The decommissioning strategies that were preferred or adopted by the countries that were reviewed are summarized in Table 2.

Table 2 Summary of Preferred Decommissioning Strategies by Country

Country	Preferred Decommissioning Strategy (or decommissioning strategies that have been adopted in practice)
Canada	<ul style="list-style-type: none"> No preference is stated in either policy or regulations. Most operators of large nuclear facilities have adopted deferred decommissioning in order to: <ul style="list-style-type: none"> Reduce occupational doses by allowing time for radiological decay; or Take advantage of efficiencies of scale by coordinating the decommissioning of different facilities located on the same site. Prompt decommissioning has been adopted for some smaller facilities (e.g.: SLOWPOKE II research reactors). There is no indication that a particular decommissioning strategy (i.e.: prompt or deferred) was ever defined for either the Tunney's Pasture (AECL Radiochemical Company) Isotope Processing Facility or the final portions of the Bruce Heavy Water Plant but both were decommissioned within a few years after shutdown.
Finland	<ul style="list-style-type: none"> The YVL Guide on Predisposal Management of Low and Intermediate Level Nuclear Waste and Decommissioning of a Nuclear Facility mandates that "Implementation of decommissioning shall not be unjustifiably postponed." Decommissioning plans for two of the four operating power reactors are based on prompt decommissioning while the plans for the other two are based on deferred decommissioning (due to the presence of another reactor on the site that will still be in operation).
France	<ul style="list-style-type: none"> The regulators state a preference for prompt decommissioning but this is not a regulatory requirement. Some operators have adopted deferred dismantling (with a 50 year deferral period) due to the lack of required waste management facilities.
Germany	<ul style="list-style-type: none"> The regulations allow either prompt decommissioning or deferred

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Country	Preferred Decommissioning Strategy (or decommissioning strategies that have been adopted in practice)
	<p>decommissioning.</p> <ul style="list-style-type: none"> Operators have tended to favour prompt decommissioning but some have adopted deferred dismantling due to the lack of appropriate waste management facilities.
Italy	<ul style="list-style-type: none"> Government policies or strategy documents call for: <ul style="list-style-type: none"> Adoption of an immediate decommissioning strategy for all national shut-down nuclear installations; and Completion of decommissioning of all major nuclear facilities by 2024. Most facilities have been forced to adopt deferred decommissioning due to a lack of required waste management facilities.
Sweden	<ul style="list-style-type: none"> No preference is stated in either policy or regulations. All three power reactor operators have adopted deferred decommissioning. Prompt decommissioning was adopted for three research reactors, a uranium mining and milling facility and an ILW management facility.
United Kingdom	<ul style="list-style-type: none"> No preference is stated in either policy or regulations. The Nuclear Decommissioning Authority identified both ‘continuous decommissioning’ and ‘deferred decommissioning’ as credible decommissioning strategies (continuous decommissioning begins immediately after shutdown but may continue over a long period while deferred decommissioning includes a deferral period to allow for radioactive decay). Most facilities (including most of the research reactors and some non-reactor facilities) have adopted deferred decommissioning but the MAGNOX have recently adopted the MAGNOX Optimized Decommissioning Programme (MODP) which utilizes a hybrid approach (see Appendix A.12) similar to the approach adopted at Vandellós-1 in Spain consisting of: <ul style="list-style-type: none"> An accelerated transition to safe storage (care & maintenance) which includes the work required to: <ul style="list-style-type: none"> Dismantle both radioactive and non-radioactive plant and buildings where radiological benefit cannot be achieved from deferral; and Place other buildings into a passively safe and secure state, which will not require the presence of staff on-site on a routine basis, for an extended period of safe storage.

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Country	Preferred Decommissioning Strategy (or decommissioning strategies that have been adopted in practice)
	<ul style="list-style-type: none"> ○ An extended safe storage period that will provide the time for radiation levels in the reactor cores to decay, the remaining buildings will remain in a secure, quiescent state during this period; and ○ Final site clearance which will include removal of the reactor building and vessels.
United States	<ul style="list-style-type: none"> ● Regulations require decommissioning of reactors to be completed within 60 years of shutdown. ● Both prompt and deferred decommissioning have been adopted by operators depending on their specific needs or circumstances. ● Several commercial nuclear power plants have largely completed decommissioning but the used fuel remains in storage on site due to the lack of required high level waste management facilities. ● In-situ confinement has been adopted at US Department of Energy sites for the decommissioning of: <ul style="list-style-type: none"> ○ Two large reactors (P- and R-reactors) and their ancillary facilities at the Savannah River Site near Augusta, Georgia; ○ Two fuel processing facilities including Buildings 601/640 at the Idaho National Laboratory near Arco, Idaho and the U Canyon at the Hanford site near Richland, Washington. ○ The below grade portion of several small reactors facilities at Idaho National Laboratory and one at the Savannah River Site. [51]

3. Comparison of the CNSC Decommissioning Framework with International Requirements and Other Countries

3.1. Regulatory Requirements in Canada

Section 41(1) of the Nuclear Safety and Control Act permits the Canadian Nuclear Safety Commission to make regulations respecting decommissioning

44. (1) The Commission may, with the approval of the Governor in Council, make regulations

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- (c) respecting the design, inspection during production or installation, production, possession, storage, import, export, use, decommissioning, abandonment and disposal of prescribed equipment;*
- (e) respecting the location, design, construction, installation, operation, maintenance, modification, decommissioning, abandonment and disposal of a nuclear facility or part of a nuclear facility;*
- (o) establishing requirements to be complied with by any person who possesses, uses, packages, transports, stores or disposes of a nuclear substance or prescribed equipment or who locates, designs, constructs, installs, operates, maintains, modifies, decommissions or abandons a nuclear facility or nuclear-powered vehicle;*

No such Regulations have been made at present but both the Class I Nuclear Facilities Regulations and the Class II Nuclear Facilities and Prescribed Equipment Regulations do require that an application for a license to prepare a site (for a Class I nuclear facility only), construct or operate a nuclear facility must include “the proposed plan for the decommissioning of the nuclear facility”.

Section 26 of the Nuclear Safety and Control Act requires that:

- 26. Subject to the regulations, no person shall, except in accordance with a licence,*
- (a) possess, transfer, import, export, use or abandon a nuclear substance, prescribed equipment or prescribed information;*
 - (e) prepare a site for, construct, operate, modify, decommission or abandon a nuclear facility; or*
 - (f) construct, operate, decommission or abandon a nuclear-powered vehicle or bring a nuclear-powered vehicle into Canada.*


Section 24(5) of the Act also permits

24(5) A licence may contain any term or condition that the Commission considers necessary for the purposes of this Act, including a condition that the applicant provide a financial guarantee in a form that is acceptable to the Commission.

It has become a common practice for the CNSC to mandate compliance with CSA N294-09 entitled “Decommissioning of facilities containing nuclear substances” [6] and certain other CSA standards by adding a condition to the licences issued to major nuclear facilities. Unless otherwise indicated by the licence condition, the licensee would only be required to comply with the normative clauses of the CSA standard in order to meet the requirement of the licence condition.

CSA N294-09 (an amendment to this standard should be published later in 2014) is intended to:

“consolidate and incorporate into one document, decommissioning principles, Canadian and international decommissioning experience, international guidance and regulatory

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expectations that could be applied to the decommissioning of all facilities and sites where nuclear substances were used or stored.

The Standard is consistent with and supplements current Canadian policy and regulatory guidance as follows:

- *CNSC Regulatory Policy P-290, Managing Radioactive Waste (July 2004)*
- *CNSC Regulatory Guide G-219, Decommissioning Planning for Licensed Activities (June 2000)*
- *CNSC Regulatory Guide G-206, Financial Guarantees for the Decommissioning of Licensed Activities (June 2000) “*

The CSA N294 standard also references other CSA nuclear standards including CSA N286 (Management system requirements for nuclear facilities) which may also be included in a licence through a licence condition.


CSA Standards can include both normative (mandatory) and informative (non-mandatory) clauses. A user of a CSA standard is not obliged to follow the recommendations or advice given in informative clauses in order to comply with the standard.

3.2. Comparison of Canadian Practice with IAEA Requirements

The IAEA has published IAEA Safety Requirements WS-R-5 (Decommissioning of Facilities Using Radioactive Material) [3] in order to “establish the basic safety requirements that must be satisfied during the planning and implementation of decommissioning for the termination of practices and for the release of facilities from regulatory control.”

A comparison of Canadian Statutes, Regulations, common Licence Conditions, Regulatory Documents, Codes and Standards to selected clauses of IAEA Safety Requirements WS-R-5 [3] is shown in Appendix A.9 in Table 12. Many of the basic safety requirements set out in IAEA Safety Requirements WS-R-5 are addressed by Canadian Statutes, Regulations, Licence Conditions, Regulatory Documents, Codes and Standards either explicitly or implicitly. The potential gaps that were identified are summarized in **Error! Reference source not found..**

A number of gaps identified in Table 12 are addressed in either CSA N294-09 [6] or in the amendment that is expected to be published in 2014 but many are addressed in either informative clauses of the standard or in annexes to the standard which are also informative. As a result, a licensee would not be required to meet these requirements in order to comply with a licence conditions that mandates compliance with the CSA standard (unless compliance with those clauses was explicitly required by the licence condition).

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3.3. Comparison with the Regulatory Framework in Other Countries

Summaries of the Regulatory Framework for the decommissioning of nuclear power plants in Canada, Finland, France, Germany, Italy, Sweden, United Kingdom and the United States are given in Appendices A.1 through A.8.


A comparison of Canadian Statutes, Regulations, common Licence Conditions and Regulatory Documents to those of seven other countries (Finland, France, Germany, Italy, Sweden, United Kingdom and the United States) is shown in Appendix A.9 in Table 11.

3.3.1. Previous Review by Thierfeld, Hans, Holli & Podlaha (2006)

In 2006, the European Commission published “Inventory of Best Practices in the Decommissioning of Nuclear Installations - Final Report” [52] which was prepared by S. Thierfeldt, P. Hans & M. Holli of Brenk Systemplanung GmbH (Germany) and J. Podlaha of the Nuclear Research Institute Řež plc (Czech Republic) on behalf of the European Commission. The aim of this project was to “To create an information bank gathering the real and most updated experience from ongoing and completed decommissioning projects, identifying the best practices, the critical path and the milestones of the projects”. The review examined decommissioning experience and planning for 61 nuclear facilities (51 power reactors, 4 research reactors, 2 submarine reactors, 2 fuel reprocessing plants, a fuel fabrication plant and an isotope processing plant) in 15 member countries of the European Union with respect to:

- Decommissioning strategy and reasons for choosing this strategy:
- Management of fresh and spent fuel:
- Planning for decommissioning and project management at different phases:
- Technological key choices:
- Waste management:
- Clearance / release of materials, buildings and sites;
- Industrial safety and Required skills;
- Control of costs;
- Human factors, social issues and local economic impact; and
- Stakeholder involvement, communication policy.

Most of this review is focused on the management and execution of nuclear decommissioning projects (particularly during the early stages) but the findings on “Decommissioning strategy and reasons for choosing this strategy” are relevant to this review. Section 5.2 of the report is quoted at length below (some paragraphs and tables that discuss specific countries or decommissioning

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projects have been omitted and these are denoted by ‘...’). However, some of the findings of this review have been superseded by more recent events.

“5.2 Decommissioning Strategy and Reasons for Choosing this Strategy

5.2.1 Introduction

The two basic decommissioning strategies which are pursued in EU Member States are:

- *early or immediate decommissioning and*
- *deferred decommissioning*

They have been implemented in various ways. There are examples of decommissioning projects that have started immediately after final shutdown with the steady progress towards green field conditions, other examples for deferred decommissioning with a safe enclosure of the nearly unaltered plant and a safe enclosure period of several decades, as well as examples for deferred decommissioning with partial dismantling and a safe enclosure of the reactor building only. In the following sections, in overview is given on the strategies which are pursued in the various countries and their relation with driving factors for choosing these strategies. As there are obvious differences in the driving factors for nuclear power plants, research reactors [sic] and fuel cycle facilities, mainly caused by the activity inventory, the decay characteristics of the leading nuclides and the resulting development of dose rate versus time, the three categories of facilities are discussed separately.

5.2.2 Nuclear Power Plants


...

Nevertheless, Table 5.2–1 shows a general tendency towards the immediate or early decommissioning strategy. This observation is corroborated by the fact that the power utilities in Italy, the United Kingdom as well as France - all countries where centralised decisions are taken on the strategy of all or at least a group of plants - have changed their earlier strategies of deferred decommissioning, in some cases with extremely long planned periods of safe enclosure (in the UK up to 30 plus 100 years), to early decommissioning. This is also the preferred option in other countries with a major decommissioning programme like Germany.

...

Exceptions from the early decommissioning strategy prevail in cases where there is no suitable waste disposal route or where the construction of interim storage facilities shall be avoided (Spain and Sweden are examples).

With the exception of those cases where there is one major driver (like the absence of the disposal route for graphite in Spain), the main driving factors which are usually named are economic reasons and employment. The decision for a certain decommissioning strategy has

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always been based on evaluation of various options (see also section 5.9 on costs). Preservation of the largest possible number of jobs is of course only achievable in the early decommissioning strategy. However, depending on the size of the nuclear programme and on the infrastructure of the power utilities, even deferred decommissioning strategies need not being accompanied by substantial job losses. In addition, the inevitable loss of plant knowledge/expertise in case of deferred decommissioning is also a major driving factor for early decommissioning. The restoration of the site infrastructure necessary for performing dismantling after a long period of safe enclosure is considered to be costly, with the additional uncertainty which technical standards would apply for this step – possibly increased legal requirements in several decades might consume the benefits to be gained from being able to use simpler decommissioning techniques.

On the other hand, several advantages of the deferred decommissioning option are often been named: named: Radioactive decay resulting in potentially smaller dose uptake during dismantling and subsequent waste treatment, lesser amount of RW to be disposed of in repository and more material to be free-released, possible new techniques available on the market.


The comparison of the chosen strategies and the size of the decommissioning programme as well as the availability of a final repository for decommissioning waste shows that there is only a minor influence of both matters on the strategy selection. Obviously, in most cases it is seen as feasible to construct an interim storage site for decommissioning waste if no repository is available rather than postponing dismantling until such a repository becomes available (while this is the general strategy pursued in Germany and also being considered in Italy, the NPP Barsebäck in Sweden forms an exception).

When deciding upon the early versus the deferred decommissioning option, especially some of the older nuclear power plants also mention the fact that early decommissioning bears the advantage that a sufficient number of knowledgeable personnel will be available who know the operating history well and may even remember minor incidents which may have led to undocumented contamination. Personnel which has a long operating experience in the particular installation has often proven to provide valuable information facilitating decommissioning. Such personnel would of course no longer be available after a few decades of safe enclosure.

In total, the reasons for selecting a particular strategy for decommissioning depend to a large extent on financial aspects and company interests as well as the specific circumstances in the country rather than on fundamental overarching principles.

5.2.3 Research Reactors

Research reactors [sic] are generally decommissioned within the scope and the financial context of the research establishments, universities, medical installations or industries that

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they belong to. The number of staff is generally small in comparison to nuclear power plants, and the employees can readily be relocated to other jobs in the research establishment if necessary. Therefore, decommissioning strategies range from early decommissioning over conversion into facilities for other purposes after partial dismantling to deferred dismantling within the timeline of the research establishment in which the reactor is situated.

The research reactors which have been included in the study show no uniform picture concerning dependence of the decommissioning strategy on driving factors for strategy selection. This also has to be viewed in the light of the fact that research reactors are usually funded by the state and that decommissioning is paid for from the current state budget. The selection of a decommissioning strategy for research reactors therefore is generally driven mainly by financial resources as well as by political decisions. Because of the comparatively low amount of decommissioning waste, the availability of a repository is generally no pre-requisite for decommissioning, as is shown by the examples of Germany and Denmark. On the other hand, the deferred decommissioning option has been chosen for the Paldiski RRs in Estonia mainly because of decommissioning costs.

5.2.4 Fuel Cycle Facilities


The strategy for decommissioning of fuel cycle facilities is generally early decommissioning, as there is no benefit from radioactive decay by a waiting time in safe enclosure. This fact is demonstrated by the decommissioning of the reprocessing plants Eurochemic in Belgium and WAK in Germany as well as by the fuel production plants in Germany. However, the time required for performing the dismantling operations may be quite long, depending on the availability of funds and a waste route (including clearance) for alpha emitting waste.

5.2.5 Conclusions – Best Practice

To make recommendations as to which decommissioning strategy should best be implemented for a particular decommissioning project is beyond the scope of this study, as it would have to evaluate the circumstances of each particular case and would touch upon politics and internal decisions of EU Member States. After all, the responsibility for the choice of the decommissioning strategy lies predominantly with the operator of the nuclear or the body that is responsible for implementing decommissioning.

However, it is nevertheless possible to summarize the main driving factors that have led decommissioning projects to choose the early decommissioning strategy or that have caused a switch from the deferred to the early decommissioning strategy or have led to shortening of the enclosure period:

- *Deferred dismantling may impose burdens on future generations.*
- *There will be costs associated with conservation of the plant infrastructure and equipment during safe enclosure. The costs will increase in more than a linear*

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manner in time because some maintenance and overhauls will be required for the systems under operation in the safe enclosure. In addition, expensive replacement of infrastructure will be necessary at the begin of dismantling operations after a long waiting period.

- *There could be legislative and financial uncertainties associated with long-term deferral periods. The regulatory framework may change and money accumulated in decommissioning funds may become devalued relative to the decommissioning costs due to the effect of general inflation or even an unforeseen economic crisis, or due to the fact that unforeseen investments have to be undertaken after the waiting period because stricter legislative requirements have entered into force.*
- *The availability of qualified staff is also an argument in favour of immediate dismantling.*
- *Loss of operational knowledge of the facility is inevitable during a safe enclosure period, regardless how comprehensive and up-to-date the documentation has been. In addition, decommissioning databases and archives may get lost or become illegible over several decades.*
- *A long waiting period will obstruct reuse of the buildings and redevelopment of the site.*
- *In the medium term, the deferred decommissioning option will create no jobs within the local market that could compensate the loss of jobs caused by the shutdown of the nuclear installation.*

These and other arguments may thus construe the early decommissioning strategy or at least the significant reduction of the duration of safe enclosure periods as the best option.”


3.3.2. Previous Review by Bredimas and Nuttall (2008)

In 2008, Alexandre Bredimas and William Nuttall published “A Comparison of International Regulatory Organizations and Licensing Procedures for New Nuclear Power Plants” [5]. Although this review focuses on licensing of new power plants, and it was conducted at a time when several of the countries considered (Canada, France, Germany, Japan, Switzerland, UK & USA) were reorganizing their regulatory system, many of their observations are also relevant to regulation of nuclear power plant decommissioning.

The authors emphasized the importance of public involvement and they noted:

“While most countries only hold one or two public hearings, Canada and Switzerland involve the public more significantly both in terms of the frequency of and the scale of interactions”.

They also noted the Canadian practice of funding interveners in the licensing process as a ‘best practice’:

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“We see merit in the Canadian policy of funding for objectors in the licensing process. Indeed, our research discussions have indicated that there appears to be widespread sympathy for such measures. It is arguable that public inquiries are somewhat unfair, because companies enjoy large financial resources while local interest groups usually only have modest resources.”

Bredimas and Nuttall also emphasized the importance of an independent specialized nuclear regulator and they gave both the CNSC and the US NRC as examples of such a regulatory agency.

“In most countries having a domestic nuclear industry, it seems advisable to have an independent regulator. This ensures to both the public and to environmental groups that nuclear project regulatory decisions are not biased by inappropriate factors.

...

It is also advisable that the nuclear safety regulator be a specialised expert agency. Nuclear power is complex and it raises special political, sociological and technical issues. Such an approach has been chosen by most countries reviewed here.”

Since the time of the Bredimas and Nuttall review, several other countries (e.g.: Sweden, France) have changed their regulatory regime and moved in this direction. They also emphasized the importance of an up-to-date and coherent set of laws covering each aspect of nuclear safety. Although they cited several examples of countries that met this goal (Canada being one of them) their review focused on the licensing of new nuclear power plants rather than the decommissioning of existing nuclear facilities.


Based on their review, Bredimas & Nuttall recommended creation of:

- An independent specialized regulator (they noted the CNSC as an example of such a regulator);
- An efficient licensing process with different licences and prescriptive conditions; and
- An up-to-date and coherent set of laws covering each aspect of nuclear safety (they noted Canada, Germany, Japan and Switzerland as models).

3.3.3. Comparison with Finland, France, Germany, Italy, Sweden and the United Kingdom

In general, the state of the Canadian regulatory system as it relates to the decommissioning of nuclear facilities seems to most closely resemble that in Finland, Italy, Sweden and the United Kingdom. In each of these countries, the statutes, regulations, licence conditions, codes and standards address:

- Planning for decommissioning; and

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- Estimating the cost of decommissioning and providing funding.

However, the statutes, regulations, licence conditions, codes and standards generally do not systematically address the execution of decommissioning or the release of the site following decommissioning. This could be due to:


- Major nuclear facilities have not shut down or progressed significantly with decommissioning implementation (for example, Finland and Sweden); or
- The nuclear facilities that have begun decommissioning were formerly owned by the Government or a government agency and responsibility for the decommissioning has been assigned to a national decommissioning authority (for example, SOGIN in Italy or the NDA in the UK) or to the national agency that operated the facilities (for example, French Atomic Energy Commission (CEA) in France).
 - In Italy, SOGIN is owned by the Ministry of Economy and Finance and operates within guidelines established by the Government;
 - In the UK, the NDA is non-departmental public body and its strategic and annual plans are approved by the Secretary of State for the Department of Energy and Climate Change; and
 - In France, the CEA is public establishment with the status and duties defined in articles L. 332-1 to L. 332-7 of the Research Code.

There may also be a desire in some jurisdictions (e.g. UK) to avoid appearing to overly-direct the operators in their specific technical choices.

3.3.4. Comparison with the United States

The United States has accumulated extensive experience in managing the decommissioning of both civilian nuclear power plants and government-owned facilities related to the production of nuclear weapons. Consequently, the regulatory system (both NRC and DOE) governing the decommissioning of major nuclear facilities is more highly developed in the United States than in any of the other countries considered in this review. Notable elements of the American system for regulating the decommissioning of nuclear power plants that do not have counterparts in the current Canadian regulatory system include:

- Requirements for certain aspects of decommissioning and licence termination of nuclear power plants are explicitly addressed in the Regulations, for example:
 - 10CFR20 Subpart E establishes the ‘*radiological criteria for license termination*’; and
 - 10CFR52 Subpart C (parts 52.109 and 52.110) establishes licensing activities and milestones for nuclear power plants issued a ‘*combined license*’;

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- NRC Regulatory Guide 1.184 [4] provides further guidance on the actions required of nuclear power reactor licensees to meet the regulatory requirements related to decommissioning nuclear power reactors;
- Several NUREG documents provide technical advice on issues related to decontamination, dismantling and site remediation;
- Extensive guidance on the development of release criteria, planning of pre-release surveys and decision making for the release of lands, buildings and materials are available in the Data Quality Objectives, MARSSIM and MARSAME publications from the NRC, EPA and other federal agencies.


In general it was observed that the United States provides more detailed guidance to nuclear power plant operators than is the practice in most other countries. A comparison between IAEA Safety Requirements WS-R-5 (Decommissioning of Facilities Using Radioactive Material) and the other countries Statutes, Regulations, Codes and Standards was not conducted during this review. However, in the United States, the section of NRC Regulatory Guide 1.184 (Decommissioning of Nuclear Power Reactors, Rev. 1, October 2013) [4] entitled “Harmonization with International Standards” states:

“IAEA Safety Standards WS-R-5 “Decommissioning of Facilities Using Radioactive Material,” (Ref. 15), and WS-G-2.1 “Decommissioning of Nuclear Power Plants and Research Reactors” (Ref. 16), provide useful information on decommissioning and their principles have been incorporated into this guide. The difference between this guide and the IAEA safety standards is that the latter are generic in nature whereas this guide provides direct linkage to NRC regulations.”

Based on the results of this review, it does appears that the regulatory system applicable to the decommissioning of nuclear power plants in the United States has addressed all or most of the gaps between the Canadian regulatory system and the requirements of IAEA Safety Requirements WS-R-5 that were noted in **Error! Reference source not found..**

4. Potential Gaps in the Canadian Regulatory System

In general, the Canadian regulatory system as it relates to the decommissioning of nuclear power plants is similar to the regulatory system of most of the other countries that were reviewed (and particularly those of Finland, Italy, the UK and Sweden) in that it primarily addresses planning for decommissioning, estimating the cost of decommissioning and assuring that funding will be available but it does not extensively address the execution or completion of decommissioning.

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4.1. Decommissioning Strategy

Although the CSA does not formally define the term ‘decommissioning strategy’ (nor does the IAEA), Section 6.1.1 of CSA N294-09 recommends (but does not require) that:

A decommissioning strategy should be developed early in the life cycle of a facility and should be reviewed and updated as new information is obtained. The strategy should contain a high-level approach and rationale for decommissioning the facility, which will be further developed in decommissioning plans (which might require approval by the regulatory authority).

Section 6.1.2 of the standard goes on to recommend that the decommissioning strategy should be “*should be based on one or a combination of*” prompt decommissioning, deferred decommissioning or in-situ confinement while Section 6.1.3 recommends a number of factors that should be considered in the selection of a decommissioning strategy but they standard does not require or recommend the adoption of any particular strategy.

Similarly, Section 6.1.1 of CNSC Regulatory Document G-219 (Decommissioning Planning for Licensed Activities) [17] requires that a Preliminary Decommissioning Plan:

“... document a preferred decommissioning strategy which, in light of current knowledge, represents a technically feasible, safe and environmentally acceptable approach ...”.


However, G-219 does not provide any guidance on which particular decommissioning strategies may be acceptable or preferred.

Section 4.2 of IAEA Safety Requirement WS-R-5 [3] requires:

“The preferred decommissioning strategy shall be immediate dismantling. There may, however, be situations where immediate dismantling is not a practical strategy when all relevant factors are considered.”

In Italy, the Ministry of Industry, Commerce and Crafts (now Ministry of Economic Development) issued a strategy document in 1999 that mandate ‘adoption of the strategy for an immediate decommissioning (IAEA level 3) of all national shut-down nuclear installations’ thus abandoning the previous “safe storage” strategy. In France, French Nuclear Safety Authority (ASN)’s preferred decommissioning strategy is ‘Prompt Decommissioning’ however there is no regulatory requirement. The majority of US nuclear facilities that have been decommissioned have adopted an immediate dismantling strategy but the lack of disposal facilities means that, in many cases, the used fuel remains in a licensed ‘Independent Spent Fuel Storage Facility’ on the site. Even in countries that have not expressed a preference for ‘immediate dismantling’, there has often been a move toward immediate dismantling or shorter deferral periods.

Recommendation:

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Licensees should be provided with guidance on the preferred or acceptable strategic approaches to decommissioning. It is recommended that this guidance should be consistent with the IAEA recommendation that “The preferred decommissioning strategy shall be immediate dismantling. There may, however, be situations where immediate dismantling is not a practical strategy when all relevant factors are considered.”

4.2. In Situ Confinement

Clause 6.1.2 of CSA N294-09 [6] identifies ‘In-Situ Confinement’ as a possible decommissioning strategy. IAEA also recognize this strategy (called Entombment by the IAEA) which IAEA Safety Reports Series No 50 [3] describes as:

Entombment is the strategy in which the radioactive contaminants are encased in a structurally long lasting material until the radioactivity decays to a level that permits release of the facility from regulatory control. The fact that radioactive material will remain on the site means that the facility will eventually become designated as a near surface waste disposal site and criteria for such a facility will need to be met.


IAEA Safety Series Report No 50 goes on to advise:

Entombment is not relevant for a facility that contains long lived isotopes because these materials are not suitable for long term surface disposal. Consequently, reprocessing facilities, fuel fabrication facilities, enrichment facilities or facilities that use or process thorium or uranium would not be appropriate for entombment. However, entombment could be a viable option for other nuclear facilities containing only short lived or limited concentrations of longlived radionuclides, i.e. in order to comply with the site release criteria.

The ‘In-Situ Confinement’ strategy has not been adopted for nuclear power plants nor is it generally identified as an acceptable strategy (e.g.: the Strategic Environmental Assessment prepared for the UK national Decommissioning Authority does not identify ‘In-Situ Confinement’ as a ‘credible’ strategy).

In-situ confinement has been adopted at US Department of Energy sites for the decommissioning of:

- Two large reactors (P- and R-reactors) and their ancillary facilities at the Savannah River Site near Augusta, Georgia;
- Two fuel processing facilities including Buildings 601/640 at the Idaho National Laboratory near Arco, Idaho and the U Canyon at the Hanford site near Richland, Washington; and

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- The below grade portion of several small reactors facilities at Idaho National Laboratory and one at the Savannah River Site [51].

Recommendation:

Licensees should be provided with clear guidance on if (or when) it would be acceptable to base decommissioning plans on an ‘In-Situ Confinement’ decommissioning strategy

4.3. Notification of Permanent Shutdown

Section 3.8 of IAEA Safety Requirement WS-R-5 [3] defines the responsibilities of the Operator of a nuclear facility with regard to decommissioning and those responsibilities include:

“Notifying the regulatory body prior to shutting down the facility permanently or terminating the activity”.

Clause 7.2 and 7.3 of CSA N294-09 [6] advises:

“7.2 Notification

Early discussion of the impending decommissioning should be held with the regulatory authority to ensure a smooth transition from operation to decommissioning. As a general rule, the regulatory authority should be notified in writing of the intent to decommission, as follows:

(a) for a planned permanent cessation of operations, no later than one year before the planned cessation; and


(b) for an unplanned permanent cessation of operations, as soon as is practical.

7.3 Permanent shutdown

A permanent shutdown date should be identified as early as possible. This date will prompt discussion with the regulatory authority and assist in the development of the final decommissioning plan.”

Both of these Clauses are informative so compliance with the standard would not require that these notifications be made.

The US Code of Federal Regulations (10 CFR 50.82(a)(1)(i)) [8] requires that a licensee who has determined, or is required to permanently cease operations must submit written certification to the NRC within 30 days of the decision or requirement to permanently cease operations.

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There does not appear to be a requirement in any of the CNSC regulatory documents that explicitly addresses the requirements for a prolonged/long term shutdown. SOR-2000-202 (General Nuclear Safety and Control Regulations) discusses the cases for amendment of an existing licence; a licensee having a licence to operate would need to amend their licence if they were no longer carrying on the licensed activities. As a result, they would have to inform the CNSC and also demonstrate that the new state of the plant would remain enveloped by the existing safety case.

Recommendation:

Licensees should be required to give formal notice of permanent shutdown in advance of, or within a reasonable time after permanent shut down for decommissioning.

Note: It is understood that the CNSC has added an additional condition to the Licence to Operate of certain reactor facilities that would require those facilities to submit an ‘end of life’ plan which may address this issue.

4.4. Order to Decommission

The United Kingdom Office of Nuclear Regulation has begun including a standard Licence Condition (LC35) [9] related to decommissioning into all major nuclear facility licences. One of the requirements of this Licence Condition is:


“6 The licensee shall, if so directed by the Executive where it appears to them to be in the interests of safety, commence decommissioning in accordance with the aforesaid arrangements and decommissioning programmes.”

Similarly, the U.S NRC has the power to issue an “order to permanently cease operations” .

It is possible that Section 25 of the Nuclear Safety & Control Act could permit the CNSC to take similar action:

25. The Commission may, on its own motion, renew, suspend in whole or in part, amend, revoke or replace a licence under the prescribed conditions.

It is also believed that, if necessary, Section 24(6) would authorize the CNSC to apply the financial guarantee that was provided to perform the decommissioning. It is not clear which agency would be responsible for performing the decommissioning in the event that the operator is unwilling or unable to perform that work. However, it is noted that all of the major nuclear facilities in Canada are currently owned by Crown Corporations or similar organizations so this issue is more likely to involve a Class IB nuclear facility.

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Recommendation:

The power of the CNSC to order a facility to decommission and the responsibility for performing the decommissioning in the event that the owner/operator is unwilling or unable to perform the work should be clarified.

4.5. Transition from Operations to Decommissioning

The CNSC Fact Sheet entitled “Decommissioning of Nuclear Power Plants” (dated October 2012) [7] states:


“Under a normal operating licence, the operator can place the nuclear facility into safe storage, if it so wished, as an initial step to decommissioning.”

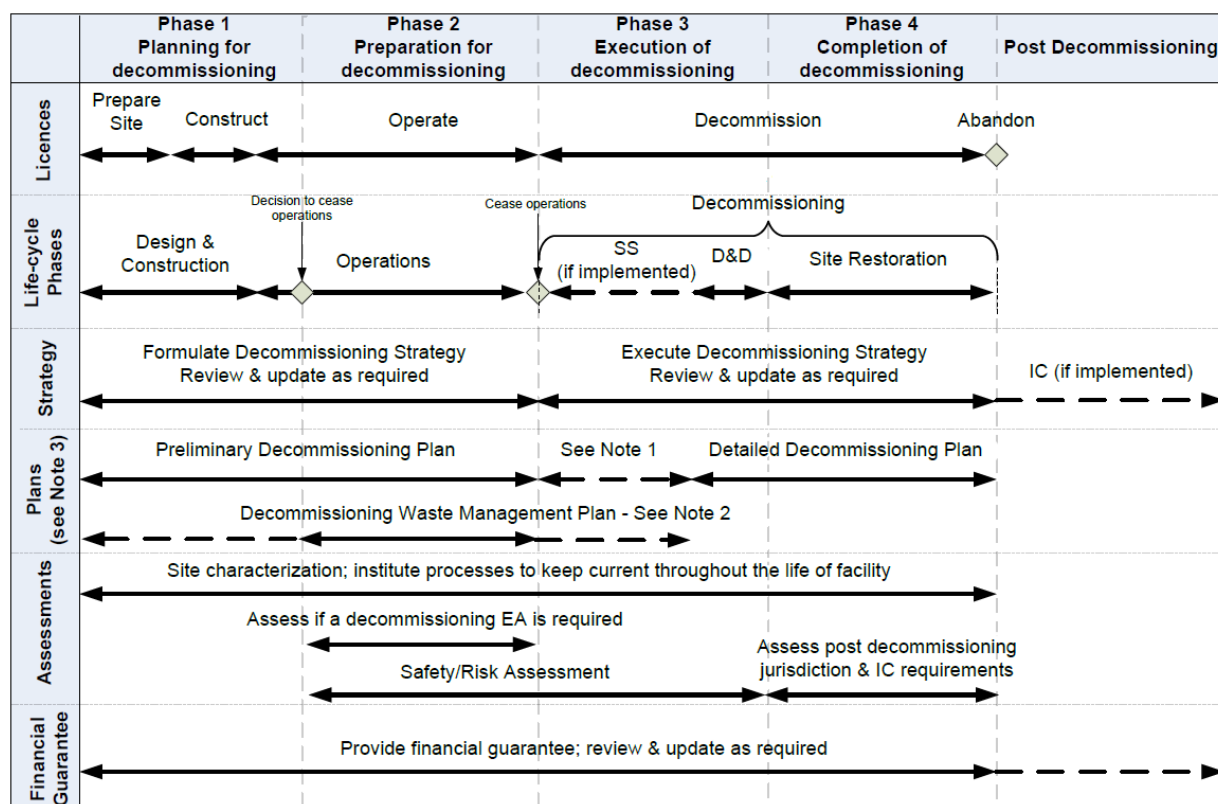
Figure 1 below, taken from Clause 5 of the proposed amendment to CSA N294-09 [6] shows that:

- The boundary between Phase 2 (Preparation for Decommissioning) and Phase 3 (Execution of Decommissioning) is the beginning of “Storage with Surveillance (if implemented)”.
- The activities in Phase 2 (Preparation for Decommissioning) are performed under a Licence to Operate while the activities in Phase 3 are performed under a Licence to Decommission.

Clause K.4.1.1 (Preparation for, and placing the reactor in safe storage, Final shutdown for decommissioning) of Annex K (Decommissioning requirements for high energy reactor facilities) of the proposed amendment to CSA N294-09 provides further guidance of the transition but Annex K of the Standard is informative rather than normative.

Consequently, it appears that there is consensus among regulators and industry on the beginning of ‘decommissioning’. But Clause 5 of the Standard is informative rather than normative so this figure is not a mandatory part of the Standard and the Regulations are currently silent on when ‘Operations’ ends and ‘Decommissioning’ begins.

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Notes:

- Note 1: If a SS stage is implemented, a Detailed Decommissioning Plan shall be submitted prior to D&D
- Note 2: May be a stand-alone document or part of the Detailed Decommissioning Plan
- Note 3: Time interval shown denotes the applicability of the plans and not the time when they are developed.

Legend:

- : identifies when the activity may be performed
- : identifies when an optional activity may be performed if required

Acronyms:

- D&D – Dismantling and Demolition
- EA – Environmental Assessment
- IC – Institutional Controls
- SS – Storage with Surveillance


Figure 1 Phases of Decommissioning (from amendment to CSA N-294-09)

(Figure included by permission of the Canadian Standards Association)¹

Recommendation:

A definition of the activities that may be performed under a Licence to Operate in anticipation of decommissioning should be provided.

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4.6. Planning for Storage with Surveillance

Regardless of whether ‘storage with surveillance’ is considered as part of ‘operations’ or ‘decommissioning’, there will be a need to develop plans for both the transition to storage with surveillance and for the storage with surveillance period itself. Section 5.3 and 5.4 of Draft CNSC Regulatory Document RD/GD-360 (Life Management of Nuclear Power Plants) Version 2 (July 2012) [13] describes the proposed requirement for a ‘Preliminary Decommissioning Plan’ and a ‘Decommissioning Plan’ respectively for a nuclear power plant.

RD/GD-360 refers to a ‘Safe State of Storage’ or ‘SSS’ which is defined as:

Strategy in which a facility or site is placed into a safe condition and in which decontamination and dismantling are delayed for up to 50–60 years (known as the safe enclosure period). ... During this time, a surveillance and maintenance programme is implemented for the facility.

Section 5.3 (Preliminary Decommissioning Plan) would require:

“If the licensee intends to defer decommissioning the NPP, the licensee shall update the preliminary decommissioning plan (PDP) to provide a clear strategy of entering the SSS.”

This appears to be compatible with the approach described in Figure 1 of the proposed CSA N294-14. Section 5.3.1 of the draft RD/GD-360 requires that:


“As part of the PDP, the licensee shall describe the arrangements and activities that will be conducted to ensure the safe transition of the NPP reactor unit(s) from a final shutdown state to the SSS. The licensee shall include information on the NPP configuration during safe storage phase and the tasks and processes to implement this configuration.”

Section 5.3.2 of the draft RD/GD-360 then requires:

“As part of the PDP, the licensee shall describe the arrangements and activities required to ensure maintenance of the SSS and its surveillance during the period of deferment prior to final dismantlement and decommissioning of the NPP. “

It is not clear that the requirements of Section 5.3.1 and 5.3.2 of RD/GD-360 are completely consistent with the guidance on the content of a Preliminary Decommissioning Plan given in Section A.2 of CSA N294-09 although neither are they clearly contradictory. This ambiguity between the two sources of guidance is likely to create confusion.

Although it is not explicitly required by either draft Regulatory Document RD/GD-360 or CSA N294-09, it has become a common practice for Canadian licensees to document the results of the stabilization activities in an Interim End State Report. The CSA N294-09 standard does not provide any guidance on the content of an Interim End State Report but it does provide guidance

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on the content of a Final End State Report (Annex D of CSA N294-09) and some licensees have used this guidance (with the modifications they believed appropriate) as the basis for an Interim End State Report.

The Electric Power Research Institute (EPRI) has also recommended that a Characterization Report should be produced to describe the state of the facility at the end of operations or each stage of decommissioning. This approach is consistent with MARSSIM but it is not required by draft Regulatory Document RD-360. Some licenses have produced Characterization Reports of some type (usually based on the MARSSIM guidance) while others have included this information in the Interim End State Report.

Recommendation:

1. Guidance on the Stabilization Activities and Storage and Surveillance Activities given in RD/GD-360 should be consistent with the guidance given in the CSA N294 standard. This may require revision of RD/GD-360, CSA N294-09 or both.
2. Guidance on the content of a Storage with Surveillance Plan should be provided although this guidance could also be included in an amendment of the CSA N294 standard.
3. Guidance on the content of an Interim End State Report (and a Characterization Report if that will be a separate document) should be provided although this guidance could also be included in an amendment of the CSA N294 standard

4.7. Submission of a Detailed Decommissioning Plan

Section 7 of the Class I Nuclear Facilities Regulations requires that:


An application for a licence to decommission a Class I nuclear facility shall contain the following information in addition to the information required by section 3:

(a) a description of and the proposed schedule for the decommissioning, including the proposed starting date and the expected completion date of the decommissioning and the rationale for the schedule;

(b) the nuclear substances, hazardous substances, land, buildings, structures, systems and equipment that will be affected by the decommissioning;

(c) the proposed measures, methods and procedures for carrying on the decommissioning;

(d) the proposed measures to facilitate Canada's compliance with any applicable safeguards agreement;

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(e) the nature and extent of any radioactive contamination at the nuclear facility;

(f) the effects on the environment and the health and safety of persons that may result from the decommissioning, and the measures that will be taken to prevent or mitigate those effects;

(g) the proposed location of points of release, the proposed maximum quantities and concentrations, and the anticipated volume and flow rate of releases of nuclear substances and hazardous substances into the environment, including their physical, chemical and radiological characteristics;

(h) the proposed measures to control releases of nuclear substances and hazardous substances into the environment;

(i) the proposed measures to prevent or mitigate the effects of accidental releases of nuclear substances and hazardous substances on the environment, the health and safety of persons and the maintenance of national security, including an emergency response plan;


(j) the proposed qualification requirements and training program for workers; and

(k) a description of the planned state of the site on completion of the decommissioning.

Clause 7.8 of CSA N294-09 [6] provides guidance on the ‘Final Decommissioning Plan’ which is described in Clause 7.81 as:

“The final decommissioning plan specifies the detailed work program, safety and environmental protection procedures, and management systems to be followed during decommissioning. The final decommissioning plan generally involves refining and developing procedures for the work packages established in the initial decommissioning plan. For a nuclear facility or a uranium mine or mill, the final decommissioning plan takes the form of a formal DDP.”

The current standard does not provide any requirement or guidance on when the Final Decommissioning plan is to be submitted but Figure 1 taken from Clause 5 of the proposed amendment to CSA N294-09 shows that a Detail Decommissioning Plan is submitted during Phase 3 (Execution of Decommissioning) and Note 1 to the Figure states:

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“If a SS stage is implemented, a Detail Decommissioning Plan shall be submitted prior to D&D”

Figure 1 also shows that all of the work in Phase 3 (including the Storage with Surveillance) is performed under the authority of a Licence to Decommission.

Section 5.10 of IAEA Safety Requirement WS-R-5 [3] requires:

“Prior to the implementation phase of decommissioning activities, a final decommissioning plan shall be prepared and submitted to the regulatory body for approval. This plan shall define how the project will be managed, including: the site management plan, the roles and responsibilities of the organizations involved, safety and radiation protection measures, quality assurance, a waste management plan, documentation and record keeping requirements, a safety assessment and an environmental assessment and their criteria, surveillance measures during the implementation phase, physical protection measures as required, and any other requirements established by the regulatory body.”

The US Code of Federal Regulations does not use the term Detailed Decommissioning Plan but 10 CFR 50.82(a)(4)(i) [8] requires that the licensee submit a Post-Shutdown Decommissioning Activities Report (PSDAR) prior to or within 2 years following the permanent cessation of operations. The PSDAR will include a description of the licensee’s planned decommissioning activities, with a schedule for the accomplishment of significant milestones and an estimate of expected costs. Further guidance of the format and content of the PSDAR is provided in Regulatory Guide 1.185, “Standard Format and Content for Post-Shutdown Decommissioning Activities Report” [10].


It appears that the intended Canadian practice is closer to that recommended by the IAEA than that adopted by the NRC, however it is not clear that the current CSA Standard (with its proposed amendment) is completely consistent with the requirements of the Class I Nuclear Facilities Regulations.

Recommendation:

The schedule for submission of a Detailed Decommissioning Plan should be clarified.

4.8. Duration of Decommissioning

Clause 6.1.2 of CSA N294-09 [6] provides guidance on the factor to be considered when selecting a decommissioning strategy but neither the CSA N294-09 standard or the proposed amendments to that standard provide guidance on the maximum duration of a storage with surveillance period. It is noted that the storage with surveillance period for some Canadian reactors has already exceeded 30 years but this is generally due to the desire to coordinate with

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other decommissioning projects, the lack of disposal facilities or other factors wholly or partly beyond the control of the operator.

The US Code of Federal Regulations (10CFR52.110(c)) [11] requires:

“Decommissioning will be completed within 60 years of permanent cessation of operations. Completion of decommissioning beyond 60 years will be approved by the Commission only when necessary to protect public health and safety. Factors that will be considered by the Commission in evaluating an alternative that provides for completion of decommissioning beyond 60 years of permanent cessation of operations include unavailability of waste disposal capacity and other site specific factors affecting the licensee's capability to carry out decommissioning, including presence of other nuclear facilities at the site.”

It does not appear that there are countries that have adopted similar limits but it does appear that there is a trend toward more timely decommissioning where that is practical.

Recommendation:

Guidance on the duration of decommissioning should be provided.

4.9. Completion of Decommissioning

Section 8 of the Class I Nuclear Facility Regulations [12] defines the requirements for an application for a Licence to Abandon as:

An application for a licence to abandon a Class I nuclear facility shall contain the following information in addition to the information required by sections 3 and 4 of the General Nuclear Safety and Control Regulations:


(a) the results of the decommissioning; and

(b) the results of the environmental monitoring programs.

However, the section does not consider the possibility of the imposition of institutional controls or release for restricted use.

The figure in the proposed amendments to CSA N294-09 (see Figure 1) allows for the possibility of a period of institutional controls following the issuance of a License to Abandon. Annex H of the proposed amendments to CSA N294-09 also allows for the possibility of ‘restricted use’ but the standard does not define either ‘institutional controls’ or ‘restricted use’. The IAEA defines ‘institutional controls’ as:

Control of a radioactive waste site by an authority or institution designated under the laws of a State. This control may be active (monitoring, surveillance,

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remedial work) or passive (land use control) and may be a factor in the design of a nuclear facility (e.g. near surface repository).

- *Most commonly used to describe controls over a repository after closure or a facility undergoing decommissioning.*
- *Also refers to the controls placed on a site that has been released from regulatory control under the condition of observing specified restrictions on its future use to ensure that these restrictions are complied with.*
- *The term institutional control is more general than regulatory control (i.e. regulatory control may be thought of as a special form of institutional control). In particular, institutional control measures may be passive, they may be imposed for reasons not related to protection or safety (although they may nevertheless have some impact on protection and safety), they may be applied by organizations that do not meet the definition of a regulatory body, and they may apply in situations which do not fall within the scope of facilities and activities. As a result, some form of institutional control may be considered more likely to endure further into the future than regulatory control.*


The second note to this definition would suggest that ‘institutional control’ and ‘restricted use’ have the same meaning.

Clause 10.1 (Institutional Controls Following Decommissioning - General) of CSA N294-09 [6] requires:

“The party responsible for decommissioning shall identify the applicable institutional control requirements following decommissioning as well as the available administrative processes in the jurisdiction in which they are located.”

Clauses 10.2 and 10.3 provide further guidance on the type and duration of institutional controls and the protective measures that should be implemented but it does not specify whether institutional controls are to precede or follow the issuance of a License to Abandon.

In Saskatchewan, the province has enacted The Reclaimed Industrial Sites Act and issued The Reclaimed Industrial Sites Regulations to establish and enforce an Institutional Control Program (ICP) administered by the Ministry of Energy and Resources. As of March 31, 2012, five decommissioned uranium mines which are all part of the Beaverlodge mine and mill complex near Uranium City, SK have been accepted into this program [53]. These five sites were accepted into the program following a decision by the Canadian Nuclear Safety Commission (CNSC) to exempt them from licensing and release them into the Saskatchewan's Institutional Control Program. Consequently, these sites do not provide any clarification as to whether or not a period of institutional controls would precede or follow issuance of a License to Abandon.

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Annex H of the proposed amendments to CSA N294-09 allows for the possibility of restricting the future use of a site following decommissioning but it refers the user to other agencies for further guidance. If this restriction is to follow issuance of a license to abandon then it is likely that it would be administered by the Provinces (which would be involved in the decision in accordance with the various Memorandum of Understanding between the CNSC and the Provinces).

In Ontario, the ‘Records of Site Condition — Part XV.1 of the Act’ Regulations (Ontario Regulation 153/04) provides a procedure for restricting the future use of lands that may be affected by residual contamination from a previous activity. The Ministry of the Environment has issued guidance on for assessing the environmental condition of a site, the cleanup of brownfield sites and the filing of records of site condition in Ontario’s Environmental Site Registry.

Recommendation:

The acceptability of institutional control or restricted release following issuance of a License to Abandon and the procedures for implementing them should be clarified.


5. Decommissioning Regulatory Good Practices

Most of the decommissioning lessons learned available are technically driven. The IAEA, through CONNECT and the IDN provide discussion of lessons learned, but these are primarily technical and not necessarily regulatory lessons learned.

The NRC maintains a collection of ‘Decommissioning Lessons Learned’ that is accessible through the NRC webpage (<http://www.nrc.gov/waste/decommissioning/lessons-learned.html>). This webpage was last reviewed/updated in December 2013 but all of the entries are dated 2007 or earlier and the majority of the entries relate to technical aspects of decommissioning.

In 2006 there was an IAEA conference pertaining to lessons learned in decommissioning and the summary of the proceedings [2] states that some of the regulatory lessons learned by the NRC include:

- *“Communications — Early and frequent discussions between NRC staff and licensees are encouraged during the planning and scoping phase in support of the preparation of the Decommissioning Plans (DPs) or Licence Termination Plans (LTPs);*
- *Groundwater — Additional environmental monitoring data may be needed because there may not be enough operational environmental monitoring of groundwater for adequate site characterization and dose assessments;*


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- *Inspections — ‘In process’ inspections are more efficient than ‘one time’ confirmatory surveys;*
- *Flexibility — Continued communications between NRC staff and the licensee during the staff’s review is encouraged — to help the licensee take full advantage of the inherent flexibility in NUREG-1575, ‘Multi-Agency Radiation Survey and Site Investigation Manual,’ and NUREG-1727, ‘NMSS Decommissioning Standard Review Plan’;*
- *Modelling Issues — The submittal of assumptions and justifications for the parameter values used in developing site-specific derived concentration guideline levels (DCGLs) and in the application of those DCGLs is encouraged;*
- *Decommissioning Cost Estimate — The discussion should include the relationship between the planned decommissioning activities and the associated updated cost estimate;*
- *Records — Old records should not be used as the sole source of information for the historical site assessment/site characterization, because these old records may be inadequate or inaccurate;*
- *Classifications of Survey Units — DPs and/or LTPs should be submitted only after sufficient site characterization has take place;*
- *Embedded Piping — Some LTPs and DPs contain an inadequate description of the methods that the licensee plans to use when surveying the embedded piping planned to be left behind.”*

There was some discussion in the IAEA document of lessons learned in other countries , but most of the discussion was focused on technical issues.

Some regulatory lessons learned could be derived from the changing of recommendations and regulations such as the change from all decommissioning options considered to the preference for prompt dismantling and other options considered with justification.

Canada’s regulatory oversight in the area of decommissioning currently exemplifies or holds open the opportunity for ready incorporation of a wide range of “good practices” evolving in the international community. This is facilitated by a flexible, non-prescriptive structure and process that aims to inform and guide decommissioning. This structure encourages the application of continuous improvement in technology and practice while avoiding the imposition of normative requirements where these may be difficult to apply and/or result in unforeseen consequences. Nevertheless, a number of potential opportunities to improve on the “status quo” have been identified in this study, including:

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- Preferred decommissioning strategies

While stopping short of prescribing prompt decommissioning, the French regulator, amongst others, clearly states the rationale and preference for this strategy. Similarly, the option of abandoning facilities in place has little support, and is seen as an acceptable option only in very limited circumstances. As more facilities are decommissioned around the world, the need for criteria and guidelines for partial release of sites is becoming ever more apparent. Delays to disposal in-service in the US, UK and elsewhere have made completion of decommissioning and site release impractical. Partial release of sites or the re-purposing of a major portion of the originally licensed site (as for Vandellós, Spain) is increasingly valued.

- Clear definition of decommissioning phases


Clear understanding of the purpose, duration and activities comprising the initial decommissioning phases commonly referred to as Transition and “storage with surveillance” is reflected in several national regulatory processes. The UK NDA guidance has resulted in readily understood objectives and goals for generation facilities undergoing decommissioning in both near-and longer-term, while the Nuclear Regulatory Commission (NRC) and the Department of Energy (DOE) guidance provide clarity of expectation for time-frames and associated activities. For decommissioning planning and management of oversight, requiring operators to give advanced notification of the intent to shutdown is an IAEA requirement that has been widely adopted. Furthermore, empowering the regulator to order the decommissioning of a facility, especially where the operator’s intentions may not have not been clearly spelled out, is a desirable option for regulators.

- Well defined waste pathways

Specific guidance on the disposition of wastes generated by decommissioning is a desirable practice. France emphasizes re-use and recycling, which reduce quantities of materials going to disposal, by stipulating acceptance that only those wastes NOT suitable for reuse and recycling may be disposed of. Many of these wastes would be considered Very Low Level Waste (VLLW). The availability of VLLW disposal facilities (as in France) permits operators to optimize decommissioning processes to minimize cost, dose, conventional risk and environmental impacts. Onsite or nearby disposal facilities (Sweden, UK) reduces public dose from waste transportation as well as the public profile of transportation, the risk of transportation incidents and transportation costs.

- Optimization of clearance strategies

The application of waste, facility, and site clearance criteria continue to evolve, and have proven challenging in their application. Emerging best practice will likely involve a combination of strategies such as clearance and VLLW utilization. France aims to avoid inadvertent release of contaminated material by requiring all waste from zoned areas potentially containing such materials to be treated as nuclear waste. Equally effective clearance strategies include using pre-sorting of materials, well defined and controlled large-

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scale monitoring, and a high standard of quality assurance have achieved acceptable results (Germany, Spain). It is important that derivation of criteria be site-specific as far as possible, rather than codified in regulations or standards, to permit criteria to reflect local usage (exposure pathways) and community expectations. In this regard, the US MARSSIM approach offers a versatile, robust tool.

In Canada, guidance on exemption and clearance is currently available in CSA Standard N292.5-11 (Guidelines for the exemption or clearance from regulatory control of materials that contain, or potentially contain, nuclear substances).

- Availability of Technical Expertise to Regulators

Several of the regulators in the reviewed countries use technical organizations to develop their guidance. This offers advantages in the formulation of technical requirements, the range of technical guidance that can be provided, and may improve the perception of independence between operator and regulator. However, careful formulation of the mandate of such organizations is required in order to avoid a proliferation of regulatory documents and overly prescriptive requirements that may rapidly become obsolete.

In Canada, recent practice has been to place greater emphasis on the development of consensus standards under the auspices of the Canadian Standards Association. This has generally relied on a cooperative approach between industry, regulators (both federal and provincial) and other interested parties.


- Decommissioning Funds and Funding

While most countries have adopted the practice of requiring designated funds subject to independent oversight to address decommissioning obligations, the actual practices for management and reporting vary widely. The Canadian practice of maintaining a high-degree of independence between those contributing to the funds and those responsible for oversight appears desirable to avoid the reality (or perception) of interference in the management of the funds. A notable effort to optimize the frequency and depth of reporting can be seen the French practice of requiring brief annual updates in the form of a “letter” between regular, formal fund-status updates.

- Design for decommissioning of new facilities

The IAEA strongly recommends, and many countries including Canada have adopted, a requirement that the measures adopted to facilitate decommissioning be spelled out in licensing documentation supporting all new nuclear facilities. The IAEA and the Organization for Economic Co-operation and Development (OECD) – Nuclear Energy Agency (NEA) have published “checklists” of such features which should be considered for incorporation in future industry and/or regulatory guides.

Section 6.2 (Planning for decommissioning throughout the lifecycle of the facility) of CSA N294-09 currently recommend that “planning for the eventual decommissioning of a facility

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should be an integral part of life-cycle planning” and sections 6.2.2 through 6.2.5 address these issues in greater detail.

6. Conclusions


The Canadian regulatory approach to the planning for decommissioning, decommissioning cost estimating and provision of funds for decommissioning is similar to the approach adopted in most of the other countries considered in this review. Canadian regulators address these matters through a combination of the use of statutory authority granted to the CNSC (financial guarantees), regulations (the requirement to include plans for decommissioning in an application for a Class I nuclear facility licence), regulatory documents (G-206 & G-219), licence conditions and code and standards (CSA N294-09 & CSA N286). Other countries also address these issues through a combination of statutes (Italy), regulations (Italy & the United States), regulatory documents (Finland, Sweden & the United States), licence conditions (United Kingdom), government policy or the policies of national decommissioning agencies (France, Italy & the United Kingdom).

The regulatory system governing the execution and completion of the decommissioning of major nuclear facilities is more highly developed in the United States (both NRC and DOE) than in any of the other countries considered in this review. The UK regulation of decommissioning is carried out effectively in a less-prescriptive manner, similar to that employed in Canada, by placing the onus to demonstrate the appropriateness of approach on a case by case basis. The US, UK, France and Germany all provide relevant models for combining the regulatory oversight interests of multiple agencies. The Canadian regulatory system includes the licensing of decommissioning and the release of nuclear facilities from regulatory control at the end of decommissioning but other issues regarding the execution and completion of the decommissioning are generally only addressed through non-mandatory sections of CSA N294-09 standard.

6.1. Summary of Recommendations

Based on the results of this comparison of Canadian regulatory practice related to the decommissioning of nuclear facilities with IAEA Safety Requirements WS-R-5 (Decommissioning of Facilities Using Radioactive Material) [3] and the practice in Finland, France, Germany, Italy, Sweden, the United Kingdom and the United States, it is recommended that:


1. Licensees should be provided with guidance on the preferred or acceptable strategic approaches to decommissioning. It is recommended that this guidance should be consistent with the IAEA recommendation that “The preferred decommissioning strategy shall be immediate dismantling. There may, however, be situations where immediate dismantling is not a practical strategy when all relevant factors are considered.”

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2. Licensees should be provided with clear guidance on if (or when) it would be acceptable to base decommissioning plans on an 'In-Situ Confinement' decommissioning strategy.
3. Licensees should be required to give formal notice of permanent shutdown in advance of, or within a reasonable time after permanent shut down for decommissioning.
4. The power of the CNSC to order a facility to decommission and the responsibility for decommissioning in the event that the owner/operator is unwilling or unable to perform the work should be clarified.
5. A definition of the activities that may be performed under a Licence to Operate in anticipation of decommissioning should be provided.
6. The schedule for submission of a Detailed Decommissioning Plan should be clarified.
7. Guidance on the acceptable duration of decommissioning should be provided.
8. Guidance on the Stabilization Activities and a Storage and Surveillance Activities given in RD/GD-360 should be consistent with the guidance given in the CSA N294 standard. This may require revision of RD/GD-360, CSA N294-09 or both.
9. Guidance on the content of a Storage with Surveillance Plan should be provided although this guidance could also be included in an amendment of the CSA N294 standard.
10. Guidance on the content of an Interim End State Report (and a Characterization Report if that will be a separate document) should be provided. This guidance could also be included in an amendment of the CSA N294 standard.
11. The acceptability of institutional control or restricted release following issuance of a License to Abandon and the procedures for implementing them should be clarified.

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Appendix A – Decommissioning Overview by Country

A.1. Canada

Twenty-five (25) power reactors have been commissioned in Canada and nineteen (19) of these remain in operation. No power reactors have been decommissioned but:

- 5 are in safe enclosure awaiting decommissioning; and
- 1 is currently being transitioned to safe enclosure.


AECL's Whiteshell Laboratories, including the WR-1 research reactor, is currently being decommissioned under the authority of a Licence to Decommission granted by the CNSC.

Several small research reactors (including the SLOWPOKE-II reactors at the University of Toronto and Dalhousie University) and some other nuclear facilities (Tunney's Pasture Isotope Production Facility and Bruce Heavy Water Plant) have either completed or are nearing completion of decommissioning and a Licence to Abandon has been granted where appropriate. Some other small nuclear facilities located at AECL's Chalk River Laboratories (including the ZEEP and Pool Test Reactors) have been decommissioned under the authority of a Licence to Operate granted by the CNSC.

The status of decommissioning facilities in Canada is provided in Table 3.

Table 3 Status of Decommissioning Facilities in Canada

Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Pickering A Unit 2	CANDU (515 MW)	1997	Deferred Dismantling	2058	Storage with Surveillance	Yes
Pickering A Unit 3	CANDU (515 MW)	1997	Deferred Dismantling	2058	Storage with Surveillance	Yes
Nuclear Power Demonstration (NPD)	CANDU Demonstration Unit (83 MW)	1987	Deferred Dismantling		Storage with Surveillance	No
Douglas Point NGS	CANDU Prototype (220 MW)	1984	Deferred Dismantling		Storage with Surveillance	Yes
Gentilly NGS Unit 1	CANDU-BWR Prototype (275 MW)	1979	Deferred Dismantling	2061	Storage with Surveillance	Yes
Gentilly NGS Unit 2	CANDU-6 (675 MW)	2012	Deferred Dismantling		Preparation for Storage with Surveillance	Yes

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Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
WR-1 (Whiteshell Reactor-1)	Organic Cooled CANDU (60 MW)	1985	Deferred Dismantling	2026	Dismantling	Yes
ZEEP (Zero Energy Experimental Pile)	Research Reactor (10 W)	1970		1997	Decommissioned	Yes
PTR (Pool Test Reactor)	Research Reactor (10 kW)	1990	Deferred Dismantling	2012	Decommissioned	Yes
NRX (National Research Experimental Reactor)	Research Reactor (42 MW)	1993	Deferred Dismantling		Storage with Surveillance	Yes
University of Toronto	SLOWPOKE -II (20 kW)	2001	Prompt Dismantling	2001	Decommissioned	No
Dalhousie University	SLOWPOKE -II (20 kW)	2009	Prompt Dismantling	2011	Decommissioned	No
Tunney's Pasture	Isotope Processing Facility with SLOWPOKE -II (20 kW)	1989	Prompt Dismantling	1994	Decommissioned	No
Bruce Heavy Water Plant	Heavy Water Plant	1998		2006 (demolition complete) 2014 (license revoked)	Decommissioned	N/A


A.1.1. Decommissioning Regulatory Framework

A.1.1.1. Statutes

Decommissioning is conducted under the authority of the Nuclear Safety and Control Act and their associated regulations.

Other statutes that might impact decommissioning of large nuclear facilities include:

- Nuclear Fuel Waste Act;
- Nuclear Liability Act;
- Canadian Environmental Assessment Act (and/or equivalent provincial statutes);

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- Canadian Environmental Protection Act (and/or equivalent provincial statutes);
- Canada Labour Code, Part II (and/or equivalent provincial statutes); and
- Transportation of Dangerous Goods Act (and/or equivalent provincial statutes).

A.1.1.2. Regulations

At present, there are no Regulations made pursuant to the Nuclear Safety and Control Act that address decommissioning or radioactive waste management in detail. Regulations made under the Nuclear Safety and Control Act that would apply to decommissioning include:


- General Nuclear Safety and Control Regulations;
- Radiation Protection Regulations;
- Class I Nuclear Facilities Regulations;
- Class II Nuclear Facilities Regulations;
- Nuclear Substances and Radiation Devices Regulations;
- Packaging and Transport of Nuclear Substances Regulations; and
- Nuclear Security Regulations.

A.1.1.3. Licences

The key regulatory agency with oversight for decommissioning in Canada is the CNSC. The Nuclear Safety and Control Act gives the CNSC the authority to issue:

- Licence to Prepare Site;
- Licence to Construct;
- Licence to Operate;
- Licence to Decommission; and
- Licence to Abandon.

An application for a Licence for a Class I Nuclear Facility (which includes power reactors) must include “the proposed plan for the decommissioning of the nuclear facility or of the site”. The Nuclear Safety and Control Act also permits the CNSC to include in any licence “any term or condition that the Commission considers necessary for the purposes of this Act, including a condition that the applicant provide a financial guarantee in a form that is acceptable to the Commission”.

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A.1.1.4. Other Documents, Codes and Standards

The CNSC also issues Regulatory Documents (which explain to licensees and applicants what they must achieve in order to meet the requirements set out in the NSCA and the regulations made under the NSCA) and Guidance Documents (which provide guidance on how to meet requirements). Two Guidance Documents have been issued that specifically relate to decommissioning:

- Regulatory Guide G-219, *Decommissioning Planning for Licensed Activities*; and
- Regulatory Guide G-206, *Financial Guarantee Guide for the Decommissioning of Licensed Activities*.

Other CNSC regulatory documents that could apply to decommissioning include:

- Regulatory Guide P-290, *Managing Radioactive Waste*; and
- Regulatory Guide G-320, *Assessing the Long Term Safety of Radioactive Waste Management*.

The Canadian Standards Association (CSA) is an independent, not-for-profit member-based association accredited by the Standards Council of Canada. Members of the CSA include government departments and agencies, industry and the general public. The CSA has issued one standard relevant to decommissioning of nuclear facilities:

- CSA N294-09, *Decommissioning of Facilities Containing Nuclear Substances*.

This standard was originally issued in 2009 and an amendment is expected to be issued in 2014.


Other CSA standards that could apply to decommissioning include:

- N292.3-08, *Management of Low- and Intermediate-Level Radioactive Waste*;
- N292.5-11, *Guideline for the exemption or clearance from regulatory control of materials that contain, or potentially contain, nuclear substances*; and
- N292.2-13, *Interim dry storage of irradiated fuel*.

A.1.2. Responsibility

Neither the Nuclear Safety & Control Act nor the Regulations made pursuant to that Act explicitly assign responsibility for decommissioning of a nuclear facility to any party. Clause 4.1 of CSA Standard N294-09 does require that:

“Responsibility for decommissioning shall be clearly established throughout the life cycle of a facility. This responsibility includes planning and preparing for, executing, and completing decommissioning (i.e., until the final end-state objective has been achieved, all documentation completed, and all regulatory

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requirements satisfied). Responsibility for the funding of the decommissioning shall be identified.”

A.1.2.1. Decommissioning Planning Execution and Completion

The Class I Nuclear Facility Regulations require that an application for a Licence for a Class I Nuclear Facility must include “the proposed plan for the decommissioning of the nuclear facility or of the site”. Both CSA Standard N294-09 (Clause 6.3 and Annex A) and CNSC Regulatory Guide G-219 (Section 6.1) set out the required contents of a decommissioning plan.

CSA Standard N294-09 recommends that:

“Initial decommissioning plans should be regularly updated and reviewed to reflect

(a) changes in site conditions;

(b) changes to the proposed decommissioning objectives or strategy;

(c) changes to ownership or management structure;

(d) advances in decommissioning technology;

(e) significant modifications to the facility;

(f) updated cost and funding information;

(g) revised regulatory requirements; and

(h) revised records requirements.


Notes:

(1) Decommissioning planning should become more thorough and detailed as the anticipated shutdown date approaches.

(2) PDPs for nuclear facilities are updated according to licence conditions.”

Section 26 of the Nuclear Safety & Control Act requires that²:

² The operator can place the nuclear facility into safe storage under a normal operating license, if it so wishes, as an initial step toward decommissioning.

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Subject to the regulations, no person shall, except in accordance with a licence,

...

(e) prepare a site for, construct, operate, modify, decommission or abandon a nuclear facility; ...

Section 24 of the Nuclear Safety & Control Act authorizes the CNSC to issue licences for the activities described in Section 26 of the Act and Section 3 and 7 of the Class I Nuclear Facility Regulations set out the requirements for a Licence to Decommission a nuclear facility.

Clauses 8 and 9 of CSA N294-09 set out requirements and recommendations on the execution and completion of decommissioning but (aside from the general requirement set out in Clause 4.1) the Standard does not assign responsibility for execution and completion of the decommissioning.

A.1.2.2. Decommissioning Waste Management

Section 26 of the Nuclear Safety & Control Act requires that:

“Subject to the regulations, no person shall, except in accordance with a licence,

...

(b) mine, produce, refine, convert, enrich, process, reprocess, package, transport, manage, store or dispose of a nuclear substance; ...’


Section 24 of the Nuclear Safety & Control Act authorizes the CNSC to issue licences for the activities described in Section 26 of the Act and the Act defines “a facility for the disposal of a nuclear substance generated at another nuclear facility” to be a nuclear facility. Consequently, any facility intended to process, manage, store or dispose of nuclear substances generated during the course of the decommissioning of a nuclear facility would be subject to licensing by the CSNC.

CNSC Regulatory Policy P-290 and Regulatory Guidance G-320 set out the CNSC’s expectations with regard to the management of radioactive wastes in general.

Clause 7.8.3 of CSA Standard N294-09 establishes a requirement to develop a Waste Management Plan but, aside from the general requirement set out in Clause 4.1.1, the Standard does not impose responsibility for waste management on any party.

A.1.2.3. Funding

Section 24(5) of the Nuclear Safety & Control Act empowers the CNSC to prescribe terms and conditions of licences:

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“A licence may contain any term or condition that the Commission considers necessary for the purposes of this Act, including a condition that the applicant provide a financial guarantee in a form that is acceptable to the Commission.”

Section 3. (1)(l) of the General Nuclear Safety and Control Regulations indicates that:

“3.(1) An application for a licence shall contain the following information:

...

(l) a description of any proposed financial guarantee relating to the activity to be licensed;”

CNSC Regulatory Guide G-206

“provides guidance regarding the establishment and maintenance of measures to fund the decommissioning of activities licensed by the Canadian Nuclear Safety Commission (CNSC)”.

It requires that

“Financial guarantees must be sufficient to cover the cost of decommissioning work resulting from licensed activities that have taken place prior to the licence period, or will take place under the current licence.”

Clause 4.1.1 of CSA Standard N294-09 requires that:

“Responsibility for the funding of the decommissioning shall be identified.”


Aside from this requirement, the Standard does not impose responsibility for funding on any party.

A.1.3. Decommissioning Strategy

CNSC Regulatory Guide G-219 recommends that:

“The following basic alternative strategies should be evaluated for each planning envelope:

- *Prompt removal;*

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- *Deferred removal (to allow for the decay of relatively short-lived nuclides (e.g., half-lives of less than 10 years), or to await the availability of waste disposal capacity);*
- *In-situ confinement (to secure and abandon the affected portions of the facility in place); and*
- *Combinations of the above.”*

CSA Standard N294-09 recommends that:

“A decommissioning strategy should be developed early in the life cycle of a facility and should be reviewed and updated as new information is obtained. The strategy should contain a high-level approach and rationale for decommissioning the facility, which will be further developed in decommissioning plans (which might require approval by the regulatory authority).”

Clause 6.1.2 of the Standard also recommends that:

“The development of a decommissioning strategy should be based on one or a combination of the following:

(a) prompt decommissioning — to decontaminate and dismantle the facility without any planned delays;


(b) deferred decommissioning

(i) to place the facility in a period of storage-with-surveillance followed by decontamination and dismantlement; or

(ii) to conduct activities directed at placing certain buildings or facilities in a safe, secure interim end state, followed by a period of storage-with-surveillance, and ultimately decontamination and dismantlement; and

(c) in-situ confinement — to place the facility in a safe and secure condition with the intention to abandon in-place.”

Clause 6.1.3 provides guidance on the factors that should be considered when developing the decommissioning strategy.

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A.1.4. Decommissioning Waste Strategy

Section 9.1 of CNSC Regulatory Guide G-219 requires that:

“The ultimate destination of materials arising from decommissioning activities, and the ability of those destinations to accommodate the types and volumes of material, should be assessed and documented in the preliminary decommissioning plan and verified in the detailed decommissioning plan.”

Clause 7.8.3 of CSA Standard N294-09 requires that:


“The strategy for managing all wastes from decommissioning shall be described in a waste management plan covering both the short term and, where possible, the long term. The waste management plan may be a stand-alone document or may be part of the final decommissioning plan. A waste management plan shall include

- (a) a description of the area, procedures, criteria, and instruments that will be used to monitor and segregate wastes into different categories;*
- (b) estimates of the waste quantities expected in each category;*
- (c) specific plans for reuse, recycling, storage, or disposition of the waste;*
- (d) clearance levels for the release of material and equipment;*
- (e) to the extent possible, a long-term waste management strategy; and*
- (f) a cost-benefit analysis.”*

CSA Standards N292.3-08 is currently being replaced by two standards, N292.0 and N292.3 which will be issued in 2014. CSA Standard N292.0-14 will set out general principles for radioactive waste management while N292.3 will deal with issues specific to the management of low and intermediate level radioactive wastes. These standards will be applicable to the management of all radioactive wastes including those generated during the course of the decommissioning of a nuclear facility. CSA Standard N292.0-14 will recognize ‘Very Low-Level Waste’ or VLLW as a classification of radioactive waste; this classification was not recognized in N292.3-08.

Nuclear Fuel Wastes are managed separately from other decommissioning wastes and in accordance with the requirements of the Nuclear Fuel Waste Act which is intended to:

“provide a framework to enable the Governor in Council to make, from the proposals of the waste management organization, a decision on the management

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of nuclear fuel waste that is based on a comprehensive, integrated and economically sound approach for Canada.”

A.1.5. Decommissioning Regulatory Lessons Learned

When the first reactors were shutdown with the intent to decommission, there were no reactor decommissioning regulations in place. These facilities were approved for shutdown and decommissioning under operating licences and in some cases, the licences were changed to similar facilities licences (e.g. Waste Management Facilities) where the process could be regulated. Since this time, regulations for reactor decommissioning have been put in place and there is a process for licensing for decommissioning.


A.1.6. Sources of information

Sources consulted in the preparation of this section include:

- Decommissioning of facilities containing nuclear substances, CSA N294-09, July 2009.
- Fact Sheet – Decommissioning of Nuclear Power Plants, CNSC, October 2012.
- Class I Nuclear Facilities Regulations, SOR/2000-204, CNSC, 2000.
- Draft - Long-term Operation Management for Nuclear Power Plants, RD/GD 360 Version 2, CNSC, July 2012.
- Radioactive Waste Management and Decommissioning in Canada, OECD/NEA, March 2008.
- Radioactive Waste Management Programmes in OECD/NEA Member Countries – CANADA, OECD/NEA, 2012.
- Financial Guarantees for the Decommissioning of Licensed Activities, CNSC Regulatory Guide G-206, June 2000.
- Decommissioning Planning for Licensed Activities, CNSC Regulatory Guide G-219, June 2000.

A.2. United States


As of April 2013, 22 nuclear power plants have been shut down and one nuclear ship has been demobilized and transferred to civilian (Department of Transport) control. A listing of these facilities and their status as of April 2013 is given in Table 4. In addition, there are 10 research and test reactors, 14 complex decommissioning materials facilities, 1 fuel cycle facility (partial decommissioning), and 32 uranium recovery facilities that are either undergoing decommissioning or are in long-term safe storage.

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As of September 2012, the Department of Energy (DOE) Office of Environmental Management has been charged with responsibility for the cleanup 107 former nuclear weapons related facilities. Work has been completed at 90 of these including Rocky Flats, Fernald Uranium Plant, Mound Radioisotopic Plant, Ashtabula Uranium Plant, and the Columbus Nuclear Research Facility and many smaller facilities.

Table 4 Status of Decommissioning Facilities in the United States of America

Class IA - A						
Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Big Rock Point (Charlevoix, MI)	BWR (67 MW)	29 Aug 1997	Prompt Dismantling	2006	ISFSI Only	Yes
Crystal River 3 (Crystal River, FL)	PWR (2609 MW)	20 Feb 2013	Deferred Dismantling	2074	SAFSTOR	Yes
Dresden 1 (Morris, IL)	BWR (700 MW)	31 Oct 1978	Deferred Dismantling	2017 + ISFSI - 2044	SAFSTOR	Yes
Fermi 1 (Monroe Co., MI)	Fast Breeder (200 MW)	22 Sep 1972	Deferred Dismantling	2032	SAFSTOR	No
Fort St. Vrain (Platteville, CO)	HTGR (842 MW)	18 Aug 1989	Prompt Dismantling	1992	ISFSI Only	Yes
GE VGBWR (Alameda Co., CA)	BWR (50 MW)	9 Dec 1963	Deferred Dismantling	2019	SAFSTOR	No
Haddam Neck (Haddam Neck, CT)	PWR (1825 MW)	9 Dec 1996	Prompt Dismantling	2007	ISFSI Only	Yes
Humboldt Bay 3 (Eureka, CA)	BWR (200 MW)	2 Jul 1976	Deferred Dismantling	2015	DECON	Yes
Indian Point 1 (Buchanan, NY)	PWR (615 MW)	31 Oct 1974	Deferred Dismantling	2026	SAFSTOR	Yes
LaCrosse (LaCrosse, WI)	BWR (165 MW)	30 Apr 1987	Deferred Dismantling	2026	DECON	Yes
Maine Yankee (Bath, ME)	PWR (2772 MW)	6 Dec 1996	Prompt Dismantling	2005	ISFSI Only	Yes
Millstone 1 (Waterford CT)	BWR (2011 MW)	21 Jul 1988	Deferred Dismantling	2056	SAFSTOR	Yes
Pathfinder (Sioux Falls, SD)	Superheat BWR (190 MW)	16 Sep 1967	Deferred Dismantling	1991	License Terminated	No
Peach Bottom 1 (York Co., PA)	HTGR (115 MW)	31 Oct 1974	Deferred Dismantling	2034	SAFSTOR	No
Rancho Seco (Sacramento, CA)	PWR (2772 MW)	7 Jun 1989	Deferred Dismantling	2009	ISFSI Only	Yes


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Class IA - A						
Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
San Onofre 1 (San Clemente, CA)	PWR (1347 MW)	30 Nov 1992	Deferred Dismantling	2030	SAFSTOR	Yes
NS Savannah (near Baltimore, MD)	PWR (80 MW)	Nov 1970	Deferred Dismantling	2031	SAFSTOR	No
Saxton (Saxton, PA)	PWR (28 MW)	1 May 1972	Deferred Dismantling	2005	License Terminated	No
Shoreham (Suffolk Co., NY)	BWR (2436 MW)	28 Jun 1989	Prompt Dismantling	1995	License Terminated	No
Three Mile Island 2 (Middleton, PA)	PWR (2772 MW)	28 Mar 1979	Deferred Dismantling	2036	Post-Defueling Monitored Storage	No
Trojan (Portland, OR)	PWR (3411 MW)	9 Nov 1992	Prompt Dismantling	2006	ISFSI Only	Yes
Yankee Rowe (Franklin Co., MA)	PWR (600 MW)	1 Oct 1991	Prompt Dismantling	2007	ISFSI Only	Yes
Zion 1 & 2 (Zion, IL)	2 x PWR (3250 MW each)	21 Feb 1997 19 Sep 1996	Deferred Dismantling	2026	DECON	Yes
Class IB – B, D, D & E						
Location	Facility Type	Shutdown	Decommissioning Strategy	Planned End Date	Status	Waste Onsite
Fernald Environment Management Project	High Purity, Low enrichment uranium reactor feed material	1989	Prompt Dismantling	2006	Dismantling Complete	
Portsmouth Gaseous Diffusion Plant	High and Low Enrichment	2010	Deferred Dismantling	2044		

Note: grayed out fields indicate where information was not readily available, or where contradictory information was found.

Acronyms used in the table:

BWR Boiling Water Reactor
DECON Immediate Dismantling
HTGR High Temperature Graphite Reactor

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ISFSI	Independent Spent Fuel Storage Facility ‘(ISFSI Only’ The license has been reduced to include only the ISFSI facility)
NS	Nuclear Ship
PWR	Pressurized Water Reactor
SAFSTOR	Safe Storage (equivalent to Deferred Dismantling)

A.2.1. Decommissioning Regulatory Framework


Separate regulatory regimes apply to civilian and nuclear weapons related facilities. The scope of this summary is limited to civilian nuclear power plants.

A.2.1.1. Statutes

The regulatory regime for the decommissioning of nuclear facilities has been defined in a series of Acts; the most important of these are:

- Atomic Energy Act of 1954 (as amended) – defines the responsibility for the regulation of civilian nuclear reactors and the commercial use of nuclear materials, by-products and sources;
- Energy Reorganization Act of 1974 and DOE Organization Act of 1977 – divided responsibility for civilian and military-related facilities between the NRC and the Department of Energy;
- Low-Level Radioactive Waste Policy Act of 1980, Nuclear Waste Policy Act of 1982 and the Low-Level Radioactive Waste Policy Amendments Act of 1985 - made each State responsible for disposal of low-level radioactive waste (LLW) generated within the State and made the DOE responsible for high level waste;
- National Environmental Policy Act (NEPA) of 1969, as amended - requires federal agencies to consider environmental values and factors in decision making; and
- Clean Air Act (CAA) and the Safe Drinking Water Act (SDWA) give the Environmental Protection Agency (EPA) the responsibility for regulating and enforcing the levels of radioactivity in air emissions and in drinking water while the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) allows the EPA to determine soil cleanup values and other residual radioactivity limits at severely contaminated sites that are covered by the Superfund Program³.

³ The Superfund program is the United States federal government's program to clean up the nation's uncontrolled hazardous waste sites.

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A.2.1.2. Regulations

The requirements for decommissioning a nuclear power plant are set out in Title 10 of the United States Code of Federal Regulations (10CFR), Part 20 Subpart E, and Parts 50.75, 50.82, 51.53, and 51.95. This rule was revised in August 1996 to redefine the decommissioning process and require owners to provide the NRC with early notification of planned decommissioning activities. The rule allows no major decommissioning activities to be undertaken until after certain information has been provided to the NRC and the public.

Additional requirements for decommissioning and licence termination of facilities that have been issued a Combined Licence are set out in 10CFR Part 52, Subpart E (52.109 and 52.110). These two parts are attached to this summary as Section A.1.5.

A.2.1.3. Licences

The NRC licenses all commercially owned nuclear power plants that produce electricity in the United States. After the initial licence is granted, the licence may be amended, renewed, transferred, or otherwise modified, depending on activities that affect the reactor during its operating life. The licence remains in effect until decommissioning is complete and the NRC terminates the licence.


The requirements for power reactor decommissioning activities may be divided into three phases:

- (1) initial activities;
- (2) major decommissioning and storage; and
- (3) licence termination activities.

A.2.1.3.1. Initial Activities

When a nuclear power plant licensee shuts down the plant permanently, the operator must submit a written certification of permanent cessation of operations to the NRC within 30 days. When radioactive nuclear fuel is permanently removed from the reactor vessel, the owner must submit another written certification to the NRC, surrendering its authority to operate the reactor or load fuel into the reactor vessel. This eliminates the obligation to adhere to certain requirements needed only during reactor operation.

Within two years after submitting the certification of permanent closure, the licensee must submit a PSDAR to the NRC. This report provides a description of the planned decommissioning activities, a schedule for accomplishing them, and an estimate of the expected costs. The PSDAR must discuss the reasons for concluding that environmental impacts associated with the site-specific decommissioning activities have already been addressed in previous environmental analyses. Otherwise, the licensee must request a licence amendment for

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approval of the activities and submit to the NRC a report on the additional impacts of decommissioning on the environment.

After receiving a PSDAR, the NRC publishes a notice of receipt in the Federal Register, makes the report available for public review and comment, and holds a public meeting in the vicinity of the plant to discuss the licensee's intentions.

A.2.1.3.2. Major Decommissioning and Storage

Ninety days after the NRC receives the PSDAR, the owner can begin major decommissioning activities without specific NRC approval. These include permanent removal of such major components as the reactor vessel, steam generators, large piping systems, pumps, and valves.

However, decommissioning activities conducted without specific prior NRC approval must not:

- prevent release of the site for possible unrestricted use
- result in there being no reasonable assurance that adequate funds will be available for decommissioning, or
- cause any significant environmental impact not previously reviewed.

If any decommissioning activity does not meet these terms, the licensee is required to submit a licence amendment request, which would provide an opportunity for a public hearing.

A.2.1.3.3. Licence Termination


The owner is required to submit a Licence Termination Plan (LTP) within two years of the expected licence termination. Before the LTP can be approved, a public meeting is held near the plant site to allow for public input. If the NRC approves the LTP, the licence is amended to allow the decommissioning to proceed.

If decommissioning has been completed in accordance with the approved LTP and the termination survey demonstrates that the facility and site are suitable for release, the NRC issues a letter terminating the operating licence.

A.2.1.4. Other Codes and Standards

The NRC issues guidance on how to implement its regulations in the form of Regulatory Guides and Staff Positions:

- Regulatory Guides are drafted by the NRC staff to establish a standard approach to licensing. They are not intended to be regulatory requirements, but they do reflect methods, procedures, or actions which would be considered acceptable by the staff for


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implementing specific parts of the Commission's regulations. Three Regulatory Guides have been issued on subjects related to decommissioning:

- Regulatory Guide 1.179 – Standard Format and Content of License Termination Plans for Nuclear Power Reactors (Rev. 1, June 2011);
 - Regulatory Guide 1.184 – Decommissioning of Nuclear Power Reactors (Rev. 1, October 2013);
 - Regulatory Guide 4.22 – Decommissioning Planning During Operations (December 2012);
- Staff Positions are divided into two general types:
 - Generic positions – deal with issues which relate to licensing activities for nuclear facilities independent of the technology or site selected; and
 - Site-specific positions – give site guidance or advice applicable to a specific site.
 - NUREG-Series Publications are reports or brochures on regulatory decisions, results of research, results of incident investigations, and other technical and administrative information:
 - NUREG-1700, “Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans” describes the standard plan for the review of Licence termination Plans;
 - NUREG-1727, “NMSS Decommissioning Standard Review Plan”;
 - NUREG-1757, “Consolidated Decommissioning Guidance”:
 - Volume 1 – Decommissioning Process for Materials Licensees;
 - Volume 2 – Characterization, Survey and Determination of Radiological Criteria; and
 - Volume 3 – Financial Assurance, Recordkeeping and Timeliness.

In addition to the above guidance mechanisms, the NRC staff uses Standard Review Plans, which provide guidance to the NRC staff in reviewing licensee submittals. These plans are made public, so that licensees and applicants understand what is needed to comply with regulations. In this respect, the licensees and applicants have this third type of guidance to assist them in preparing their demonstration of compliance with the applicable regulations and standards.

Extensive guidance has been issued by the Environmental Protection Agency (EPA) through its Superfund program for remediation of sites contaminated with radionuclides, including guidance on risk assessment and cleanup technologies.

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Joint guidance has been issued by the EPA and NRC on various aspects of mixed waste management, including mixed waste identification, storage, and disposal. The EPA, NRC, DOE and Department of Defense have also issued joint guidance on surveys for decommissioning, and licence termination (MARSSIM) and clearance of wastes for reuse, recycling or disposal (MARSAME).

A.2.2. Responsibility

A.2.2.1. Decommissioning Planning, Execution and Completion

Under NRC regulations, the licensee is responsible for safely removing an NRC-licensed facility from service and reducing residual radioactivity to a level that permits the property to be released for either restricted or unrestricted future use.

A.2.2.2. Decommissioning Waste Management


A.2.2.2.1. Spent Nuclear Fuel and High Level Waste

The Nuclear Waste Policy Act of 1982 made the U.S. government (DOE) responsible for managing Spent Nuclear Fuel (SNF) and High Level waste (HLW). The Nuclear Waste Policy Amendments Act of 1987 (NWPAA) specified the Yucca Mountain site as the only site to be characterized as a candidate repository and established a detailed approach for the disposal of SNF and HLW.

In 2009, the Administration announced its intention to terminate the Yucca Mountain program. Alternative approaches for meeting the Federal responsibility to manage and ultimately dispose of spent nuclear fuel and high-level radioactive waste from both commercial and defense activities are being evaluated.

A.2.2.2.2. Low Level Waste

The Low-Level Radioactive Waste Policy Amendments Act of 1985 made States responsible for providing for the disposal of commercial Class A, B, and C LLW generated within their borders. The Act authorized States to enter into compacts that would allow several States to dispose of waste at a regional disposal facility. A 1985 amendment to the Act made DOE the responsibility for disposal of Greater-Than-Class C (GTCC) LLW.

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A.2.2.3. Funding

Each nuclear power plant licensee must report to the NRC every two years the status of its decommissioning funding for each reactor or share of a reactor that it owns. The report must estimate the minimum amount needed for decommissioning by using the formulas found in 10 CFR 50.75(c). Licensees may alternatively determine a site-specific funding estimate, provided that amount is greater than the generic decommissioning estimate.

Before a nuclear power plant begins operations, the licensee must establish a mechanism – such as a trust fund or a guarantee from its parent company – to ensure that there will be sufficient money to pay for the ultimate decommissioning of the facility.

Licensees must report on the accumulation of reactor decommissioning funds every two years. When the facility is within five years of the end of its licensed life, the fund status report must be submitted annually. The licensee must plan to accumulate the required amount by the time that the licence authority to operate expires. However, the licence continues in effect until decommissioning is complete and the NRC terminates the licence.

The decommissioning funds required by regulation do not include costs of spent fuel management. Those costs are provided for in a separate fund. No minimum amount is set by regulation; rather, the licensee makes its own estimate of spent fuel management costs. The licensee must then accumulate sufficient funds to cover the cost. Where the licensee has its electric rates set by a State regulatory authority, the cost of spent fuel management is often included in the rates.


A.2.3. Decommissioning Strategy

Licensees may choose from three alternative decommissioning strategies:

- DECON, which is generally equivalent to ‘immediate dismantling’ as defined by the IAEA;
- SAFSTOR, which is generally equivalent to ‘deferred dismantling’ as defined by the IAEA; or
- ENTOMB, which is generally equivalent to ‘in situ abandonment’ as defined by the IAEA.

The licensee may also choose to adopt a combination of the first two choices in which some portions of the facility are dismantled or decontaminated while other parts of the facility are left in SAFSTOR. The decision may be based on factors besides radioactive decay such as availability of waste disposal sites.

In order to meet regulatory requirements, decommissioning must be completed within 60 years of the plant ceasing operations. A time beyond that would be considered only when necessary to protect public health and safety in accordance with NRC regulations.

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The majority of the commercial nuclear power plants listed in Table 4 have adopted the DECON strategy. Of these:

- 3 have completed decommissioning and the licence has been terminated;
- 7 have completed decommissioning but the spent fuel remains in storage in an onsite ISFSI facility; and
- 3 are currently being decommissioned (in these cases, the spent fuel is currently being stored in an onsite ISFSI facility).

Nine of the facilities are following a SAFSTOR strategy and one (the damaged Three Mile Island Unit 2) is in “Post Defueling Monitored Storage”.

A.2.4. Decommissioning Waste Strategy

All of the operating nuclear power reactors are currently storing SNF in either onsite spent fuel pools or in ISFSI. In 1990, the NRC amended its regulations to authorize licensees to store spent fuel in dry storage casks at reactor sites. Sixteen SNF cask designs have received certificates of compliance as a result of this regulation change, and are in use by about 48 facilities in the U.S. The licence for several commercial nuclear power plants that have largely completed decommissioning has been reduced to include only the SNF remaining in storage in an ISFSI facility.


One of the three operating LLW disposal sites for commercial LLW in the U.S., the Barnwell facility in South Carolina, restricted access to out-of-compact waste in mid-2008. This has caused LLW generators in 36 States to store their Class B and C waste pending a new disposition option.

A potential disposal option these wastes may be available with the opening of the new commercial facility in Texas. Generators from states other than Texas and Vermont, which already have access, may now seek approval from the Texas Compact to dispose of their out-of-compact class A, B, and C LLW at the Texas facility.

A.2.5. Sources of information

Sources consulted in the preparation of this section include:

- Decommissioning of Nuclear Power Reactors, Regulatory Guide 1.184, U.S. Nuclear Regulatory Commission, 2013.
- Termination of License, 10 CFR 50.82, U.S. Nuclear Regulatory Commission, 2011.
- LC35 Decommissioning, NS-INSP-GD-035, Rev.3, Office for Nuclear Regulation, 2013.

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- Standard Format and Content for Post-Shutdown Decommissioning Activities Report, Regulatory Guide 1.185, U.S. Nuclear Regulatory Commission, 2000.
- Termination of License, 10 CFR 52.110, U.S. Nuclear Regulatory Commission, 2007.
- Radioactive Waste Management and Decommissioning in the United States of America, OECD/NEA, 2011.
- Radioactive Waste Management Programmes in OECD/NEA Member Countries – USA, OECD/NEA, 2011.

A.3. France

Seventy (70) power reactors have been commissioned in France. Fifty-eight (58) of these are still operating and twelve (12) of them are shutdown with the intention to decommission. Of these, six (6) have been partially dismantled with final dismantling deferred for 50 years. The Brennilis Nuclear Power Plant (NPP) is currently in the final stages of decommissioning (Phase 3). The status of decommissioning facilities in France is provided in Table 5.



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Table 5 Status of Decommissioning Facilities in France

Class IA - A						
Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Chinon A-1	GCR (70MW)	1973	Deferred Dismantling (50 years)	2023	Safe Enclosure (turned into a museum in 1986)	
Chinon A-2	GCR (180MW)	1985	Deferred Dismantling (50 years)	2035	Safe Enclosure	
Chinon A-3	GCR (360MW)	1990	Deferred Dismantling (50 years)	2040	Safe Enclosure	
Saint-Laurent A-1	GCR (390MW)	1990	Deferred Dismantling (50 years)	2040	Safe Enclosure	
Saint-Laurent A-2	GCR (465MW)	1992	Deferred Dismantling (50 years)	2042	Safe Enclosure	
Superphenix	FBR (1200MW)	1998	Deferred Dismantling	2029	Safe Enclosure	
Bugey-1	GCR (540MW)	1994	Deferred Dismantling (50 years)	2044	Safe Enclosure	
Brennilis	HWGCR (70MW)	1985	Deferred Dismantling	2019	Dismantling	
Chooz-A	PWR (305MW)	1991	Prompt Dismantling	2016	Dismantling	
Marcoule G-2	GCR (260MW)	1980	Deferred Dismantling	2035	Safe Enclosure	Yes
Marcoule G-3	GCR (260MW)	1984	Deferred Dismantling	2035	Safe Enclosure	Yes
Phenix	FBR (130MW)	2009	Deferred Dismantling	2029	Safe Enclosure	

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Class IB – B, C, D & E						
Location	Facility Type	Shutdown	Decommissioning Strategy	Planned End Date	Status	Waste Onsite
La Hague	Pilot Re-processing Plant for FBR	1979		2001	Decommissioned	
APM Marcoule	Pilot Re-processing facility	1997		2020	Dismantling	
UP1, Marcoule	Industrial Re-processing plant	1997		2032	Dismantling	
Saclay NLF	R&D U enrichment, isotopes	1996		2018	Dismantling	
Elan IIB	Manufacture of ¹³⁷ Cs and ⁹⁰ Sr sources	1973		2018	Dismantling	
Radio Chemistry Laboratory	Re-processing R&D	1995		2015	Dismantling	
ATUE	Recovery of Enriched Uranium	1996		2012	Dismantling	


Note: grayed out fields indicate where information was not readily available, or where contradictory information was found.

A.3.1. Decommissioning Regulatory Framework

The institutions in charge of energy policy in France are the Parliament, the Government and more specifically the General Directorate for Energy and Climate (DGEC) on behalf of the ministry for Ecology and Energy. The Public Health Code governs all nuclear activities in France.

A.3.1.1. Statutes

Decommissioning is conducted under the authority of the Public Health Code through the Transparency and Security in the Nuclear Field Act and the Planning Act on the Sustainable Management of Radioactive Materials and Waste and their associated government decrees.

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Other Statutes that may affect decommissioning include the Environment Code (following Act n° 75-633 of 15 July 1975), and its associated decrees about recycling of materials and disposal of waste.

A.3.1.2. Regulations

The Transparency and Security in the Nuclear Field" Act of 13 June 2006 created an independent administrative authority called the ASN to be the regulator of nuclear activities in France.

Government Decrees (regulations) pertaining to decommissioning include:

- Decree of May 30th 2005 on the traceability of waste.
- Decree 2007-1557 of November 2nd 2007 pertains to the definition, licensing and control of “basic nuclear installations” (INB) which include nuclear waste processing plants, storage and disposal facilities. It also provides licensing procedures for the final shutdown and decommissioning/dismantling of nuclear facilities.
- ASN decision n°2008-DC-0095 published on January 29th 2008 that provides technical requirements for radioactive waste management and releases of facilities. It requires that each facility establish an internal radioactive waste management plan.
- Decree 2010-1673 of December 29th 2010 modifying decree 2007-243 of February 23rd 2007 pertaining to the securing of sufficient funding for the management of radioactive waste and decommissioning.

A.3.1.3. Licences

According to decree 2007-1557 of November 2nd 2007, pursuant to the Transparency and Security in the Nuclear Field Act, a decommissioning licence is required prior to the final shut-down and decommissioning of a nuclear facility. It also indicates that the licence application is to include information on the expected shut-down conditions, the decommissioning and waste management procedures, the target end-state, and the surveillance and subsequent maintenance of the facility/site.


There are 2 primary licences: Operating Licence and Decommissioning Licence. Each of these licences can have many phases.

Operating Licence phases pertaining to decommissioning:

- decision to shutdown
- preparation for shutdown and the end of operation

Decommissioning Licence phases:

- Preparation for shutdown of the facility

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- Shutdown of the facility (this would include deferral period)
- Decommissioning/dismantling

A.3.1.4. Other Codes and Standards

ASN produces many guidance documents that could pertain to decommissioning including:


- RFS I.2 (19 June 1984): Safety objectives and design basis for surface disposal of short lived, low and intermediate level radioactive waste.
- RFS III.2.a (24 September 1982): General safety measures for production, control, treatment, conditioning and storage of reprocessing waste.
- RFS III.2.b (12 November 1982): Particular safety measures for production, control, treatment, conditioning and storage of high-level waste from reprocessing to be conditioned in glass matrix.
- RFS III.2.c (5 April 1984): Particular safety measures for production, control, treatment, conditioning and storage of low- or intermediate-level waste from reprocessing to be conditioned in bitumen matrix.
- RFS III.2.d (1 February 1985): Particular safety measures for production, control, treatment, conditioning and storage of waste from reprocessing to be conditioned in concrete matrix.
- RFS III.2.e (31 October 1986 revised 29 May 1995): Conditions prior to acceptance of solid waste in surface repositories.
- RFS III.2.f (2 February 2008): Guidelines for the deep geological disposal of radioactive waste.
- Guide n°14 published 26 June 2010: Recommendations on methodologies for clean-up of contaminated or activated structures (notably concrete structures) in nuclear facilities.

A.3.2. Responsibility

According to the Transparency and Safety in the Nuclear Field Act:

“If a basic nuclear installation ceases to operate for a continuous period of over two years, the ministers tasked with nuclear safety can, by a decree adopted upon advice of the Nuclear Safety Authority, ban the resumption of the operation of the installation and call on the licensee to file, within a period they determine, an authorisation application for the definitive shut-down and decommissioning of the installation.”

The Licensee is responsible for decommissioning the facility in accordance with their licence conditions and under the regulatory direction of ASN.

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A.3.2.1. Decommissioning Planning, Execution and Completion

The Licensee is responsible for providing the regulator with a dismantling plan for the nuclear facility including a projected timeline. Both prompt and deferred dismantling are acceptable, but current plans seem to favour prompt dismantling to take advantage of the facility knowledge of the current operating staff.

Decree n°1557 requires an updated decommissioning plan to be submitted and accepted at least three years before the final shutdown date. This plan is to include:

- the description of the preparatory activities for the final shutdown
- the systems and components important for decommissioning
- the waste disposal routes


The decree also requires an application to be filed at least one year before final shutdown that includes:

- a description of the nuclear facility before shutdown
- an updated decommissioning plan
- an environmental impact assessment
- a preliminary safety analysis report
- a risk analysis (public inquiry)
- operating rules
- restricted use foreseen after decommissioning (if any)

A.3.2.2. Decommissioning Waste Management

According to the Environment Code, processing and disposal of waste is the responsibility of the waste producer and that only waste that cannot currently be reused or recycled may be disposed of. The French National Radioactive Waste Management Agency (ANDRA), under the authority of the Planning Act, is responsible for the long-term management of radioactive waste produced in France with the exception of waste generated by processing foreign waste.

The National Assessment Board (CNE2), also under the authority of the Planning Act, is responsible for the evaluation and review of the various programs for the management of high-level and long-lived intermediate-level radioactive waste. Similarly to the NWMO, this organization is responsible for the planning of waste disposal facilities, in this case, high-level and long lived intermediate level wastes.

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A.3.2.3. Funding

Decommissioning and waste management funding is the responsibility of the licensee (operator).

It is important that financial resources (funds) will be sufficient and available when needed. Each nuclear operator (EDF, AREVA, CEA) manages its own fund, and fund management differs from one company to the other.

The 2006 Planning Act on the Sustainable Management of Radioactive Materials and Waste stipulates that licensees (operators):


- shall assess prudently the costs of dismantling their installations and management of their spent fuel and radioactive waste,
- shall establish financial provisions to cover the above-mentioned costs and earmark the necessary assets for the exclusive coverage of these costs.
- shall account separately for these assets which shall present a sufficient degree of security and liquidity to meet their purpose,
- shall submit a report to the administrative authority, every three years, describing the assessment of the costs, the methods applied for the calculation of these costs and the choices adopted with regard to the composition and management of the assets earmarked to cover the reserves. The report shall include a plan for constituting the assets. Every year operators shall transmit to the administrative authority a note updating this report and inform it without delay of any event likely to modify its content.

The 2006 Planning Act also indicates that, except where the State wields its powers to get the operators to respect their obligations to dismantle their installations and manage their spent fuels and radioactive waste, nobody can claim to have a right over the assets, even on the basis of the Commercial Code,

A.3.3. Decommissioning Strategy

The ASN's preferred decommissioning strategy is Prompt Dismantling, however, there is no regulatory requirement. The Operator is responsible for selection of the dismantling strategy and for providing justification for the chosen strategy by showing that it is the best alternative in terms of safety, radiation protection, waste management, and site end state.

The end state goal of decommissioning in France is for unconditional site release, with the understanding that there may be sites where restricted use may be required. The site release criteria are established on a case by case basis taking into account future site use scenarios as there are no mandated release criteria.

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A.3.4. Decommissioning Waste Strategy

In France, there is no distinction between decommissioning waste and operational waste in terms of disposal. France employs waste zoning that divides facilities into zones generating nuclear waste and zones generating conventional waste. Any waste from a nuclear waste generating zone cannot be released for conventional disposal. All nuclear waste is processed and disposed of in facilities based on its activity and half life as shown in Table 6 below.

Table 6 France - Waste Processing and Disposal Facilities

Waste Activity Level	Half-Life	Very-Short-Lived (Half-Life < 100 Days)	Short-Lived (Half-Life ≤ 31 Years)	Long-Lived (Half-Life > 31 Years)
Very-Low-Level	Management by in situ radioactive decay		Surface Disposal (CIRES waste disposal facility at Morvilliers)	
Low-Level			Surface Disposal (CSA waste surface disposal at l'Aube)	No disposal facility at this time
Intermediate - Level				No disposal facility at this time
High-Level			No disposal facility at this time	

Under the Planning Act (2006-739), studies are being conducted for LL-LLW, LL-ILW, SL-HLW and LL-HLW. Recycling is also an option being considered for Short-Lived - Low and Intermediate Level Waste (SL-LILW).


A.3.5. Decommissioning Regulatory Lessons Learned

Although there is a fair bit of information on technical decommissioning lessons learned, information on regulatory lessons learned is not readily available.

A.3.6. Sources of information

Sources consulted in the preparation of this section include:

- Radioactive Waste Management and Decommissioning in France, OECD/NEA, March 2013.
- Radioactive Waste Management Programmes in OECD/NEA Member Countries – FRANCE, OECD/NEA, March 2013.
- Nuclear Power in France, World Nuclear Association, January 2014.

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- French Regulatory Framework: the guarantees of ASN independence and the obligation for ASN to maintain relations with the licensees, ASN, March 2013.
- Operational Decommissioning Experience in France, CEPN, September 2013.
- France - Nuclear Regulatory Authority, European Nuclear Safety Regulators Group, February 2014.

A.4. Germany


Thirty-six (36) power reactors have been commissioned in Germany. Nine (9) of these are still operating and twenty-seven (27) of them have been shutdown; of these three (3) have been dismantled, two (2) are in Safe Enclosure and fourteen (14) are being dismantled. The three decommissioned facilities; KKN in Niederaichbach, HDR in Großwelzheim and VAK in Kahl, were restored to "green-field conditions" and released from regulatory control. The status of decommissioning facilities in Germany is provided in Table 7.

Table 7 Status of Decommissioning Facilities in Germany


Class IA - A						
Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Niederaichbach - KKN	DRR (106MW)	1974	Deferred Dismantling	1995	Dismantled – Green field	
Heissdampfreaktor Grosswelzheim - HDR	HDR (25MW)	1971	Deferred Dismantling	1998	Dismantled – Green field	
Versuchsatomkraftwerk Kahl - VAK	BWR (16MW)	1985	Deferred Dismantling	2010	Dismantled – Green field	
Lingen - KWL	BWR (268MW)	1977	Deferred Dismantling		Safe Enclosure / Dismantling	
Thoriumhochtemperaturreaktor – THTR-300	GCHTR (308MW)	1988	Deferred Dismantling		Safe Enclosure	
Arbeitsgemeinschaft Versuchsreaktor - AVR	HTR (15MW)	1988	Deferred Dismantling		Safe Enclosure	
Stade - KKS	PWR (672MW)	2003	Prompt Dismantling	2015	Dismantling	
Wurgassen - KWW	BWR (670MW)	1994	Deferred Dismantling	2014	Dismantling	
Mulheim-Karlich - KMK	PWR (1302MW)	1988 – 1998*	Prompt Dismantling		Dismantling	

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Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Rheinsberg - KKR	PWR / WWER (70MW)	1990	Deferred Dismantling		Dismantling	
Kompakte Natriumgekuhlte Kernanlage – KNK II	SNR (21MW)	1991	Deferred Dismantling		Dismantling	
Mehrzweck- forschungsreaktor - MZFR	PWR (57MW)	1984	Deferred Dismantling		Dismantling	
Obringheim - KWO	PWR (357MW)	2005	Prompt Dismantling		Dismantling	
Gundremingen-A – KRB-A	BWR (250MW)	1977	Deferred Dismantling		Dismantling	
Greifswald-1 – KGR 1	PWR / WWER (440MW)	1990	Deferred Dismantling		Dismantling	
Greifswald-2 – KGR 2	PWR / WWER (440MW)	1990	Deferred Dismantling		Dismantling	
Greifswald-3 – KGR 3	PWR / WWER (440MW)	1990	Deferred Dismantling		Dismantling	
Greifswald-4 – KGR 4	PWR / WWER (440MW)	1990	Deferred Dismantling		Dismantling	
Greifswald-5 – KGR 5	PWR / WWER (440MW)	1989	Deferred Dismantling		Dismantling	
Neckarwestheim-1	PWR (840MW)	2011	**		Shutdown	
Philippsburg-1	BWR (926MW)	2011	**		Shutdown	
Isar-1	BWR (912MW)	2011	**		Shutdown	
Biblis-A	PWR (1225MW)	2011	**		Shutdown	
Biblis-B	PWR (1300MW)	2011	**		Shutdown	
Unterweser	PWR (1410MW)	2011	**		Shutdown	
Brunsbüttel	BWR (806MW)	2011	**		Shutdown	
Krummel	BWR (1402MW)	2011	**		Shutdown	

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Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Forschungsreaktor München - FRM	Pool-type / MTR (4MW)	2000				
SUR Hannover – SUR-H	SUR-100 (1.0E-07 MW)	2008				
Siemens- Unterrichtsreaktor Aachen – SUR-AA	SUR-100 (1.0E-07 MW)	2008				
Forschungsreaktor Geesthacht-1 – FRG-1	Pool-type / MTR (5MW)	2010				
Forschungsreaktor Geesthacht-2 – FRG-2	Pool-type / MTR (15MW)	1993				
Forschungsreaktor- 2 – FR-2	Tank-type / D ₂ O (44MW)	1982	Deferred Dismantling		Safe Enclosure	
Forschungsreaktor Neuherberg - FRN	Pool-type / TRIGA MARK-III (1MW)	1982	Deferred Dismantling		Safe Enclosure	
Forschungs- und Messreaktor Braunschweig - FMRB	Pool-type / MTR (1MW)	1995	Prompt Dismantling	2005	Released from regulatory control (except for interim storage)	
DIDO – FRJ-2	Tank-type / D ₂ O (23MW)	2006	Prompt Dismantling		Dismantling	
Rosendorfer Forschungsreaktor - RFR	Tank-type / WWR-SM (10MW)	1991	Deferred Dismantling		Dismantling	
Schnelle Nullenergie- Anordnung - SNEAK	(1.0E-03MW)	1985	Prompt Dismantling	1987	Released from regulatory control	
Schnell- Thermischer Argonautreaktor - STARK	Modified Argonaut reactor (1.0E-05MW)	1976	Prompt Dismantling	1977	Released from regulatory control	
Siemens- Unterrichtsreaktor Karlsruhe – SUR- KA	SUR-100 (1.0E-07MW)	1996	Prompt Dismantling	1998	Released from regulatory control	

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Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
TRIGA Heidelberg I – TRIGA HD I	Pool-type / TRIGA MARK-I (0.25MW)	1977	Deferred Dismantling	2006	Released from regulatory control	
TRIGA Heidelberg II – TRIGA HD II	Pool-type / TRIGA MARK-I (0.25MW)	1999	Prompt Dismantling	2006	Released from regulatory control	
AEG- Nullenergiereaktor, Thermisch- Kritische Anordnung - TKA	Tank-type (1.0E-04MW)	1973	Prompt Dismantling	1981	Released from regulatory control	
AEG-Prüfreaktor – PR-10	Argonaut (1.8E-04MW)	1976	Prompt Dismantling	1978	Released from regulatory control	
Siemens Argonaut Reaktor - SAR	Argonaut (1.0E-03MW)	1968	Deferred Dismantling	1998	Released from regulatory control	
Siemens Unterkritische Anordnung - SUA	Sub Critical Assembly (0MW)	1968	Prompt Dismantling	1998	Released from regulatory control	
Siemens- Unterrichtsreaktor München – SUR-M	SUR-100 (1.0E-07MW)	1981	Prompt Dismantling	1998	Released from regulatory control	
Berliner Experimentier- Reaktor – BER I	L-54 (0.05MW)	1972	Prompt Dismantling	1974	Released from regulatory control	
Siemens- Unterrichtsreaktor Berlin – SUR-B	SUR-100 (1.0E-07MW)	1993	Prompt Dismantling	2000	Released from regulatory control	
Siemens- Unterrichtsreaktor Bremen – SUR-HB	SUR-100 (1.0E-07MW)	1993	Prompt Dismantling	2000	Released from regulatory control	
Siemens- Unterrichtsreaktor Hamburg – SUR- HH	SUR-100 (1.0E-07MW)	1992	Prompt Dismantling	1999	Released from regulatory control	
Forschungsreaktor Frankfurt -1 – FRF 1	L-54 (0.05MW)	1968	Deferred Dismantling	2006	Released from regulatory control	
Siemens- Unterrichtsreaktor Darmstadt – SUR- DA	SUR-100 (1.0E-07MW)	1985	Prompt Dismantling	1996	Released from regulatory control	

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Class IA - A						
Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
TRIGA-Hannover – FRH/TRIGA MHH	Pool-type / TRIGA MARK-I (0.25MW)	1996	Prompt Dismantling	2008	Released from regulatory control	
Forschungsreaktor MERLIN – FRJ-1	Pool-type / MTR (10MW)	1985	Prompt Dismantling	2007	Released from regulatory control	
Abbrandmessung differentieller Brennelemente mit kritischer Anordnung - ADIBKA	L77A (10E-04MW)	1972	Prompt Dismantling	1977	Released from regulatory control	
Kritische Anordnung für Hochtemperaturrea- ktoren - KATHER	Critical Assembly (1.0E-04MW)	1984	Prompt Dismantling	1988	Released from regulatory control	
Kritisches Experiment zum Incore-Thermionik- Reaktor - KEITER	Critical Assembly (1.0E-06MW)	1982	Prompt Dismantling	1988	Released from regulatory control	
Rossendorfer Anordnung für kritische Experimente - RAKE	Tank-type / Critical Assembly (1.0E-05MW)	1991	Prompt Dismantling	1998	Released from regulatory control	
Rossendorfer Ringzonenreaktor - RRR	Argonaut (1.0E-03MW)	1991	Prompt Dismantling	2000	Released from regulatory control	
Zittauer Lehr- und Forschungsreaktor - ZLFR	Tank-type / WWR-M (1.0E-05MW)	2005	Prompt Dismantling	2006	Released from regulatory control	
Anlage für Nulleistungsexperi- mente - ANEX	Critical Assembly (1.0E-04MW)	1975	Prompt Dismantling	1980	Released from regulatory control	
Nuclear cargo vessel "Otto Hahn" - OH	PWR / Propulsion Reactor (38MW)	1979	Prompt Dismantling	1982	Released from regulatory control	
Siemens- Unterrichtsreaktor Kiel – SUR-KI	SUR-100 (1.0E-07MW)	1997	Prompt Dismantling	2008	Released from regulatory control	

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Class IB – B, C, D & E						
Location	Facility Type	Shutdown	Decommissioning Strategy	Planned End Date	Status	Waste Onsite
Wieder-aufarbeitungs-anlage Karlsruhe - WAK	Reprocessing Facility	1990		2023	Dismantling	
Siemens Power Generation Karlstein - SPGK	Post-irradiation Examinations, Waste Incineration, Waste Water Treatment, MOX Production.	1989			Dismantling	
Brennelementewerk - NUKEM-A	Production of MTR Fuel Elements	1988		2006	Released from regulatory control	
Anlage zur Gewinnung von Mo-99 – AMOR I-II	Producer of Mo-99/Tc-99m	1991			Dismantling	
Plutonium-Testextraktion - PUTE	Plutonium-extraction research plant	1991	Prompt Dismantling	1996	Released from regulatory control	
Wiederaufarbeitungs-anlage im Millitonnen-Maßstab - MILLI	Reprocessing research plant	1991	Prompt Dismantling	2000	Released from regulatory control	
Siemens Brennelementewerk Hanau - SBWK	Fuel element production from uranium oxide with up to 4 % enrichment and gadolinium oxide	1993	Prompt Dismantling	1999	Released from regulatory control	
Hochtemperatur-reaktor-Brennelementfabrik - HOBEG	Production of HTR fuel spheres with particles from NUKEM-A	1988	Prompt Dismantling	1995	Released from regulatory control	
Siemens Brennelementewerk Hanau – SBH-Uran	Production of light water reactor fuel elements with an enrichment up to 5 %	1995	Prompt Dismantling	2006	Released from regulatory control	

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Class IB – B, C, D & E						
Location	Facility Type	Shutdown	Decommissioning Strategy	Planned End Date	Status	Waste Onsite
Siemens Brennelementewerk Hanau – SBH-MOX	Production of fuel elements for light water and fast breeder reactors on basis of mixed uranium/plutonium oxide	1991	Prompt Dismantling	2006	Released from regulatory control	
Juelich Pilot plant for Thorium Element Reprocessing - JUPITER	Research plant for reprocessing of HTR fuel spheres by incineration	1987	Prompt Dismantling	1987	Released from regulatory control	

Note: grayed out fields indicate where information was not readily available, or where contradictory information was found.

* shutdown for repairs, building permit granted and revoked, duration of legal battle.

** Shutdown, pending decommissioning licence.

DRR – Druckröhrenreaktor (similar to CANDU)

HDR – Hot Steam Reactor

BWR - Boiling Water Reactor

PWR - Pressure Water Reactor


GCHTR - Gas Cooled High Temperature Reactor

GCR - Gas Cooled Reactor

FSCR - Fast Sodium Cooled Reactor

A.4.1. Decommissioning Regulatory Framework

The Republic of Germany (similarly to Canada) has Federal (Bund) laws and provincial (Länder) laws and regulations. The Länder are responsible for the administration of the laws legislated by the Bund. Decommissioning Licensing and Oversight are the responsibility of the individual Länder.

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A.4.1.1. Statutes

The Atomic Energy Act empowers the Bund to issue ordinances and administrative regulations that are implemented by the Lander acting on behalf of the Bund. Decommissioning is conducted under the authority of the Atomic Energy Act (AtG) and its associated Ordinances. The Act stipulates that a decommissioning licence is required for both safe enclosure and dismantling activities (in its entirety or in phases). This licence is granted by the federal state authority through the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) which directs the Lander.

The Environmental Impact Assessment Act (UVPG) would also impact decommissioning.

Other Statutes pertaining to decommissioning include:

- Environmental Impact Assessment Act (UVPG);
- Radiation Protection Ordinance (StrlSchV);
- Nuclear Licensing Procedure Ordinance (AtVfV); and
- Nuclear Safety Officer and Reporting Ordinance (AtSMV).


A.4.1.2. Regulations

The Federal regulators are the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Office for Radiation Protection (BfS). There are no regulations specific to decommissioning, but the BMU within the Federal State Committee for Nuclear Energy and in association with the Decommissioning Working Committee of the Reactor Safety Technical Committee, prepared a Decommissioning Guideline that amalgamates requirements “scattered” through other legal and guidance documents. This Decommissioning Guide also proposes practical approaches to the decommissioning of nuclear facilities and serves to harmonize the licensing procedures pursuant to the Atomic Energy Act.

The regulatory authorities are assisted by technical safety organizations such as the Technical Inspection Agency (TÜV) or the organization for facility and reactor safety (GRS).

A.4.1.3. Licences

The Federal Government (Bund) is responsible for granting licences for nuclear facilities. Licences include: Concept (Planning), Construction, Operation, Decommissioning (One or many) and Termination Licences. The Decommissioning licences can be issued either for the decommissioning as a whole, or phase by phase.

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A.4.1.4. Other Codes and Standards


Recommendations of the Waste Management Commission (ESK), the Reactor Safety Commission (RSK) and the Commission on Radiological Protection (SSK), standards of the Nuclear Safety Standards Commission (KTA), and DIN standards need to be considered as they may also apply to decommissioning.

KTA Nuclear Standards that could be applicable to decommissioning include (68):

- KTA-1401 - General Requirements on Quality Assurance
- KTA-1501 - Stationary System for Monitoring the Local Dose Rate Within Nuclear Power Plants
- KTA-1503.3 - Monitoring the Discharge of Radioactive Gasses and Airborne Radioactive Particles: Part 3 Monitoring the Non-stack Discharge of Radioactive Matter
- KTA-1504 - Monitoring and Assessing the Discharge of Radioactive Substances in Liquid Effluents
- KTA-1508 - Instrumentation for Determining the Dispersion of Radioactive Substances in the Atmosphere
- KTA-2101.1 - Fire Protection in Nuclear Power Plants; Part 1: Basic Requirements
- KTA-3502 - Accident Measuring Systems
- KTA-3601 - Ventilation Systems in Nuclear Power Plants
- KTA-3602 - Storage and Handling of Fuel Assemblies and Associated Items in Nuclear Power Plants with Light Water Reactors
- KTA-3603 - Facilities for Treating Radioactively Contaminated Water in Nuclear Power Plants
- KTA-3604 - Storage, Handling and Plant-internal transport of radioactive substances in Nuclear Power Plants
- KTA-3605 - Treatment of Radioactively Contaminated Gasses in Nuclear Power Plants with Light Water

DIN Nuclear Standards that could be applicable to decommissioning include:

- DIN 25457-1 - Activity Measurement Methods for the Clearance of Radioactive Substances and Nuclear Facility Components - Part 1: Fundamentals
- DIN 25457-4 - Activity Measurement Methods in the Clearance of Radioactive Substances and Components of Nuclear Facilities - Part 4: Contaminated and Activated Metal Scrap

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- DIN 25457-7 - Activity Measurement Methods for the Release of Radioactive Waste Materials and Nuclear Facility Components - Part 7: (Nuclear) Sites
- DIN CWA 16519 - Design and Construction Code for Mechanical Equipments of Innovative Nuclear Installations
- DIN ISO 2889 - Sampling Airborne Radioactive Materials from the Stacks and Ducts of Nuclear Facilities
- DIN 25441-1 - Monitoring of Radioactivity in the Inner Atmosphere of Nuclear Power Plants; Safety Requirements
- DIN 25458 - Stationary System for the Surveillance of Local Dose-Rates Within Nuclear Power Stations; Safety Requirements

A.4.2. Responsibility

A.4.2.1. Decommissioning Planning, Execution and Completion


Neither the Atomic Energy Act nor the Ordinances made pursuant to the Act explicitly assign responsibility for decommissioning of a nuclear facility to any party. However, in August 2011, an amendment was made to the Atomic Energy Act to phase out nuclear power by 2022. According to the Act, the Licensee is responsible for ensuring that the decommissioning concept is feasible before final shutdown and a decommissioning plan must be submitted to and approved by the regulatory body prior to the acquisition of a decommissioning licence.

If the decommissioning is to be conducted in a phased approach, there needs to be an overarching document that defines the decommissioning throughout the phases as well as the individual phase's activities.

Decommissioning activities are subject to intensive, on site regulatory supervision with technical experts for the duration of the project.

A.4.2.2. Decommissioning Waste Management

Waste management is the responsibility of the waste generator. Where possible wastes are repatriated, but where that is not possible, the waste is stored for eventual disposal at the geological disposal facility (Konrad ca.2019) or at the heat-generating waste geological disposal facility (still conceptual ca. 2035).

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A.4.2.3. Funding

Decommissioning and waste management funds (with the exception of East German reactors) are managed by the utilities as a levy on power bills and the funds themselves are currently tax free. The funds are accumulated over an assumed 25 year life for the power stations. The decommissioning of reactors from the former German Democratic Republic (East Germany) are financed from the federal budget.

A.4.3. Decommissioning Strategy

According to the Atomic Energy Act, the operator of a nuclear facility may choose between prompt dismantling and deferred dismantling after a safe enclosure period. Recent decisions by operators of power reactors have been in favour of prompt dismantling, primarily due to cost considerations, social concerns and the availability of qualified and trained staff.

Two power reactors, KWL in Lingen and THTR-300 in Hamm-Uentrop, have chosen deferred dismantling. Safe enclosure has been licensed for THTR-300. Deferred decommissioning licencing requirements include having the conceptual decommissioning steps for the entire decommissioning process accepted by the regulatory body prior to the issuance of a decommissioning Licence.


A.4.4. Decommissioning Waste Strategy

In Germany there are 2 main waste categories: Heat Producing and Negligible Heat Producing Wastes.

Heat Producing Waste or High Level Waste (HLW) - This waste is dealt with by repatriation (where possible) or by onsite wet/dry storage (until permanent disposal options exist). There are currently no permanent disposal options in Germany for this type of waste, but there is a conceptual repository design and the goal is to have it operational by the year 2035.

Heat producing waste storage options include:

- the interim storage facilities at the nuclear power plant sites,
- the central interim storage facilities at Gorleben (TBL-G) and Ahaus (TBL-A),
- the interim storage facility “Zwischenlager Nord” (ZLN) near Greifswald (for used fuel from the Rheinsberg and Greifswald NPPs)
- the interim storage facility at Jülich (for the used fuel from the AVR reactor)
- the pilot conditioning plant at Gorleben (PKA).

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Negligible Heat Producing Waste or LILW – This waste is to be stored until such time as geological disposal is available. The current WAC for the proposed geological repository (Konrad) indicate that only stable (or fixed) radioactive waste will be accepted for disposal, so any liquid or gaseous waste would require conditioning prior to disposal.

The Konrad geological disposal facility is an old iron mine that is currently being refurbished (demolition of unnecessary surface facilities, reconstruction of mine shafts, repair of underground vehicles, hoisting and transport equipment). It is expected to be operational around 2019.

Waste Reduction is a primary concern in dealing with decommissioning waste. Waste is decontaminated, size reduced, melted down, etc. in an attempt to reduce the quantity that needs to be disposed of in the geological repository. The Konrad geological repository WAC does not permit cemented waste.

A.4.5. Decommissioning Regulatory Lessons Learned

Although there is a fair bit of information on technical decommissioning lessons learned, information on regulatory lessons learned is not readily available.


A.4.6. Sources of information

Sources consulted in the preparation of this section include:

- Radioactive Waste Management Programmes in OECD/NEA Member Countries – GERMANY, OECD/NEA, 2013.
- Nuclear Power in Germany, World Nuclear Association, January 2014.
- Radioactive Waste Management and Decommissioning in Finland, OECD/NEA, 2013.
- Nuclear Facilities in Germany, Bundesamt für Strahlenschutz, November 2013.
- Decommissioning Strategies, Bundesamt für Strahlenschutz, June 2013.
- Germany - Nuclear Regulatory Authority, European Nuclear Safety Regulators Group, February 2014.

A.5. Finland

Four (4) power reactors have been commissioned in Finland; all of these remain in operation and 3 more are planned. No power reactors have been decommissioned and the first reactors expected to be shutdown are the Loviisa reactors 1&2 with expected shutdown dates of 2027 & 2030 respectively.

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There is also one research reactor in Finland, the FiR 1 (a 250 kW TRIGA II research reactor) which has been in operation at VTT (Technical Research Centre of the Finnish State) in Espoo since 1962.

A.5.1. Decommissioning Regulatory Framework

A.5.1.1. Statutes

Decommissioning is conducted under the authority of the Nuclear Energy Act (990/1987) and Nuclear Energy Decree (161/1988) and their associated Government Decrees and regulatory guides. The Act and its associated Decree include some general provisions for decommissioning.

Other statutes that might impact decommissioning of large nuclear facilities include:

- The Radiation Act (1991/592); and
- Environmental Impact Assessment Act (1994).

A.5.1.2. Regulations


Nuclear Energy Decree (161/1988) was issued pursuant to the Nuclear Energy Act (990/1987) and it includes some general provisions for decommissioning.

Other decrees that might impact decommissioning of large nuclear facilities include:

- The Radiation Decree (1512/1991);
- Decree on the State Nuclear Waste Management Fund (1988);
- Government Decree on safety of nuclear power plants (717/2013);
- Government Decree on physical protection of nuclear power plants (734/2008);
- Government Decree on nuclear power plant emergency response arrangements (716/2013); and
- Government Decree on safety of the disposal of nuclear waste (736/2008).

A.5.1.3. Licences

The Finnish Government is responsible for granting licences for nuclear facilities and issuing general safety regulations while the Ministry of Employment and Economy (MEE) is responsible for the oversight of waste management and related R&D activities, ensuring that they comply with national policy and that financing of future waste management activities are adequately

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funded (through the State Nuclear Waste Management Fund). The Radiation and Nuclear Safety Authority (STUK), a government agency, is responsible for regulatory oversight, issuing detailed safety regulations and for the technical and safety-related review of licence applications and other important documents. As well as being a regulatory body, STUK also has administrative control of a central interim storage facility for small-user radioactive waste.

There are 2 classes of licences in Finland; those issued by the government and those issued by STUK. Those issued by the government are the Decision-in-Principle, Construction licence and Operating licence.

The key regulatory agency with regulatory oversight for decommissioning in Finland is the Radiation and Nuclear Safety Authority (STUK).

An application for a Construction Licence for a nuclear facility must show the feasibility of decommissioning and an application for an Operating Licence must include a plan for decommissioning of the nuclear facility. The utilities must update the decommissioning plans of NPPs for regulatory review every six years.

A.5.1.4. Other Codes and Standards


STUK issues detailed safety regulatory guides (YVL Guides) which have been recently updated (2013). One of these guides relates to decommissioning a nuclear facility and LILW processing and 6 more could be applicable to decommissioning (one of these is still in draft):

YVL D.1	Regulatory control of nuclear safeguards	15 Nov 2013
YVL D.2	Transport of nuclear materials and nuclear waste	15 Nov 2013
YVL D.3	Handling and storage of nuclear fuel	15 Nov 2013
YVL D.4	Predisposal management of low and intermediate level nuclear waste and decommissioning of a nuclear facility	15 Nov 2013
YVL D.5	Disposal of nuclear waste	15 Nov 2013
YVL C.3	Limitation and monitoring of radioactive releases from a nuclear facility	15 Nov 2013
YVL C.4	Radiological monitoring of the environment of a nuclear facility	(Draft)

These Guides are primarily for new build facilities still in the planning stages and will be applied to operating facilities or facilities under construction on a case by case basis.

A.5.2. Responsibility

Neither the Nuclear Energy Act and Decree nor the Government Orders made pursuant to the Act explicitly assign responsibility for decommissioning of a nuclear facility to any party. However, the operator (or future operator) is responsible for assessing and presenting the

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feasibility of decommissioning for inclusion in the Construction Licence application, and for preparing a decommissioning plan for inclusion with the Operating Licence application. STUK is responsible for the technical and safety reviews on the applications for Construction and Operating Licences that the Government approves.

A.5.2.1. Decommissioning Planning, Execution and Completion

According to the YVL Guide on Predisposal Management of Low and Intermediate Level Nuclear Waste and Decommissioning of a Nuclear Facility, the feasibility of decommissioning the facility must be addressed in order to obtain a Construction Licence and a decommissioning plan needs to be submitted with the application for the Operating Licence. These plans need to be updated every 6 years.

A.5.2.2. Decommissioning Waste Management


The operators of nuclear facilities are responsible for financing the management of the wastes that they generate. Currently, LILW is stored on site by the nuclear facilities (with the exception of smaller producers). The Radiation and Nuclear Safety Authority (STUK), as well as being a regulatory body, also has administrative control of a central interim storage facility for small user radioactive waste. Responsibility for HLW (Used Fuel) has been assigned to Posiva Oy, a company owned jointly by FPH and TVO (Similar to Canada's NWMO), for the purposes of developing and implementing a Used Fuel disposal facility.

A.5.2.3. Funding

Funding of future Decommissioning and Waste Management costs are managed by including the costs into the price of nuclear electricity. They are managed in such a way as to ensure that the assets will be available even if something happens to the waste generator.

The funds are collected, held and invested by the MEE as the State Nuclear Waste management Fund. The power utilities and the operators of the research reactor pay annual fees to cover their liabilities. Should their liabilities decrease, there is a mechanism for them to be paid back from the fund. The whole of the liability is covered by each facility either by money or securities. The amount to be funded is determined by cost estimates based on the remaining management costs of existing waste amounts, current prices, and on the use of currently available technology. This fund covers the costs of all spent fuel and nuclear wastes management and decommissioning activities, including R&D.

The 2012 estimate for the management of all waste from operation and decommissioning in Finland is estimated at about 2,200 million Euros.

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A.5.3. Decommissioning Strategy

The YVL Guide on Predisposal Management of Low and Intermediate Level Nuclear Waste and Decommissioning of a Nuclear Facility indicates that “Implementation of decommissioning shall not be unjustifiably postponed.” This could imply that the preferred strategy for Finland is Prompt Dismantling, but that all options would be considered if justifiable.

The decommissioning strategies for Finnish NPPs:

- Loviisa NPP - Prompt Dismantling within eight years from shutdown
- Olkiluoto Units 1&2 - Deferred Dismantling with a 30 year deferral (due to likelihood of other operating units on site – Unit 3)
- Olkiluoto Unit 3 (Tentative) - Prompt Dismantling.

A.5.4. Decommissioning Waste Strategy

The Nuclear Energy Act states that only the nuclear waste generated in Finland will be handled, stored and permanently disposed of in Finland. Current plans are for decommissioning wastes to be co-located with the operational wastes in extensions of the existing disposal facilities.

In Finland, waste is classified according to its disposal route:

- Used Fuel - Geological Repository (to be constructed near the Olkiluoto site)
- LILW - Disposal in rock caverns at intermediate depth (located at the NPP sites)
- VLLW - Released without further radiological control for disposal into landfill or recycling in the metal industry


Large components, such as pressure vessels and steam generators, are planned (in the current NPP decommissioning plans), to be emplaced into the disposal shafts or vaults without cutting them into smaller pieces.

A Spent Fuel disposal site has been selected (near Olkiluoto) and construction of an underground rock characterization facility began in 2004. Plans are for the construction of the DGR to commence around 2015 and for the facility to be ready to accept waste by 2020.

FPH and TVO have rock cavern-type repositories for operational LILW at their NPP sites.

A.5.5. Decommissioning Regulatory Lessons Learned

Although there is a fair bit of information on technical decommissioning lessons learned, information on regulatory lessons learned is not readily available.

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A.5.6. Sources of information

Sources consulted in the preparation of this section include:

- Radioactive Waste Management Programmes in OECD/NEA Member Countries – FINLAND, OECD/NEA, 2013.
- Nuclear Power in Finland, World Nuclear Association, January 2014.
- Finland – Nuclear Regulatory Authority, European Nuclear Safety Regulators Group, February 2014.
- Regulations, STUK, February 2014.

A.6. Italy

Four (4) power reactors were commissioned in Italy between 1963 and 1978 but all were shut down between 1982 and 1990:

- Latina – a 153 MWe GCR that operated from 1963 to 1987;
- Garigliano – a 150 MWe BWR that operated from 1964 to 1982;
- Enrico Fermi (Trino Vercellese) – a 260 MWe PWR that operated from 1964 to 1990; and
- Caorso – a 860 MWe BWR that operated from 1978 to 1990.

Work on several other planned nuclear power plants was halted before completion. Five small research reactors (1 MW or less) remain in operation and another 5 are ‘not operating’.


No power reactors have been completely decommissioned but decommissioning of the nuclear island of the Trino Vercellese nuclear power plant started in 2012 and it is anticipated that the site is to be released for new development in 2024.

Decommissioning of several other small nuclear facilities including a fuel fabrication plant and four experimental/prototype facilities (a post-irradiation examination facility, two pilot fuel reprocessing facilities and a pilot plutonium fuel fabrication facility) is either underway or pending.

The status of decommissioning facilities in Italy is provided in Table 8.

Table 8 Status of Decommissioning Facilities in Italy

Class IA - A						
Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Latina	GCR (153MW)	1987	Deferred Dismantling	2035	Safe Enclosure	

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Class IA - A						
Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Garigliano	BWR (150MW)	1982	Deferred Dismantling	2025	Dismantling	
Enrico Fermi	PWR (260MW)	1990	Deferred Dismantling	2024	Dismantling	
Caorso	BWR (860MW)	1990	Deferred Dismantling	2026	Dismantling	
Bosco Marengo				2022	Dismantling	
Trisaia				2026		
Saluggia				2029		
Casaccia				2025		
Class IB – B, C, D & E						
Location	Facility Type	Shutdown	Decommissioning Strategy	Planned End Date	Status	Waste Onsite
SOGIN Pilot U-Th Reprocessing Plant	Re-processing and fabrication of fuel	1978		2018	Dismantling	

Note: grayed out fields indicate where information was not readily available, or where contradictory information was found.

A.6.1. Decommissioning Regulatory Framework


Legislation has to be passed by both chambers of the Italian Parliament, promulgated by the President and then published in the Gazzetta Ufficiale della Repubblica and the official statute book, the Raccolta Ufficiale delle leggi e dei Decreti.

The Government can issue Decreti legge when the parliament has officially delegated the power to do so, or in cases of urgent necessity.

A.6.1.1. Statutes

The regulatory regime for decommissioning is largely based on 2 Laws:

- Framework Act on the Peaceful Uses of Nuclear Energy (No. 1860 of 31 December 1962) introduces a general regime based on a series of procedural requirements such as notifications and licences. Amendments were subsequently made under which small quantities of special fissile materials, raw materials and other radioactive materials were

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no longer subject to such formalities (Act No. 1008 of 9 December 1969; Ministerial Decree of 15 December 1970).


- Articles 25, 26 and 29 of Law No. 99 of 23 July 2009 include enabling provisions empowering the Government to issue one or more implementing decrees providing rules for the siting of new nuclear power plants, the licensing process for the construction, operation and dismantling of those plants, as well as rules for interim storage and the final disposal of nuclear waste.

A.6.1.2. Regulations

The Legislative Decrees issued by the Italian Government that are relevant to the decommissioning of nuclear facilities include:

- Legislative Decree No. 230 of 17 March 1995 related to the safety of nuclear installations and the protection of workers and the general public against the hazards of ionising radiation arising from the peaceful uses of nuclear energy. This decree provided, inter alia, for the implementation of existing Euratom Directives on radiation protection.
- Legislative Decree No. 241 of 26 May 2000 which amends and completes the previous decree, taking into account the provisions of Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation, in particular with regard to natural sources of ionising radiation, interventions and possible exposure.
- Legislative Decree No. 187 of 26 May 2000, which implements Council Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionising radiation in relation to medical exposure, and repealing Directive 84/466/Euratom.
- Legislative Decree No. 99 of 17 March 1999 (issued pursuant to Law No. 86 of March 9, 1989) which is also called the Bersani Decree, transferred all of the nuclear assets, liabilities and resources of ENEL (Ente Nazionale per l'Energia Elettrica, Italian Electricity Generating Board) to a newly established company, named SO.G.I.N. (Società Gestione Impianti Nucleari), which is now responsible for maintaining and decommissioning these facilities.

In addition, Legislative Decree no. 31/2010 provides criteria for the selection of the site for a national radioactive waste disposal facility and makes SOGIN responsible for the site selection procedure with the involvement of local administration, for the approval and for the compensation of the local municipality.

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A.6.1.3. Licences

Licensing (or Authorization) of decommissioning activities is regulated by articles 55, 56 and 57 of Legislative Decree no. 230/1995. The Ministry of Economic Development is the authority which grants the licence for nuclear activities from the design and construction to the decommissioning and waste disposal. Licences are granted on the basis of the:

- Technical advice and specifications formulated by the Regulatory Authority (ISPRA – Institute for the Environmental Protection and Research);
- Environmental assessment provided by the Ministry of the Environment Land and Sea, when applicable, and
- Other advice provided by the Ministries for the Interior; Labour, Health and Social Affairs; and by the Region where the installation is located.

The applicant for a licence is required to submit a Global Decommissioning Plan and a more detailed report related to the first decommissioning phase.


A.6.1.4. Other Codes and Standards

The National Standardization Organization (UNI) has prepared a series of Technical Standards on the decommissioning of nuclear facilities:

- UNI 9498/1 - General criteria
- UNI 9498/2 - Decontamination techniques
- UNI 9498/3 - Storage and surveillance
- UNI 9498/4 - Dismantling of structures and components
- UNI 9498/5 - Radioactive inventory
- UNI 9498/6 - Radiological characterization and classification of materials
- UNI 9498/7 - Criteria for partial release of a nuclear plant and/or site
- UNI 9498/8 - Requirements for the temporary storage of radioactive wastes and materials

The categorization scheme for radioactive waste is established in ISPRA Technical Guide No. 26 which recognizes three categories:

- Category I (disposal performed according to general waste regulations): Wastes which decay in a few months to radioactivity level below safety concerns (mainly hospital and research waste with $T_{1/2} < 1$ year);

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- Category II (near surface disposal): Wastes which decay to radioactivity level of a few hundreds of Bq/g within a few centuries (and the activity of several radionuclides does not exceed specified limits); and
- Category III (deep geological disposal): Long lived waste not included in category I or II; high level waste from reprocessing of spent fuel and alpha bearing waste from the fuel cycle and R&D activities.

UNI has also released a series of standards on the management of low level radioactive waste based on the requirements of a generic near surface disposal facility.

A.6.2. Responsibility

A.6.2.1. Decommissioning Planning, Execution and Completion

Legislative Decree No. 99 of 17 March 1999 (issued pursuant to Law No. 86 of March 9, 1989) which is also called the Bersani Decree, transferred all of the nuclear assets, liabilities and resources of ENEL (Ente Nazionale per l'Energia Elettrica, Italian Electricity Generating Board) to a newly established company, named SOGIN (Società Gestione Impianti Nucleari). SOGIN is a state-owned company that was original part of the ENEL Group but it is now 100% owned by the Italian Ministry of the Economy and Finance.

SOGIN is responsible for the management and decommissioning of:


- The four former ENEL nuclear power plants (Latina, Garigliano, Trino Vercellese and Caorso); and
- Four ENEA (Agency for New Technologies, Energy and Sustainable Economic Development) nuclear fuel cycle research facilities (two in the Casaccia research centre, one in Saluggia and one in Rotondella); and
- The Fabbricazioni Nucleari (FN) nuclear fuel fabrication plant in Bosco Marengo.

A.6.2.2. Decommissioning Waste Management

SOGIN is responsible for the selection of the site for a national radioactive waste disposal facility and for the management of radioactive waste generated by research, nuclear medicine and industrial activities.

A.6.2.3. Funding

ENEL started to set aside funds for the decommissioning while the nuclear power plants were still into operation. This funding was based of the estimated cost of maintaining the plants in a

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SafeStor condition for 40 years before dismantling. These funds have been transferred to SOGIN but the early shut down of these plants, together with the decision to accelerate the decommissioning means that these funds will not adequate to complete the decommissioning.

No funds were set aside for the decommissioning of the ENEA research facilities.

Additional funding is being raised through a levy on the price of electricity. The levy is paid by electricity users and it is adjusted every 3 years on the basis of decommissioning and waste management cost estimates prepared by SOGIN. The funds collected from the levy are managed in a segregated fund supervised by the National Authority for Electricity and Gas (AEEG).

A.6.3. Decommissioning Strategy


When the government decided to finally end the country's nuclear power program in 1990, a deferred decommissioning (or SAFSTOR) strategy was adopted. However, in 1999, the Ministry of Industry, Commerce and Crafts (now Ministry of Economic Development) issued a strategy document providing guidelines for the management of liabilities resulting from past national nuclear activities.

Key aspects of this policy were the:

- adoption of the strategy for an immediate decommissioning (IAEA level 3) of all national shut-down nuclear installations, thus abandoning the previous “safe storage” option;
- treatment and conditioning of all radioactive waste stored at the nuclear sites; and
- imposition of a special charge on electricity bills to fund these activities.

The directive established the year 2020 as the deadline for the completion of these activities (in 2004, the deadline for decommissioning was put back to 2024, and the option of reprocessing was allowed). The reasons for selecting the target date were:

- The retention of nuclear skills and knowledge is problematic in a country that has — at least for the time being — abandoned nuclear power.
- Each nuclear plant was based on a single unit site and storage expenses could not be shared between any plants, increasing total costs.
- More than 12 years had elapsed since all the nuclear plants had shutdown, weakening the argument for waiting for radioactivity to decrease.
- The social and industrial context made it difficult to reassign plant personnel, so it was extremely important to maintain their services within the decommissioning sphere.
- With good planning on a national level, a constant number of staff could be maintained, with personnel shared between sites; this could be achieved by accelerating the timescale.

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- The accumulation of decommissioning experience in a shorter period would allow the company to expand into the international decommissioning market.
- The sites could be reused for other industrial applications, including electrical power stations.

The new policy was implemented by a Ministerial Decree of January 26, 2001, which established the plans and procedures for funding the activities associated with decommissioning of NPPs and nuclear fuel-cycle facilities. The strategy defined in this Decree was further detailed by another Ministerial Decree of May 7, 2001, which directed SOGIN to implement prompt decommissioning of the four national NPPs with a view to unconditional release of their respective sites within twenty years. The Decree also charged SOGIN with the safe management of radioactive waste and spent fuel from these NPPs using funds provided by the levy on electricity sale.

In 2003, SOGIN was also given responsibility to decommission the fuel cycle facilities owned by ENEA and the nuclear fuel fabrication plant owned by FN.

A.6.4. Decommissioning Waste Strategy

The 1999 strategy document also provided for the:

- selection of a national site to build a near surface repository for low and intermediate level waste and an interim storage facility for the spent fuel and Category III (high level) waste; and
- establishment of a National Agency for the management and disposal of radioactive waste, whose main mandate would be to realize and operate the national radwaste disposal site.

A.6.5. Decommissioning Regulatory Lessons Learned


Issues that continue to hinder decommissioning are:

- Lack of a national site for the disposal of LLW; and
- Lack of a centralised interim storage facility for ILW and HLW or a national site for their disposal.

A.6.6. Sources of information

Sources consulted in the preparation of this section include:

- Radioactive Waste Management and Decommissioning in Italy, OECD/NEA, 2013.

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- Radioactive Waste Management Programmes in OECD/NEA Member Countries – ITALY, OECD/NEA, 2013.
- Nuclear Power in Italy, World Nuclear Association, September 2013.
- Italian Decommissioning Programme Overview, SOGIN, March 2013.
- Nuclear Legislation in OECD Countries – Italy, OECD, 2010.

A.7. Sweden

Thirteen (13) power reactors have been commissioned in Sweden and 10 of these remain in operation. No power reactors have been completely decommissioned but:

- The 12 MW prototype PHWR power reactor in Ågesta was permanently shut down in 1974 and is currently in Safe Storage; and
- Two 615 MW BWR reactors in Barsebäck were permanently shut down in 1999 and 2005, dismantling of these reactors is currently scheduled to begin in 2022.


Two material test reactors in Studsvik (one tank type and one mobile pool type) were permanently shut down in 2005. Decommissioning of several small nuclear facilities in Studsvik is either underway or nearing completion.

Sweden's first reactor, R1, was in operation between 1954 and 1970. The reactor itself was dismantled in the early 1980s, but the reactor hall is still in place.

The status of decommissioning facilities in Sweden is provided in Table 9.

Table 9 Status of Decommissioning Facilities in Sweden

Class IA - A						
Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Ågesta	PHWR (12MW)	1974	Deferred Dismantling	2026	Safe Enclosure	
Barsebäck 1	BWR (615MW)	1999	Deferred Dismantling	2023	Safe Enclosure	
Barsebäck 2	BWR (615MW)	2005	Deferred Dismantling	2023	Safe Enclosure	
Studsvik – R2	Tank Type (50MW)	2005	Prompt Dismantling	2018	Dismantling	No
Studsvik – R2-0	Mobile Pool Type (1MW)	2005	Prompt Dismantling	2018	Dismantling	No
Studsvik - R1	Underground experimental reactor	1970	Prompt Dismantling	1980's	Dismantled (reactor hall still remains)	

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Class IB – B, C, D & E						
Location	Facility Type	Shutdown	Decommissioning Strategy	Planned End Date	Status	Waste Onsite
Ranstad	Uranium Mining and Milling Facility	2009	Prompt Dismantling	2016	Dismantling	
Studsvik - Active Central Laboratory	Research and MOX fuel production	1997		2006	Dismantling Completed	
Studsvik – 2 Underground Silos for Liquid ILW	Liquid ILW Storage Facility		Prompt Dismantling		Decontaminated and partially dismantled	

Note: grayed out fields indicate where information was not readily available, or where contradictory information was found.

A.7.1. Decommissioning Regulatory Framework

In Sweden, lagar (Acts) are passed by the Riksdag (Parliament) and förordningar (Ordinances) are issued by the Government. föreskrifter (Regulations) are issued by governmental agencies pursuant to acts and ordinances.

A.7.1.1. Statutes

Decommissioning is conducted under the authority conferred by licences granted under the Act on Nuclear Activities and the regulations issued pursuant to that Act.


Other statutes that might impact decommissioning of large nuclear facilities include:

- The Radiation Protection Act;
- The Act on Financing of Management of Residual Products from Nuclear Activities; and
- The Environmental Code.

A.7.1.2. Regulations

Ordinances (equivalent to Regulations in Canada) made under the Act on Nuclear Activities and the Radiation Protection Act that would apply to decommissioning include:

- The Ordinance on Nuclear Activities; and

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- The Ordinance on Radiation Protection.

A.7.1.3. Licences

Section 5 of the Act on Nuclear Activities requires:

“A licence under this Act is required for nuclear activities. Matters concerning licences shall be considered by the Government or the public authority appointed by the Government.”

The Act defines “nuclear activities” as:

- *“the construction, possession or operation of a nuclear facility,*
- *acquisition, possession, transfer, handling, processing, transport of or other dealings with nuclear material or nuclear waste,*
- *import of nuclear material or nuclear waste into the country, and*
- *export of nuclear waste from the country.”*


Operation of a nuclear facility requires a licence under the Nuclear Activities Act and permissibility under the Environmental Code.

Licences can be issued by the Government or by a public authority appointed by the Government. The public authority appointed by the government to be responsible for the licensing under the:

- Environmental Code is Sveriges Domstolar (Environmental Court); and
- Act on Nuclear Activities is Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority).

In certain cases, the Municipal Council may have veto power over an application but the Government may override that veto and issue a licence if the application is of sufficient importance to the national interest.

The Environmental Courts are special administrative courts that deal with environmental and water issues, property registration and planning and building matters. The Court considers applications for permits for environmentally hazardous activities under the Environmental Code and holds hearings on their acceptability before rendering an opinion on the acceptability of the application. If the Government declares the application permissible under the Environmental Code, the Court may issue a permit and stipulate any conditions necessary to ensure compliance with the Environmental Code.

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The Swedish Radiation Safety Authority reports to the Ministry of the Environment and has a mandate from the Government within the areas of nuclear safety, radiation protection and nuclear non-proliferation. The Authority reviews applications for licences under the Act on Nuclear Activities and may issue a licence (or make a recommendation to the Government). Licences issued under the Act on Nuclear Activities may contain any condition(s) considered necessary from the standpoint of safety. The Authority may also give direction to a licensee to ensure compliance with the conditions, to access a site or obtain any information or documents necessary to verify compliance and to act if the licensee fails to take the actions necessary to maintain compliance.

A.7.1.4. Other Codes and Standards

The Swedish Radiation Safety Authority has also issued Regulations (equivalent to Regulatory Documents in Canada) pursuant to the Acts and Ordinances on issues related to ionizing and non-ionizing radiation.

The main Regulations that are relevant to decommissioning and waste management are:


- The Regulations Concerning Safety in Nuclear Facilities (2008:1, Consolidated version with amendments made up to and including SSMFS 2011:3);
- The Regulations Concerning the Protection of Human Health and the Environment in Connection with the Final Management of Spent Nuclear Fuel and Nuclear Waste (2008:37);
- The Regulations on Planning before and during Decommissioning of Nuclear Facilities (2008:19); and
- The Regulations Concerning Safety in Connection with the Disposal of Nuclear Material and Nuclear Waste (2008:21).

A.7.2. Responsibility

A.7.2.1. Decommissioning Planning, Execution and Completion

Two Sections of the part of the Act on Nuclear Activities entitled “General Obligations for Licensees” define the responsibility for decommissioning of a nuclear activity:

“Section 10 A party that holds a licence for nuclear activities shall be responsible for ensuring that all the necessary measures are taken for:

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3. safe decommissioning and dismantling of facilities in which the operation shall be discontinued until all operations at the facilities have ceased and all nuclear material and nuclear waste have been placed in a repository that has been sealed permanently.

“Section 14 The obligations under Section 10 shall remain until they have been fulfilled, regardless of whether:

- 1. a licence has been revoked,*
- 2. a licence expires,*
- 3. the right to operate a nuclear power reactor has ceased under the repealed Act on Nuclear Power Phase-Out (1997:1320), or*
- 4. a nuclear power reactor has been permanently shut down.*


Despite the first paragraph, an exemption from the obligations imposed under Section 10 may be granted by the Government or the public authority appointed by the Government.”

Section 4 of The Regulations on Planning before and during Decommissioning of Nuclear Facilities requires:

“The licensee shall ensure that there are preliminary plans for future decommissioning of the facility. The plans shall include the items referred to in Sections 5 to 8.

Plans shall be kept up to date and shall be revised in the event of changes to the facility or operations at the facility.

Certain regulations of the Swedish Work Environment Authority and the Swedish Radiation Safety Authority contain rules concerning work environment matters and safety that are applicable in connection with the planning of decommissioning and demolition of nuclear facilities.”

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Sections 5 through 8 of the Regulation address:

- Documentation;
- Analysis of Decommissioning Alternatives;
- Investigations Concerning Radioactive Materials; and
- Organizational Matters.

Sections 9 and 10 of the Regulation require:

“Section 9 The licensee shall within one year after final shutdown of the facility submit to the Swedish Radiation Protection Authority a general report explaining objectives, measures and a time schedule for decommissioning ...


Section 10 The licensee shall prior to commencement of dismantling and demolition of systems or facility parts containing radioactive material submit a report to the Swedish Radiation Safety Authority covering ...”.

A.7.2.2. Decommissioning Waste Management

The Act on Nuclear Activities defines nuclear waste as:

- “a. spent nuclear fuel that has been placed in a repository,*
- b. radioactive material that has been generated in a nuclear facility and that has not been produced at or taken from the facility to be used for educational or research purposes or for medical, agricultural engineering or commercial purposes,*
- c. material or item that has belonged to a nuclear facility and become contaminated by radioactivity and which shall no longer be used in such facility, and*
- d. radioactive parts of a nuclear facility that is being decommissioned,”*

Section 10 of The Act on Nuclear Activities defines the responsibility for managing radioactive wastes:

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“Section 10 A party that holds a licence for nuclear activities shall be responsible for ensuring that all the necessary measures are taken for:

2. safe management and disposal of nuclear waste generated by the operation or nuclear material derived from the operation that is not reused,“

A.7.2.3. Funding


Section 14 of the Act on Nuclear Activities defines the responsibility for decommissioning funding:

“Section 13 *A party that holds a licence to conduct nuclear activities is obliged to:*

- 1. bear the costs for the measures referred to in Sections 10 to 12, and*
- 2. have an organisation for the activity with sufficient financial, administrative and human resources in order to implement:*
 - a) the measures referred to in Sections 10 to 12,*
 - b) measures ensuing from conditions or regulations issued under this Act, and*
 - c) protective measures in the event of disruptions in the operations or accidents in the facility.*

The Act on Financing of Management of Residual Products from Nuclear Activities (2006:647) contains provisions regarding the obligation of licensees to bear certain costs incurred by the State and to ensure financing of the costs referred to in the first paragraph.”

The Act on Financing of Management of Residual Products from Nuclear Activities contains provisions for the future costs of spent fuel and nuclear waste disposal, decommissioning of reactors and other nuclear installations and research in the field of nuclear waste.

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A.7.3. Decommissioning Strategy

No particular decommissioning strategy is prescribed but section 6 of The Regulations on Planning for and during Decommissioning of Nuclear Facilities requires that the Licensee prepare an analysis of the decommissioning alternatives:

“Section 6 Plans must identify possible decommissioning methods with estimated time requirements and ultimate objectives. Any consequences of the identified alternatives shall be investigated concerning


- 1. occupational radiation doses,*
- 2. emissions of radioactive substances to the environment,*
- 3. risk of unplanned events that may cause radiation doses or emission of radioactive substances,*
- 4. handling and storage of radioactive material that arises and*
- 5. requirements of information for and training of various personnel categories.”*

All three of the power reactors that have been shutdown have adopted a ‘deferred dismantling’ strategy.

A.7.4. Decommissioning Waste Strategy

There is no legally prescribed waste classification scheme in Sweden but 4 categories of radioactive waste have been recognized by repository operators:

- Very Low Level Waste (VLLW) – VLLW may be cleared for recycling or disposal in municipal landfills (although it does not appear that this option has been used) or it may be managed in near-surface facilities located at each of the four major nuclear sites;
- Low & Intermediate Level Waste (Short-lived) – At present, there is no disposal facility for short-lived LILW from decommissioning but SKB is currently in the final stages of preparing an application for major expansion of the SFR facility to accommodate decommissioning wastes;
- Low & Intermediate Level Waste (Long-lived) – At present, there is no disposal facility for long-lived LILW from decommissioning but it is anticipated that a disposal facility will be built near one of the other final repositories;

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- Spent Fuel – At present, spent fuel is stored at a central interim storage facility near the Oskarshamn nuclear power plant. A site for a disposal facility has been selected in Forsmark and applications were submitted in March 2011 to the Swedish Radiation Safety Authority and to the Land and Environment Court to build the spent fuel repository.

Svensk Kärnbränslehantering AB (SKB, Swedish Nuclear Fuel and Waste Management Company) was established by the nuclear power companies to be responsible for the operation and management of the central repositories for Low & Intermediate Level Waste and Spent Fuel.

A.7.5. Decommissioning Regulatory Lessons Learned

Although there is a fair bit of information on technical decommissioning lessons learned, information on regulatory lessons learned is not readily available.

A.7.6. Sources of information


Sources consulted in the preparation of this section include:

- Radioactive Waste Management and Decommissioning in Sweden, OECD/NEA, 2013.
- Radioactive Waste Management Programmes in OECD/NEA Member Countries – SWEDEN, OECD/NEA, 2013.
- Nuclear Power in Sweden, World Nuclear Association, January 2014.
- Decommissioning of Nuclear Facilities in Sweden, Swedish National Council for Nuclear Waste, December 2007.
- Decommissioning, Strålsäkerhetsmyndigheten, December 2012.

A.8. United Kingdom

At present there are 10 nuclear power reactors operating at 8 sites in the United Kingdom. In addition to several military-related facilities there are also:

- One operating research reactor;
- A mixed oxide (MOX) fuel fabrication plant that manufactures reactor fuel from uranium and plutonium separated from used fuel at the Thermal Oxide Reprocessing Plant (THORP) at Sellafield; and
- Two operational low level radioactive waste disposal facilities.

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Twenty-nine (29) nuclear power reactors have been shut down and are being decommissioned or have completed decommissioning (see Table 10). Research and prototype reactors that are being or have been decommissioned include:

- DIMPLE, JUNO, NESTOR, PILE 1, PILE 2, ZEBRA, ZENITH and ZEUS research reactors on the Winfrith site;
- BEPO, DIDO, GLEEP, LIDO and PLUTO research reactors on the Harwell site;
- Dounreay Materials Test Reactor on the Dounreay site (the Dounreay Submarine Prototype Reactor 1 and the Shore Test Facility operated by the Vulcan Naval Reactor Test Establishment located on the Dounreay site are scheduled to be shutdown in 2015); and
- CONSORT (Imperial College London), JASON (Greenwich), Queen Mary College (Stratford Marsh), Scottish Universities Research Reactor (East Kilbride), Universities Research Reactor (Risley).


A variety of other civilian nuclear facilities have also been shutdown or fully decommissioned. The status of decommissioning facilities in the United Kingdom is provided in Table 10.

Table 10 Status of Decommissioning Facilities in the United Kingdom

Class IA - A						
Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Berkeley 1 & 2	Magnox (138 MWe each)	1988 & 89	Deferred Dismantling		Preparing for 'Care & Maintenance' (expected to begin in 2021), 11 ha of land de-licensed	
Bradwell 1 & 2	Magnox (123 MWe each)	2002 & 03	Deferred Dismantling		Preparing for 'Care & Maintenance' (expected to begin in 2015)	
Calder Hall 1,2,3 & 4	Magnox (50 MWe each)	2003	Deferred Dismantling		Preparing for 'Care & Maintenance' (interim C&M expected to begin in 2017)	

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Class IA - A						
Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Chapelcross 1,2,3 & 4	Magnox (49 MWe each)	2004	Deferred Dismantling		Preparing for 'Care & Maintenance' (interim C&M expected to begin in 2019)	
Dragon (Winfrith)	HTGCR (20 MWe)	1976			Decommissioning, expected to be complete in 2021	
Dounreay Fast Reactor (Dounreay)	FBR (14 MWe)	1977			Preparing to remove liquid metal	
Dungeness A1 & A2	Magnox (225 MWe each)	2006	Deferred Dismantling		Preparing for 'Care & Maintenance' (interim C&M expected to begin in 2019)	
Hinkley Point A1 & A2	Magnox (235 MWe each)	2000	Deferred Dismantling		Preparing for 'Care & Maintenance' (expected to begin in 2025)	
Hunterston A1 & A2	Magnox (160 MWe each)	1989 & 90	Deferred Dismantling		Preparing for 'Care & Maintenance' (expected to begin in 2022)	
Oldbury 1 & 2	Magnox (217 MWe each)	2011 & 12	Deferred Dismantling		Preparing for 'Care & Maintenance' (expected to begin in 2027), 35 ha of land de-licensed	
Prototype Fast Reactor (Dounreay)	FBR (250 MWe)	1994			Preparing to remove liquid metal	
Sizewell A1 & A2	Magnox (210 MWe each)	2006	Deferred Dismantling		Preparing for 'Care & Maintenance' (interim C&M expected to begin in 2027)	


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Class IA - A						
Reactor (Location)	Type (Thermal Power)	Shutdown	Decommissioning Strategy	Planned End Date	Status	Fuel Onsite
Trawsfynydd 1 & 2	Magnox (196 MWe each)	1993	Deferred Dismantling		Preparing for 'Care & Maintenance' (interim C&M expected to begin in 2016)	
Winfrith Steam Generating Heavy Water Reactor	SGHWR (100 MWe)	1990			Preparing detailed plan to remove reactor core, expected to be complete in 2021	
Windscale Advanced Gas Cooled Reactor (Winfrith)	AGR (33 MWe)	1981		2015	Being used as a pilot project to demonstrate techniques for reactor decommissioning	
Class IB – B, C, D & E						
Location	Facility Type	Shutdown	Decommissioning Strategy	Planned End Date	Status	Waste Onsite
BNFL, B204 Primary Separation Plant	Reprocessing Facility	1973	Deferred Dismantling	2090		
Sellfield – B243 Intermediate Waste Recovery	Solid Waste Storage Cells	1986	Deferred Dismantling	2040		
BNFL Co-precipitation Plant	Production of mixed plutonium and UO ₂ fuel	1976		1990	Dismantling Completed	

Note: grayed out fields indicate where information was not readily available, or where contradictory information was found.

Acronyms used in the table:

AGR	Advanced Gas-cooled Reactor
FBR	Fast Breeder Reactor
HTGCR	High Temperature Gas Cooled Reactor
SGHWR	Steam Generating Heavy Water Reactor

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A.8.1. Decommissioning Regulatory Framework

In the United Kingdom, Acts are passed by Parliament and Regulations are made by the Queen-in-Council (the government). In the nuclear field, a division is sometimes made between Acts and Regulations that deal with protection of people (such as the radioactive Substances Act and the Health and Safety at Work, etc Act) and those concerned with licensing and controlling the operation of nuclear facilities (such as the Nuclear Installations Act)..

A.8.1.1. Statutes

Decommissioning is conducted under the authority conferred by licences granted under the Nuclear Installations Act 1965 and the regulations issued pursuant to that Act.

Other statutes that might impact decommissioning of large nuclear facilities include:


- Health and Safety at Work, etc Act 1974;
- The Environment Act 1965;
- The Energy Act 2004; and
- The Radioactive Substances Act 1993 (in force in Scotland and Northern Ireland and generally equivalent to the Environmental Permitting (England and Wales) Regulations).

A.8.1.2. Regulations

Regulations are made by the Queen-in-Council pursuant to Act passed by Parliament.

Regulations that might impact decommissioning of a large nuclear facility include:

- Nuclear Installations Regulations 1971;
- Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999;
- Radioactive Contaminated Land Regulations 2007 (separate but similar regulations were made for each of England & Wales, Scotland and Northern Ireland);
- Ionizing Radiation Regulations 1999;
- Justification of Practices Involving Ionizing Radiation Regulations 2004;
- Environmental Permitting (England and Wales) Regulations 2010 (generally equivalent to The Radioactive Substances Act 1993 in Scotland and Northern Ireland);
- Radiation (Emergency Preparedness and Public Information) Regulations 2001; and

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- Management of Health and Safety at Work Regulations 1999.

A.8.1.3. Licences

Section 1 of the Nuclear Installations Act 1965 requires:

“1 Restriction of certain nuclear installations to licensed sites.

... no person shall use any site for the purpose of installing or operating—

(a) any nuclear reactor (other than such a reactor comprised in a means of transport, whether by land, water or air); or

(b) subject to subsection (2) of this section, any other installation of such class or description as may be prescribed, being an installation designed or adapted for—

(i) the production or use of atomic energy; or

(ii) the carrying out of any process which is preparatory or ancillary to the production or use of atomic energy and which involves or is capable of causing the emission of ionising radiations; or


(iii) the storage, processing or disposal of nuclear fuel or of bulk quantities of other radioactive matter, being matter which has been produced or irradiated in the course of the production or use of nuclear fuel,

unless a licence so to do (in this Act referred to as a “nuclear site licence”) has been granted in respect of that site by the Minister and is for the time being in force. “

The Act also permits the regulator (the Health & Safety Executive prior to April 2011 and the Office for Nuclear Regulation since April 2011) to attach conditions to nuclear site licences. Some conditions impose specific duties others require the licensee to devise and implement adequate arrangements in particular areas. A schedule of 36 standard Licence Conditions has been incorporated into all nuclear site licences. Licence Condition 35 is entitled “Decommissioning” and it requires:

“1 The licensee shall make and implement adequate arrangements for the decommissioning of any plant or process which may affect safety.

2 The licensee shall make arrangements for the production and implementation of decommissioning programmes for each plant.

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3 The licensee shall submit to the Executive⁴ for approval such part or parts of the aforesaid arrangements or programmes as the Executive may specify.

4 The licensee shall ensure that once approved no alteration or amendment is made to the approved arrangements or programmes unless the Executive has approved such alteration or amendment.

5 The aforesaid arrangements shall where appropriate divide the decommissioning into stages. Where the Executive so specifies the licensee shall not commence nor thereafter proceed from one stage to the next of the decommissioning without the consent of the Executive. The arrangements shall include a requirement for the provision of adequate documentation to justify the safety of the proposed decommissioning and shall where appropriate provide for the submission of this documentation to the Executive.

6 The licensee shall, if so directed by the Executive where it appears to them to be in the interests of safety, commence decommissioning in accordance with the aforesaid arrangements and decommissioning programmes.

7 The licensee shall, if so directed by the Executive, halt the decommissioning of a plant and the licensee shall not recommence such decommissioning without the consent of the Executive.”

Licence Condition 14 also requires the licensee to set up arrangements for the preparation and assessment of the safety related documentation comprising ‘safety cases’ to ensure that the licensee justifies safety during design, construction, manufacture, commissioning, operation and decommissioning.


A.8.1.4. Other Codes and Standards

Parts of some standards published by the British Standards Institute may be applicable to aspects of the decommissioning of a nuclear facility but none are dedicated to that subject.

The Nuclear Industry Safety Directors Forum has published several “Nuclear Industry Code of Practice” that may be applicable to decommissioning. These include:

- “Clearance and Exemption Principles, Processes and Practices for Use by the Nuclear Industry” which applies “to articles and substances which are to be transferred either physically or in the management sense outside the scope of continuous control (such as that maintained within a controlled contamination area) because they have no or only very low levels of radioactivity”;

⁴ Health & Safety Executive, replaced by the Office for Nuclear Regulation in April 2011

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- “Best Available Techniques (BAT) for the Management of the Generation and Disposal of Radioactive Wastes” which “applies throughout the lifetime of a process, from design to implementation, operation, maintenance and decommissioning.”

This Code is intended to provide guidance on meeting the requirements established by the Environmental Agency in the various part of the UK;

A.8.2. Responsibility


A.8.2.1. Decommissioning Planning, Execution and Completion

The Nuclear Decommissioning Authority (NDA) is a Non-Departmental Public Body established under the Energy Act 2004 to ensure that the UK’s 19 designated civil public sector nuclear sites are decommissioned and cleaned up safely and efficiently. The NDA assumed responsibility for the designated public sector nuclear sites from the United Kingdom Atomic Energy Authority (UKAEA) and British Nuclear Fuels Limited (BNFL).

Each of the 19 sites is operated by one of seven Site Licence Companies (SLCs) under contract to the NDA. The SLCs are responsible for day-to-day operations and the delivery of site programs. Parent Body Organizations (PBOs), selected through a competitive bidding process, own the SLCs for the duration of their contract with the NDA and bring private sector expertise and management to the projects.

The seven Site Licence Companies are:

- Sellafield Limited – responsible for the Sellafield (including Calder Hall) and Windscale nuclear licensed sites (the current PBO is Nuclear management Partners Limited);
- Magnox Limited – responsible for the Berkeley, Bradwell, Chapelcross, Dungeness A, Hinkley Point A, Hunterston A, Oldbury, Sizewell A, Trawsfynydd and Wylfa licensed nuclear sites (the current PBO is EnergySolutions EU Limited);
- Dounreay Site restoration Limited – responsible for the Dounreay licensed nuclear site (the current PBO is Babcock Dounreay Partnership Limited);
- Research Sites Restoration Limited – responsible for the Harwell and Winfrith licensed nuclear sites (the current PBO is Babcock International Group (BIG) plc);
- Springfields Fuels Limited – responsible for the nuclear fuel manufacturing site located near Preston, Lancashire (the current PBO is Westinghouse Electric);
- Capenhurst Nuclear Services – responsible for a uranium enrichment plant near Ellesmere Port, Cheshire (the current PBO is URENCO); and

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- Low Level Waste Repository Limited –responsible for the Low Level Waste site near Drigg, Cambria and other activities described in Section A.8.2.2 (the current PBO is UK Nuclear Waste Management Limited).

The licensees are responsible for the eventual decommissioning of licensed nuclear sites that are not under the control of the NDS. In particular, EDF Energy is responsible for the eventual decommissioning of seven AGR nuclear power plants (Dungeness B; Hinkley Point B; Hunterston B; Hartlepool; Heysham 1; Heysham 2 & Torness) and one PWR nuclear power plant (Sizewell B). In the event that funding for this work is inadequate, the NDA would assume responsibility for completing the decommissioning as a consequence of the Government's previous ownership of the plants.

A.8.2.2. Decommissioning Waste Management

A.8.2.2.1. Spent Nuclear Fuel and High Level Waste


At present, used nuclear fuel is either reprocessed at the Thermal Oxide Reprocessing Plant on the Sellafield licensed nuclear site or stored onsite at the licensed nuclear sites. Liquid High Level Waste produced as a consequence of the reprocessing of used fuel is vitrified and stored in canisters which are loaded into silos at Sellafield licensed nuclear site.

The Government has made the Nuclear Decommissioning Authority responsible for the planning and delivery of disposal facilities for 'Higher Activity Waste'. NDA's Radioactive Waste Management Director is responsible for carrying out this directive and it is being developed into a delivery organization which is capable of applying for and holding the necessary regulator licences and permits. Different approaches have been adopted in England and Wales (which favour geological disposal) and Scotland (which favours near surface disposal).

A.8.2.2.2. Low Level Waste

Most Low-Level Radioactive Wastes generated in the UK are managed in a central repository located at Drigg village on the West Cumbrian coast approximately six kilometres south east of the Sellafield licensed nuclear site. The NDA's Low Level Waste Repository Limited is responsible for the delivery of a national program for the future management of LLW.

A second LLW repository located on the Dounreay licensed nuclear site was used for LLW generated at that site only and it is currently being remediated. A replacement site is under construction and is scheduled to begin operations in 2014.

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A.8.2.3. Funding

The NDA is funded by a combination of grants from the UK Government and the revenue derived from its continuing commercial operations.

The decommissioning of the eight nuclear power plants operated by EDF Energy is funded from:


- Nuclear Liabilities Fund which manages contributions made under the Nuclear Liabilities Funding Agreement by:
 - British Energy prior to its restructuring in 2005;
 - British Energy since its restructuring and by EDF Energy since its acquisition of British Energy in 2009;
 - The proceeds of the sale of the Government's stake in British Energy; and
 - Contributions from the UK Government will contribute in the event that the Nuclear Liabilities Funds is inadequate to complete the decommissioning;
- UK Department of Business, Innovation and Skills under the Historic Liabilities Funding Agreement (covers the management of spent AGR fuel loaded into reactors prior to 14 January 2005).

A.8.3. Decommissioning Strategy

The Nuclear Decommissioning Authority has prepared a Strategic Environmental Assessment that identified two credible decommissioning strategies:

- continuous decommissioning - decommissioning commences at the end of operations and continues until final demolition of the plant/facility/installation; and
- deferred decommissioning - decommissioning comprises one or more periods when the plant/ facility/ installation is purposely kept in a state of Care and Maintenance as part of the program for achieving the Site End State.

Both continuous and deferred decommissioning have been shown to offer long-term environmental benefits with continuous decommissioning potentially providing the greatest benefit. Where risk is the dominant relevant factor, as with the Legacy Ponds and Silos at Sellafield, the priority will be to decommission continuously until the risk is at least tolerable. Otherwise, decommissioning will be deferred to permit the decay of radioactive contamination and the accumulation of funds (since the cost of decommissioning of gas cooled reactors is much higher than the cost of decommissioning light water reactors because of the need to manage large volumes of graphite and other materials). The condition of the plants and facilities will be managed during the 'Care and Maintenance' period to ensure that currently tolerable risks do not increase to become intolerable and that all risks are kept As Low As Reasonably Practicable.

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A.8.4. Decommissioning Waste Strategy

The Nuclear Decommissioning Authority is responsible for the management of radioactive waste including spent nuclear fuel. The NDA currently manages a low-level waste repository and it is developing plans for both high-level waste repositories and additional LLW capacity.

A.8.5. Decommissioning Regulatory Lessons Learned

Although there is a fair bit of information on technical decommissioning lessons learned, information on regulatory lessons learned is not readily available.

A.8.6. Sources of information

Sources consulted in the preparation of this section include:

- Radioactive Waste Management and Decommissioning in the United Kingdom, OECD/NEA, 2011.
- Radioactive Waste Management Programmes in OECD/NEA Member Countries – UNITED KINGDOM, OECD/NEA, 2011.
- Nuclear Power in the United Kingdom, World Nuclear Association, February 2014.
- Nuclear Development in the United Kingdom, World Nuclear Association, January 2013.
- Nuclear Decommissioning Authority – Business Plan 2013-2016, NDA, March 2013.

A.9. Comparison of Decommissioning Regulatory Framework

Table 11 Comparison of International Decommissioning Regulatory Framework

	Canada	United States	France	Germany	Finland	Italy	Sweden	United Kingdom
Decommissioning Regulatory Framework								
Requirements								
Statutes	All countries have established a statutory basis for the regulation of nuclear facilities.							
Licensing	All countries have established a licensing system for nuclear facilities. Licences may be issued by the government or by an independent regulatory agency.							
Regulations	Regulations do not address decommissioning in detail	Regulations address decommissioning	Regulations do not address decommissioning in detail	Regulations do not address decommissioning in detail	Regulations do not address decommissioning in detail	Regulations do not address decommissioning in detail	Regulations do not address decommissioning in detail	Regulations do not address decommissioning in detail
Licence Conditions	Compliance with CSA N294-09 may be required						Standard Licence Condition regarding decommissioning	
Codes & Standards	CSA N294-09	NRC Regulatory Guide 1.184, NUREG-1757 and others	No decommissioning specific codes and standards, requirements are spread out through many different documents.	“Decommissioning Guideline” created by the Decommissioning Working Group, Reactor Safety Technical Committee	“Predisposal management of low and intermediate level nuclear waste and decommissioning of a nuclear facility” YVL guide created by STUK	UNI 9498 Parts 1 through 8	“The Regulations on Planning before and during Decommissioning of Nuclear Facilities”	
Administration								

	Canada	United States	France	Germany	Finland	Italy	Sweden	United Kingdom
Regulatory Agencies	Independent regulator	Independent regulator	Independent regulator created in 2006	Government (Federal Ministry of Environment) supported by two government agencies	Government agency (STUK) responsible for inspection & regulation	Creation of an independent regulatory body was authorized in 2009	Two previous national regulatory authorities were consolidated into SSM ⁵ in 2009	The Office for Nuclear Regulation is working towards becoming an independent statutory corporation.
Responsible for licensing	Regulatory authority	Regulatory authority	Regulatory authority (major licensing decisions require government approval)	Government (state with federal oversight)	Government	Government	Government	Government
Implementation								
Strategy								
Permitted	Not prescribed	Not prescribed (decommissioning is to be completed within 60 years of permanent shutdown unless otherwise authorized)	April 2008 draft policy on decommissioning proposes that licensees adopt "immediate dismantling strategies"	Both Prompt and Deferred Dismantling are permitted under the applicable statutes	Both Prompt and Deferred Dismantling are permitted with justification.	Prompt Dismantling (as practical)	Not prescribed	Not prescribed
Adopted	Deferred Dismantling has	Many licensees have adopted	CEA has completed	2 PWRs will be decommissioned	n/a	Prompt Dismantling	Deferred Dismantling has	Deferred Dismantling has

⁵ Strålsäkerhetsmyndigheten – Swedish Radiation Safety Authority

	Canada	United States	France	Germany	Finland	Italy	Sweden	United Kingdom
	been adopted by most licensees	Prompt Dismantling but some have adopted Deferred Dismantling	decommissioning of 1 reactor and is responsible for 4 more EdF has proposed 'total and immediate dismantling' of 9 reactors that have been permanently shut down	without deferral			been adopted for all NPP that have been shutdown	been adopted for all NPP that have been shutdown
Responsibility								
Planning	Operator	Operator	Operator	Operator	Operator	National Agency	Operator	National Agency
Decommissioning	Operator	Operator	Operator	Operator	Operator	National Agency	Operator	National Agency
Waste Management								
HLW Waste	Consortium of Operators (NWMO)	National Agency (DOE)	National Agencies (ANDRA and CNE2)	Government	Consortium of Operators (Posiva Oy)	National Agency	Consortium of Operators (SKB)	National Agency
LILW Waste	Operator	States or State Compacts	National Agency (ANDRA)	Government	Operator	National Agency	Consortium of Operators	National Agency
Source of Funding								
Operating NPPs	Operators	Operators	Operator	Levy on electricity rates	Operator (amount set annually by government)	Levy on electricity rates	Operators	Operators
Source of Funding – Civilian Legacy Sites	Government (e.g.: Nuclear Liability)		Government	Government		Government		Proceeds from sale of government

	Canada	United States	France	Germany	Finland	Italy	Sweden	United Kingdom
	Management Program)							assets, previous operator contributions and Government

Table 12 Potential Gaps in the Canadian Decommissioning Requirements

Section of IAEA WS-R-5	IAEA Requirement	Potential Gap (per Facility Type)					
		Class IA - A	Class IB - B	Class IB - C	Class IB - D	Class IB - E	Class II - F
2. Protection of Human Health & the Environment							
2.1	The activities associated with the decommissioning of a facility shall be considered part of the original practice	No Gap					
2.2	The dose limits for the normal exposure of workers and members of the public shall be applied	No Gap					
2.3	Provision shall be made during decommissioning for protection against, and mitigation of, potential exposures that may result from an incident or accident	No Gap					
2.4	A safety culture shall be fostered and maintained in both the operating organization and the regulatory body	No gap, assuming that normative clauses of CSA N286-12 are indicated as licence conditions.					
2.5	Environmental radiation protection, consistent with that for a practice, shall be maintained during the entire decommissioning process and beyond if a facility is released with restrictions on future use	No Gap					
3. Responsibilities associated with decommissioning							

Section of IAEA WS-R-5	IAEA Requirement	Potential Gap (per Facility Type)					
		Class IA - A	Class IB - B	Class IB - C	Class IB - D	Class IB - E	Class II - F
3.4	<p>The responsibilities of the government include:</p> <ul style="list-style-type: none"> —Defining the national policy for decommissioning and for management of the resulting radioactive waste; —Defining the legal, technical and financial responsibilities of organizations to be involved in decommissioning; —Ensuring that the necessary scientific and technical expertise remains available both for the operating organization and for the support of independent regulatory and other national review functions; —Establishing a mechanism to provide and ensure adequate financial resources for safe and timely decommissioning 	Canada has not explicitly stated a policy on decommissioning of nuclear facility or on ensuring that the necessary scientific and technical expertise remains available for decommissioning.					
3.6	<p>The responsibilities of the regulatory body include:</p> <ul style="list-style-type: none"> —Establishing criteria for determining when a facility or part of a facility is permanently shut down, based on termination of the authorized activities; —Establishing safety and environmental criteria for the decommissioning of facilities, including criteria for clearance of material during decommissioning and conditions on the end state of decommissioning and on the removal of controls; —Establishing requirements for decommissioning planning; —Reviewing the initial decommissioning plan and reviewing and approving the final decommissioning plan before allowing decommissioning activities to be commenced; —Implementing inspection and review of decommissioning activities and taking enforcement actions in case of non-compliance with safety requirements; —Establishing policies and requirements for the collection and retention of records and reports relevant to decommissioning; —Evaluating the end state of a decommissioned facility and deciding whether the conditions have been met to allow the termination of the practice and/or release from regulatory controls or whether further activities or controls are needed; 	Criteria for determining when a facility or part of a facility is permanently shut down are not explicitly defined.					

Section of IAEA WS-R-5	IAEA Requirement	Potential Gap (per Facility Type)					
		Class IA - A	Class IB - B	Class IB - C	Class IB - D	Class IB - E	Class II - F
	—Giving interested parties an opportunity to provide comments on the plan before it is approved.						
3.8	<p>The responsibilities of the operating organization include:</p> <ul style="list-style-type: none"> —Establishing a decommissioning strategy and preparing and maintaining a decommissioning plan throughout the lifetime of the facility; —Establishing a quality assurance programme as part of the management system; —Notifying the regulatory body prior to shutting down the facility permanently or terminating the activity; —Managing the decommissioning project and performing the decommissioning activities; —Identifying an acceptable destination for all waste arising from decommissioning; —Performing safety assessments and environmental impact assessments related to decommissioning; —Preparing and implementing appropriate safety procedures, including emergency preparedness, and applying good engineering practices; —Ensuring that properly trained, qualified and competent staff are available for the decommissioning project; —Performing appropriate radiological surveys in support of decommissioning; —Ensuring that end state criteria have been met by performing a final survey; —Keeping records and submitting reports as required by the regulatory body. 	<p>Notifying the regulatory body prior to shutting down the facility permanently or terminating the activity is not explicitly required by regulation.</p>					

Section of IAEA WS-R-5	IAEA Requirement	Potential Gap (per Facility Type)					
		Class IA - A	Class IB - B	Class IB - C	Class IB - D	Class IB - E	Class II - F
4. Decommissioning Strategy							
4.1	The operating organization shall define a decommissioning strategy on which the planning for decommissioning will be based.	There is a regulatory requirement to submit a Preliminary Decommissioning Plan as part of an application for a licence and both CSA N294 Annex A and CNSC Regulatory Document G-219, Section 6.1.2 recommend (but do not require) that the PDP include the decommissioning strategy.					
4.2	The preferred decommissioning strategy shall be immediate dismantling. There may, however, be situations where immediate dismantling is not a practical strategy when all relevant factors are considered.	No preference is stated in either the regulations or standard.					
4.6	Appropriate means shall be available to manage waste of all categories in a timely manner, with account taken of the overall decommissioning management strategy.	By reference to normative clauses of CSA N294-09, there is no gap.					
5. Decommissioning Plan							
5.1	The operating organization shall prepare and maintain a decommissioning plan throughout the lifetime of the facility, unless otherwise approved by the regulatory body, in order to show that the decommissioning can be accomplished safely to meet the defined end state						
5.3	A graded approach shall be applied to the development of the decommissioning plan. The type of information and the level of detail in the plan shall be commensurate with the type and status of the facility and the hazards associated with the decommissioning of the facility						
5.4	For new facilities, consideration of decommissioning shall begin early in the design stage and shall continue through to the termination of the practice or the final release of the facility from regulatory control						
5.6	The operating organization shall prepare and submit an initial decommissioning plan together with the application for authorization to operate the facility						
5.7	This initial plan shall be reviewed and updated periodically, at least every five years or as prescribed by the regulatory body, or when specific circumstances warrant, such as if changes in an operational process lead to						

Section of IAEA WS-R-5	IAEA Requirement	Potential Gap (per Facility Type)					
		Class IA - A	Class IB - B	Class IB - C	Class IB - D	Class IB - E	Class II - F
	significant changes to the plan.						
5.9	Provision shall be made, as far as possible, to ensure that key staff are retained and that institutional knowledge about the facility is maintained and is accessible. Appropriate records and reports that are relevant to decommissioning (e.g. records on the use of the facility, events and incidents, radionuclide inventories, dose rates and contamination levels) shall be retained during the lifetime of the facility.	All these Clauses and Annexes of CSA N294 are informative (recommendations) rather than normative (requirements).					
5.10	Prior to the implementation phase of decommissioning activities, a final decommissioning plan shall be prepared and submitted to the regulatory body for approval.						
5.12	The methodology and criteria that the operating organization will use to demonstrate that the proposed end state has been achieved shall be stated in the decommissioning plan	All these Annexes of CSA N294 are informative (recommendations) rather than normative (requirements).					
5.14	If the deferred dismantling strategy has been selected, it shall be demonstrated in the decommissioning plan that such an option will be implemented safely and will require minimum active safety systems, radiological monitoring and human intervention and that future requirements for information, technology and funds have been taken into consideration	CSA N294-09 Clause 6.2.5 does require that “If decommissioning is deferred, the owner shall ensure that processes and systems are in place to maintain the facility in a safe condition during the interim phase”.					
6. Decommissioning Funding							
6.1	National legislation shall set out the responsibilities with respect to financial provisions for decommissioning. These provisions shall include establishing a mechanism to provide and ensure adequate financial resources for safe and timely decommissioning.						
6.2	Adequate financial resources to cover the costs associated with safe decommissioning, including the management of the resulting waste, shall be available when needed, even in the event of premature shutdown of the facility.						
7. Decommissioning Management							
7.1	An organization for the management and implementation of						

Section of IAEA WS-R-5	IAEA Requirement	Potential Gap (per Facility Type)					
		Class IA - A	Class IB - B	Class IB - C	Class IB - D	Class IB - E	Class II - F
	decommissioning shall be established as part of the operating organization, with the responsibility for ensuring that decommissioning will be conducted safely.						
7.2	The ultimate responsibility for safety shall remain with the operating organization, although it is permissible to delegate the performance of specific tasks to a subcontractor	It is not clear how this would be addressed in the event of the insolvency of the operating organization (although this is not a consideration if the facility is owned/operated by a agency of a government).					
8. Conduct of Decommissioning							
8.1	The operating organization shall implement the decommissioning and related waste management activities in compliance with the national safety standards and requirements.						
8.2	The operating organization shall inform the regulatory body prior to shutting down the facility permanently	Notification of reactor shutdown could be required as a condition of the operating licence.					
8.3	In the case of deferred dismantling, the operating organization shall ensure that the facility has been placed, and will be maintained, in a safe configuration and will be appropriately decommissioned in the future.						
8.5	Decontamination and dismantling techniques shall be chosen such that the protection of workers, the public and the environment is optimized and the generation of waste is minimized.						
8.6	A proper waste management path shall be established for all waste streams arising from decommissioning activities. If a final decision on disposal has not been made for particular waste types, the operating organization shall arrange for the safe storage of the waste until its final disposition is completed.						
9. Completion of Decommissioning							
9.1	On completion of decommissioning it shall be demonstrated that the end state criteria as defined in the decommissioning plan and any additional regulatory requirements have been met						
9.2	The facility shall not be released from regulatory control, nor shall authorization be terminated until the operating organization has demonstrated that the end state in the decommissioning plan has been						

Section of IAEA WS-R-5	IAEA Requirement	Potential Gap (per Facility Type)					
		Class IA - A	Class IB - B	Class IB - C	Class IB - D	Class IB - E	Class II - F
	reached and that any additional regulatory requirements have been met.						
9.3	A final decommissioning report shall be prepared that documents, in particular, the end state of the facility or site, and this report shall be submitted to the regulatory body for review.						
9.6	If a facility cannot be released for unrestricted use, appropriate controls shall be maintained to ensure the protection of human health and the environment. These controls shall be specified and shall be subject to approval by the regulatory body	This may be a requirement of provincial regulations that would apply once the site is released from federal control.					

Appendix B– Examples of Decommissioning Strategies Adopted in Canada and Internationally

A.10. CANDU Nuclear Power Plants

The decommissioning strategies adopted by CANDU NPPs (and some other similar pressurized heavy water plants) are shown in Table 13. The majority of these plants that have announced a decommissioning strategy have selected the ‘deferred dismantling’ strategy with a deferral period of 30-50 years. The decommissioning plan for the Wolsong (월성원자력발전소) NPP in South Korea is based on deferred dismantling with a short (5 year) deferral period.

Table 13 Decommissioning Strategies Adopted at Other CANDU Nuclear Power Plants

Country	Station Name	Net Capacity (MWe)	Date of Operation	Date of Shutdown	Status	Decommissioning Strategy
Argentina	Embalse	648	1983	2023	Operating	
Canada	Nuclear Power Demonstration	28	1962	1987	Safe Store	Deferred dismantling
Canada	Douglas Point	206	1967	1984	Safe Store	Deferred dismantling
Canada	Pickering 1	515	1971	1997	Operating	Deferred dismantling
Canada	Pickering 2	515	1971	1997	Safe Store ⁶	Deferred dismantling
Canada	Pickering 3	515	1972	1997	Safe Store ⁶	Deferred dismantling
Canada	Pickering 4	515	1973	2013	Operating	Deferred dismantling
Canada	Pickering 5	516	1982	2022	Operating	Deferred dismantling
Canada	Pickering 6	516	1983	2023	Operating	Deferred dismantling
Canada	Pickering 7	516	1984	2024	Operating	Deferred dismantling
Canada	Pickering 8	516	1986	2026	Operating	Deferred dismantling
Canada	Bruce 1	769	1977	1997	Operating	Deferred dismantling
Canada	Bruce 2	769	1976	1995	Operating	Deferred dismantling
Canada	Bruce 3	790	1977	2017	Operating	Deferred dismantling
Canada	Bruce 4	790	1978	2018	Operating	Deferred dismantling
Canada	Bruce 5	790	1984	2024	Operating	Deferred dismantling
Canada	Bruce 6	790	1984	2024	Operating	Deferred dismantling
Canada	Bruce 7	790	1986	2026	Operating	Deferred dismantling
Canada	Bruce 8	790	1987	2027	Operating	Deferred dismantling
Canada	Darlington 1	881	1990	2030	Operating	Deferred dismantling
Canada	Darlington 2	881	1990	2030	Operating	Deferred dismantling
Canada	Darlington 3	881	1992	2032	Operating	Deferred dismantling
Canada	Darlington 4	881	1993	2033	Operating	Deferred dismantling
Canada	Point Lepreau	635	1982	2022	Operating	Deferred dismantling
Canada	Gentilly I	250	1972	1977	Safe Store	Deferred dismantling
Canada	Gentilly 2	635	1982	2022	Shutdown	Deferred dismantling
China	Qinshan 4	650	2002	2042	Operating	

⁶ PNGS A is still under an ‘operating’ license

Country	Station Name	Net Capacity (MWe)	Date of Operation	Date of Shutdown	Status	Decommissioning Strategy
China	Qinshan 5	665	2003	2043	Operating	
India	Rajasthan (RAPS) 1	90	1972	2012	Laid up	No nuclear power reactors are planned as of now to be taken up for decommissioning. The emphasis is on plant life extension.
India	Rajasthan (RAPS) 2	187	1980	2020	Operating	
India	Rajasthan 3 ⁷	220	2000	2040	Operating	
India	Rajasthan 4	220	2000	2040	Operating	
India	Rajasthan 5	220	2010	2050	Operating	
India	Rajasthan 6	220	2010	2050	Operating	
India	Tarapur 3	540	2006	2046	Operating	
India	Tarapur 4	540	2005	2045	Operating	
India	Kaiga 1	220	2000	2040	Operating	
India	Kaiga 2	220	1999	2039	Operating	
India	Kaiga 3	220	2007	2047	Operating	
India	Kakrapar 1	220	1992	2032	Operating	
India	Kakrapar 2	220	1995	2035	Operating	
India	Kalpakkam 1	220	1983	2023	Operating	
India	Kalpakkam 2	220	1985	2025	Operating	
India	Narora 1	220	1989	2009	Operating	
India	Narora 2	220	1992	2032	Operating	
Pakistan	KANUPP Unit 1	125	1972	2011	Operating	
South Korea	Wolseong 1	679	1983	2022	Refurbishment	“...dismantling and demolition of nuclear power plants will be conducted after the safe store of approximately 5-10 years.”
South Korea	Wolseong 2	700	1997	2037	Operating	
South Korea	Wolseong 3	700	1998	2038	Operating	
South Korea	Wolseong 4	700	1999	2039	Operating	

A.11. Other Nuclear Power Plants

A number of NPPs have already completed decommissioning and most of these projects followed an immediate dismantling approach. Immediate dismantling has the advantage of freeing the site for other uses more quickly which can be advantageous when there is only one facility on the site.

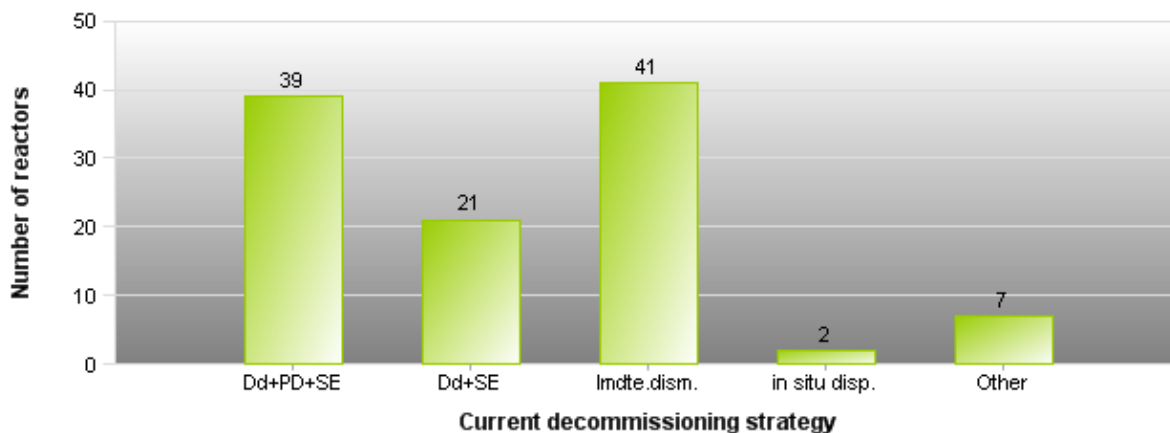
Immediate dismantling strategies have generally been selected by plant operators in France, Italy, Japan, and Sweden.

Deferred dismantling or combination strategies have generally been selected by plant operators in Canada, Czech Republic (gradual dismantling with deferred site clearance), Netherlands, Spain (partial immediate dismantling with deferred decommissioning of remaining parts), and the United Kingdom.

⁷ CANDU Derivatives - “Based on CANDU design but developed domestically within India”.

There is no preferred strategy at the national level In Finland, Germany and the United States; different operators have selected either immediate dismantling or deferred dismantling strategies according to their individual needs and priorities.

As can be seen from Figure 2, the decommissioning strategy of reactors favoured worldwide is deferred dismantling. Where ‘deferred dismantling’ has been adopted as the decommissioning strategy, the current trend has been to limit deferral periods to no more than 50 years but a nearly as many sites have adopted a hybrid of Immediate and Deferred Dismantling consisting of immediate dismantling of most or all non-radiological structures and systems together with placing remaining radiological areas into safe enclosure.



Strategy	Description
Dd+PD+SE	Deferred dismantling, including partial dismantling and placing remaining radiological areas into safe enclosure
Dd+SE	Deferred dismantling, placing all radiological areas into safe enclosure
Imdte.dism.	Immediate dismantling and removal of all radioactive materials
in situ disp.	In situ disposal, involving encapsulation of radioactive materials and subsequent restriction of access
Other	Any other decommissioning strategy

Figure 2 Current Decommissioning Strategy for International Reactors

A.12. Hybrid Immediate and Deferred Dismantling Strategy

The Vandelois 1 NPP in Spain has adopted a hybrid of Immediate and Deferred Dismantling; the decommissioning of all structures and systems outside of the reactor building has been

completed while the Reactor Building and active systems inside the building have been placed in Safe Storage for a period of 25 years. The decommissioning approach is described in the Vandellos 1 Nuclear Power Plant Decommissioning Report (1998-2003) published by ENRESA:

LEVEL 1

Conditioning activities

These activities were carried out by HIFRENSA, the plant operator, during the period 1991 to 1997 in compliance with the Ministerial Order of July 1990 establishing the definitive shutdown of the plant. The work performed during this period included the unloading of the reactor core and the removal of the fuel from the site, the conditioning of the operating wastes and the removal and preliminary conditioning of the wastes stored in the graphite silos. In addition, certain disassembly tasks were performed on conventional elements such as the CO₂ tanks and the main turbine-alternator sets.



Figure 3 Vandellos-1 during Operations

LEVEL 2

Decommissioning of structures and preparation for the latency period

This level was carried out under the responsibility of ENRESA between February 1998 and the structures, systems and components except the reactor box, releasing most of the site and leaving the rest as a regulated zone with the reactor box confined and covered by a newly built structure providing protection against weather.

This level has included two phases of performance:

First phase

This phase was carried out between February 1998 and February 1999 and had the following objectives:

- *Conditioning of the site for the performance of disassembly work in radiological zones.*
- *Dismantling and removal from the site of conventional equipment and structures not logistically required to support project activities. These activities are described in the Conventional Components Decommissioning Plan (PDCC).*

Second phase

This phase was carried out between March 1999 and June 2003 and had the following objectives:

- *Performance of the Active Parts Decommissioning Plan (PDPA).*
- *Application of the Declassification Plan to ensure that clean materials are not contaminated and may, therefore, be managed by conventional means.*
- *Continuation of the PDCC.*
- *Dispatch of low and intermediate level radioactive wastes (LILW) to the El Cabril Disposal Facility.*
- *Dispatch of conventional materials to authorised centres for recycling.*
- *Dispatch of conventional wastes to specialist tips.*

The overall budget for Level 2 decommissioning amounts to €94.6 million.

LATENCY PERIOD

On completion of Level 2 decommissioning, the unreleased parts of the site remain under the responsibility and surveillance of ENRESA. This situation will continue for 25 years, during which time the radiological activity of the internal structures of the reactor will decay to approximately 5% of the initial level. This will allow them to be dismantled with a minimum radiological burden for the personnel performing the work.

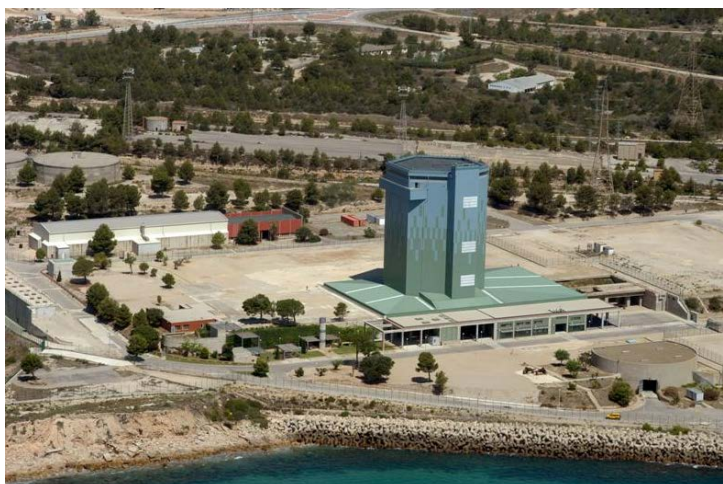


Figure 4 ‘Reactor Box’ at Vandellós-1

LEVEL 3

Decommissioning of reactor box

On completion of the latency period, around the year 2028, work will begin on the last level of decommissioning, which will include the removal of the reactor box and its internals and the complete release of the site.

MAGNOX in the UK adopted the MAGNOX Optimized Decommissioning Programme (MODP), which utilizes a hybrid approach to decommissioning similar to the approach adopted at Vandellós-1, following a costing analysis that showed this approach would reduce the cost of the decommissioning. The MODP envisions:

- An accelerated transition to safe storage (care & maintenance) which includes the work required to:
 - Dismantle both radioactive and non-radioactive plant and buildings where radiological benefit cannot be achieved from deferral; and
 - Place other buildings into a passively safe and secure state, which will not require the presence of staff on-site on a routine basis, for an extended period of safe storage.
- An extended safe storage period that will provide the time for radiation levels in the reactor cores to decay, the remaining buildings will remain in a secure, quiescent state during this period; and
- Final site clearance which will include removal of the reactor building and vessels.



Figure 5 Artist' Conception of a MAGNOX Site During Care & Maintenance

A.13. Decommissioning Cost Estimates

Two nuclear power plants in the United States (Three Mile Island and Zion Units 1 & 2) have published decommissioning cost estimates for decommissioning based on Immediate Dismantling and various periods of deferral. These estimates (and the percentage of the estimated costs attributable to the various Level 1 categories of the International Structure for Decommissioning Costing) are shown in Table 14. These estimates also suggest that long periods of deferral may not decrease the cost of decommissioning by as much as may be expected.

Table 14 Percent of Total Decommissioning Costs by ISDC Level 1 Category (except Spent Fuel Management)

Nuclear Power Plant & Decommissioning Strategy	Total Estimated Cost of Decommissioning (excluding Spent Fuel Management)	Percentage of Estimated Decommissioning Cost due to										
		Pre-Decom Activities (01)	SD Activities (02)	Safe Encl. & Entombment (03)	Dismantling Inside CA (04)	Waste management (05)	Site Infrastr. & Operations (06)	Conv. Dismtl, Demo, Site Rest (07)	PM, Eng Support (08)	R & D (09)	Fuel & Nuclear Materials (10)	Misc – taxes, insur, etc. (11)
Three Mile Island U1 (Immediate Dismantling)	\$618,898 K	2%	2%	0%	12%	20%	22%	9%	30%	0%	0%	3%
Three Mile Island U1 (55Y deferral)	\$828,390 K	1%	1%	1%	8%	12%	33%	6%	25%	0%	0%	13%
Zion U1 (Immediate Dismantling)	\$468,810 K	2%	0%	0%	20%	27%	18%	6%	25%	0%	0%	2%
Zion U1 (30Y deferral)	\$442,063 K	2%	0%	0%	20%	28%	17%	7%	24%	0%	0%	2%
Zion U1 (55Y deferral)	\$543,404 K	2%	0%	0%	17%	23%	24%	6%	22%	0%	0%	6%

Nuclear Power Plant & Decommissioning Strategy	Total Estimated Cost of Decommissioning (excluding Spent Fuel Management)	Percentage of Estimated Decommissioning Cost due to										
		Pre-Decom Activities (01)	SD Activities (02)	Safe Encl. & Entombment (03)	Dismantling Inside CA (04)	Waste management (05)	Site Infrastr. & Operations (06)	Conv. Dismtl, Demo, Site Rest (07)	PM, Eng Support (08)	R & D (09)	Fuel & Nuclear Materials (10)	Misc – taxes, insur, etc. (11)
Zion U2 (Immediate Dismantling)	\$489,840 K	1%	0%	0%	21%	24%	19%	8%	25%	0%	0%	2%
Zion U2 (30Y deferral)	\$449,384 K	1%	0%	0%	22%	26%	17%	9%	24%	0%	0%	2%
Zion U2 (55Y deferral)	\$504,019 K	1%	0%	0%	20%	23%	19%	8%	23%	0%	0%	7%

Appendix B – Methodology

Data for this report were gathered from January 6th to March 31st 2014. Decommissioning regulations, strategies, waste disposal/storage options and lessons learned were researched online searching primarily for information provided by the regulators themselves, and then by international organizations such as the IAEA and the OECD/NEA.

Data for this report were gathered from January 6th to May 31st 2014. Decommissioning regulations, strategies, waste disposal/storage options and lessons learned were researched online searching primarily for information provided by the regulator authorities in each country, by other national agencies (such as the Nuclear Decommissioning Authority in the United Kingdom or SOGIN in Italy) and by international organizations such as the IAEA and the OECD/NEA.

The regulatory framework and practices relevant to decommissioning were identified for each of the 8 countries considered and summaries were prepared for each country which describe:

- Types and status of nuclear facilities in the country;
- Decommissioning regulatory framework;
- Responsibilities for decommissioning;
- Decommissioning strategies mandated by the government or adopted by licenses;
- Waste management strategies and practices relevant to decommissioning; and
- Any lessons learned for decommissioning work that has been completed.

These summaries are provided in Appendix A of the report.

Canadian practice was then compared with the requirements of IAEA Safety Requirements WS-R-5 (Decommissioning of Facilities Using Radioactive Material) and the practices observed in the other seven countries. A gap analysis was conducted to assess for potential gaps in the Canadian regulatory framework and decommissioning practice.

This was summarised in Section 3 and recommendations on how to address the identified gaps are provided in Section 6.1 of the report.