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04	PCER March 2011 update
	Sub-chapter 5.1:
	- Minor editorial changes
	- Incorporation of more detailed information regarding decommissioning:
	  - summary added before §1,
	  - §2.2 (new) “Hazards and challenges” added,
	  - §3 updated to include “Decommissioning logistics”,
	  - §4 “Design principles” updated,
	  - §5 (new) “Baseline principles and objectives” added, and
	  - §6 (new) “Records” added.
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REVISION HISTORY (Cont'd)

Issue	Description	Date

04 (cont'd)	- Incorporation of more detailed information regarding decommissioning:
	  - summary added before §1,
	  - §3.1, §3.2, text added covering minimisation of activation and corrosion products, and decontamination,
	  - §4.4.2 (new) "Waste from interim storage facilities decommissioning" added,
	  - §4.4.3 (new) "Secondary waste arising from decommissioning" added,
	  - §4.5 summary of disposability assessment added,
	  - §6.1 (new) "Timings of decommissioning" added,
	  - §6.2 (new) "Assumed plant status at decommissioning" added,
	  - §6.3 (new) "Decommissioning techniques and logistics" added, and
	  - §8, concluding paragraphs added.
	- Addition of information regarding decontamination:
	  - §4.2, text added on decontamination techniques
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05	Consolidated PCER update: - References listed under each numbered section or sub-section heading numbered [Ref-1], [Ref-2], [Ref-3], etc - Clarification of units in Sub-chapter 5.2 (§4.4.1) - Minor formatting changes	08-06-2012

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CONTENTS CHAPTER 5

SUB-CHAPTER 5.1 – GENERAL DECOMMISSIONING PRINCIPLES – REGULATIONS

Although decommissioning is the final stage in the overall lifecycle of a facility and will be the responsibility of the future UK EPR Licensee, the need for decommissioning must be taken into account at all stages in the lifecycle, starting at the design stage.

This sub-chapter deals with the general principles and regulations related to decommissioning.

1. PHASES

The dismantling of a nuclear facility comprises several technical operations and administrative processes which result in the site regulatory de-licensing.

In most cases, the following sequence applies:

- decision to permanently shut down the facility by the operator;
- removal of fissile materials and radioactive liquids, while the nuclear-side plants are still operational, although in a simplified way;
- depending on the technical requirements, demolition or re-equipment of the non-nuclear plant and possibly a reduction of the perimeter of the facility;
- phased dismantling of the activated and contaminated equipment;
- phased deactivation and decontamination of components;
- after establishing what remains of the facility, partial or total de-licensing;
- a period of safe store, if required.

The waste produced by these operations is removed from the site, possibly after interim storage on the site.

Finally, the remaining structures and the site itself are redeveloped according to the owner's requirements and the obligations to which the owner is bound under the terms of decommissioning.

2. RISK AND HAZARD REDUCTION

2.1. RISK REDUCTION

During the dismantling phase, the required safety functions to be ensured are the containment of radioactive materials and the minimisation of the risk of public external exposure.

The removal of fissile materials and radioactive liquids eliminates the largest part of the radiological hazard. Consequently, only one containment system is required between the radioactive materials and the environment during the subsequent phases.

At the start of dismantling, the original containment system is used; however, some of the ventilation systems may not be used. Nevertheless, the dismantling of the facility involves the ultimate removal of certain protective barriers.

As a result, there may be a temporary increase in residual risk, which is permissible as long as:

- each decommissioning task serves to reduce the remaining risk;
- the ultimate aim of the dismantling works is to eliminate the hazard;
- the level of risk, related to the total radioactive inventory and the thermal and mechanical energy potentially available for uncontrolled release, is far smaller than that during the operating phase of the facility;
- the nuclear safety case requirements are satisfied.

These conditions also apply to the consideration of the consequences of external hazards (e.g. earthquakes, aircraft crashes, etc.). Protection against flooding, provided during the operating phase, remains effective during most of the dismantling phase. The removal of protection provided against external hazards cannot occur before the reduction in the radioactive inventory.

The auxiliary buildings that are erected specifically for the dismantling works must comply with all of the safety requirements in force at the start of work.

The risks to the containment system of the facility related to dismantling operations will be identified and reduced to a very low frequency through appropriate measures, and their consequences will be limited. This particularly applies to:

- the rupture of water and air pipes;
- fires and explosions;
- the dropping of waste containers;
- equipment failure and human error.

2.2. HAZARDS AND CHALLENGES

Hazards management is key in the nuclear industry during all periods of design, construction, operation or decommissioning. As such, identification of all hazards and analysis of the risk that they can present is essential before and during all decommissioning activities. Similarly, feedback and learning from experience is also essential once decommissioning activities are complete, to ensure that all hazards were identified and managed, and that the controls put in place to protect against these hazards were optimised. It is important that learning is gained so that the management of hazards is improved for future projects.

Details on the hazards and challenges expected to be met during the decommissioning of the UK EPR are provided in Chapter 4 of document “GDA UK EPR – Decommissioning” [Ref-1]. Additional details are provided regarding:

- EDF and AREVA experience of decommissioning, participation in working groups and the type of hazards encountered;

- the potentially significant hazards that could reasonably be anticipated during the decommissioning of an EPR;
- the protection measures implemented, along with the controls that have been (or will be) put in place to protect against these hazards;
- control of the likely radiological and industrial safety hazards;
- the criteria for the use of remote-controlled equipment and techniques in decommissioning tasks.

3. DISMANTLING PROCESS

Before being implemented, the dismantling process chosen by the operator is defined through documents dealing with:

- the scheduling and nature of the dismantling works and the facility final state;
- the origin, characterisation, quantity, treatment, packaging, transportation, disposal and recycling of nuclear waste and other kinds of waste as well as the management of the aforementioned;
- the risks to the public and workers and the measures taken to detect, prevent, limit and progressively reduce such risks;
- the maintenance requirements for the facility and the auxiliary buildings during the dismantling phases;
- the on-site emergency plan;
- the predicted impact of dismantling and the facility final state on the environment.

For the UK EPR, the logistical challenges presented by the reactor design, which will have to be dealt with during decommissioning, need to be understood at the design stage, in order to be able to demonstrate the credibility of the baseline decommissioning strategy and that it will be possible to safely decommission both the reactor and the associated interim waste and spent fuel storage facilities.

Chapter 2 of document "GDA UK EPR – Decommissioning" [Ref-1] presents the strategic options with respect to logistical challenges, envisaged decommissioning sequence and methodology including considerations such as safety, decontamination, space, access and infrastructure requirements. It demonstrates how decommissioning can proceed throughout the plant allowing the most activated and contaminated equipment to be decontaminated and subsequently decommissioned safely, and also provides decommissioning principles and considerations for the ILW and Spent Fuel storage facilities.

4. DESIGN PRINCIPLES

The design of the EPR must ensure that decommissioning of the plant will be possible in a safe and environmentally acceptable way. Moreover the design should include specific features and encourage operational philosophies which will enable suitable decommissioning solution(s).

As Low As Reasonably Practicable' (ALARP) considerations must be applied to the decommissioning aspects of the design and philosophies, including incorporation of key design features to facilitate the application of these principles, such as building layout, choice of component material and equipment design.

The measures included in the EPR design to facilitate the decommissioning of the unit mean that the following two main aims can be fulfilled at an acceptable cost:

- reduction of the radioactive dose received by workers;
- reduction of radioactive waste and hazardous material.

In addition to the information provided in this section, Chapter 1 of document "GDA UK EPR – Decommissioning" [Ref-1] identifies the underpinning principles adopted in the design to allow the plant to be decommissioned and waste to be minimised. This includes design principles and fulfilment of IAEA requirements related to decommissioning.

4.1. DOSE REDUCTION

The collective and individual doses are reduced to As Low As Reasonably Practicable (ALARP). All of the factors which contribute to the dose are considered in fulfilling this aim, in particular:

- the intensity of the sources to which the workers are exposed;
- the time spent close to these sources;
- the maintenance of the contaminated equipment;
- the provision of protective measures such as shielding.

All internal contamination is avoided without relying on measures which involve a large increase in the time spent in controlled areas.

4.2. WASTE REDUCTION

All methods of waste minimisation including decontamination, volume and size reduction of radioactive waste and in the categorisation of such waste are considered, particularly:

- the maximum use of recycling of materials, with or without the need to demonstrate their suitability for re-use;
- minimal production of waste which is difficult to dispose of, particularly, long-lived, high activity waste and fibrous and chemically reactive waste;
- minimal production of 'secondary' waste (equipment used for the decommissioning phase and contaminated during the operations).

Uncertainties in waste characterisation are reduced to a minimum as they could otherwise lead to an unnecessarily high categorisation of waste; this applies, in particular, to the unjustified classification of conventional hazardous waste as radioactive waste.

4.3. DESIGN REQUIREMENTS

Design features which facilitate decommissioning must not interfere with the correct operation of the nuclear facility.

The means used to achieve this are as follows:

- the choice of materials with a minimal propensity to become radioactive through activation, by avoiding in particular the use of materials containing high concentration levels of additives or impurities which are likely to generate gamma emitters and long-lived radionuclides after irradiation;
- the use of shielding and barriers which minimise the activation and contamination of equipment in normal and accident conditions;
- the choice of materials and design of systems and rooms which aim to minimise the creation, transportation and deposition of contamination;
- design of access points in nuclear areas, handling equipment and access routes, and use of equipment which is easy to disassemble and protective devices which are easy to clean, with the objective of reducing the expected duration of exposure of workers to radioactivity and contamination;
- complete design and construction documentation, providing with the operating instructions an accurate inventory and location of the radioactive materials and other hazardous materials at the end of reactor operation, and a decommissioning plan.

The designers will make use of international experience from previous decommissioning activities as well as the studies under way and the initial feedback from significant decommissioning projects in France and worldwide.

The experience gained in the replacement of large components in the operating nuclear plants during shutdown for annual and ten-yearly outages of these facilities have identified the causes of high doses to maintenance staff. Except for those associated with the presence of a neutron flux or very short-lived radionuclides, most of the causes, and particularly those which extend the time spent by workers close to irradiated equipment elements, will apply during decommissioning. The design measures taken to facilitate maintenance will therefore have a positive effect on the decommissioning operations.

5. DECOMMISSIONING PRINCIPLES AND OBJECTIVES

During the plant operation and maintenance period, the licensee should adopt principles which will support the baseline decommissioning approach. Examples include updating of the decommissioning plan, collection of records, measurements, decontamination, radiation and contamination surveys, collection of lessons learned and operational experience feedback, and anticipation of future needs.

The baseline principles and objectives that should then be adopted during decommissioning, to enable adequate management of the decommissioning process and preparation of plans and proposals for the decommissioning of an EPR, include items such as:

- safety of the public, and staff;
- safety of the plant;
- protection of the environment;
- waste management;
- financial provisions;
- maintenance of resources and records;
- periodic review of strategy;
- organisation of the activities.

Other principles are those which facilitate the operator to learn from experience, to adopt industry good practice and follow guidance. This includes maintaining knowledge of best practice in all aspects of decommissioning, for example through membership of suitable professional organisations or bodies, and employment of Suitably Qualified and Experienced Personnel.

This is further developed in Chapter 1 of document “GDA UK EPR – Decommissioning” [Ref-1].

6. RECORDS

Whilst record information (baseline data, operational records etc), including that relevant to decommissioning, will be the responsibility of the Licensee, it is recognised that information pertinent to decommissioning should be specifically identified and recorded at the generic design stage of the life-cycle, in order to capture the design features which underpin the baseline decommissioning plans. Systems to facilitate knowledge transfers from all stages of the life-cycle need also to be defined.

Chapter 8 of document “GDA UK EPR – Decommissioning” [Ref-1] identifies the types of information and knowledge, which will be required to be preserved from the initial design stages for the EPR and associated facilities through their operational life and the decommissioning phase itself, so as to ensure that decommissioning may be undertaken safely and efficiently.

Differentiation is made between information which the designer will be required to generate and retain through the design process and operational information and knowledge which the Site Licensee will be required to generate and retain.

SUB-CHAPTER 5.1 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

2. RISK AND HAZARD REDUCTION

2.2 HAZARDS AND CHALLENGES

[Ref-1] GDA UK EPR – Decommissioning. Chapter 4 - Hazards and Challenges. UKEPR-0016-001 Issue 01. EDF/AREVA. March 2011. (E)

3. DISMANTLING PROCESS

[Ref-1] GDA UK EPR – Decommissioning. Chapter 2 – Decommissioning Logistics. UKEPR-0016-001 Issue 01. EDF/AREVA. March 2011. (E)

4. DESIGN PRINCIPLES

[Ref-1] GDA UK EPR – Decommissioning. Chapter 1 – Principles underpinning the design. UKEPR-0016-001 Issue 01. EDF/AREVA. March 2011. (E)

5. BASELINE PRINCIPLES AND OBJECTIVES TO BE ADOPTED DURING DECOMMISSIONING

[Ref-1] GDA UK EPR – Decommissioning. Chapter 1 – Principles underpinning the design. UKEPR-0016-001 Issue 01. EDF/AREVA. March 2011. (E)

6. RECORDS

[Ref-1] GDA UK EPR – Decommissioning. Chapter 8 – Knowledge Management. UKEPR-0016-001 Issue 01. EDF/AREVA. March 2011. (E)

SUB-CHAPTER 5.2 – DECOMMISSIONING – IMPLEMENTATION FOR THE EPR

This sub-chapter deals in part with the requirements 1.4, 1.5, 2.1 and 2.4 of the Environment Agency P&I document [Ref-1].

It describes how the principles and regulations discussed in PCER Sub-chapter 5.1 have been followed at the early UK EPR design stage to ensure and facilitate future decommissioning in a safe and environmentally acceptable way.

Following a description of the measures implemented in the EPR design to facilitate decommissioning, the waste produced during the decommissioning process and the disposability thereof, are discussed.

Finally, the baseline decommissioning plan currently envisaged is presented. This plan will be the responsibility of the Licensee for the lifetime of the site, including decommissioning of the interim storage facilities for Spent Fuel and ILW (defined in PCER Sub-chapter 6.5). Site de-licensing is not considered within GDA.

1. CHOICE OF MATERIALS

1.1. REDUCTION OF ACTIVATION

This applies to all materials irradiated either directly or through their corrosion products.

With regard to reduction of dose rates, the measures adopted at the design stage concerning the choice of materials principally include:

- elimination wherever possible of cobalt, for example, by reducing wear through design modifications, and by replacing materials with a high cobalt content level (stellites) by alloys without cobalt. Activated cobalt constitutes the main source of dose during decommissioning;
- the use of alloy 690 for the steam generator tubes minimises the quantity of cobalt in the corrosion products circulating in the primary system;
- limiting the amount of silver and cobalt in steel and alloys and the replacement of seals coated with silver by graphite seals (an isotope of silver represents a significant source of dose during the first few years after the shutdown of a unit);
- limiting seals and bearings made with antimony;
- provision of neutron shielding to minimise activation of components.

1.2. STRENGTH OF THE FUEL CLADDING

Improving the fuel cladding materials significantly impacts the classification of waste by limiting the release of alpha and beta emitters. The fuel cladding is addressed in PCSR Sub-chapter 4.2.

1.3. HAZARDOUS MATERIALS

The use of materials which constitute hazardous industrial waste is minimised as far as possible, particularly in applications in which such materials can be activated or contaminated because the disposal of mixed waste is particularly difficult.

This particularly applies to:

- corrosive and toxic substances;
- flammable liquids (oils);
- heavy concretes (containing barium);
- metals which are flammable or metals such as zircaloy which require particularly stringent precautions during cutting and packaging operations;
- fibrous materials.

1.4. NON-INERT MATERIALS

The use of porous materials is avoided in areas which can be contaminated as they are poorly suited to radioactive waste storage.

The use of non-inert materials, such as brick and plaster, whose presence in a significant quantity prohibits the use of the waste as fill, is avoided.

1.5. RECYCLABLE MATERIALS

As far as possible, the selection of materials takes account of their suitability for re-cycling, whether for free or restricted use. Recycling is not only an option for materials used outside of the contaminated or activated areas but also, subject to certain conditions, to materials from these areas.

2. DESIGN MEASURES FACILITATING DECOMMISSIONING

If it has not been used for maintenance during plant operation, equipment provided specifically for decommissioning is at risk of becoming obsolete, contaminated and degraded over the lifetime of the facility. The design therefore focuses on arrangements that facilitate both decommissioning and maintenance.

2.1. MEASURES FACILITATING DECOMMISSIONING

The objective is to reduce the dose to workers by reducing the time they spend near highly active components and increasing the speed with which these components are removed.

The following are some of the main measures adopted:

- the design of many items of equipment (e.g. core instrumentation, steam generators, reactor coolant pumps, pressuriser, heat exchangers, evaporator-degasser, particularly) facilitates their decommissioning;
- for the majority of the above components located in inaccessible areas due to the level of radiation, disposal in one piece was investigated; this implies the implementation of handling processes, appropriately designed openings and access which enable removal in a single piece and its subsequent processing in a more suitable environment;
- the position of the in-containment water storage tank (IRWST) under the reactor vessel allows the collection of any water leaks during the dismantling of the reactor internal components;
- the thermal insulation on the main primary circuit is easy to remove from around the welds due to its modular assembly;
- several operations have been identified as significant aids to dismantling:
    - draining, filling and filtering of the spent fuel pool;
    - draining and filling of the steam generators;
    - transfers between the reactor building and the fuel building;
    - treatment of solid, liquid and gaseous waste;
    - ventilation;
    - fire surveillance and protection;
    - radioactivity and anoxia controls, monitoring of the environment;
    - draining of cavities and floors;
    - power supply, compressed air and raw water.

The measures implemented for the related circuits and systems mean that they can be kept in service and maintained after the permanent shutdown of the reactor.

It should be noted that the design of the reactor in four separated trains allows the dismantling works to be phased train by train, while keeping in-service the auxiliary systems housed in the fuel building and the nuclear auxiliary building.

2.2. MEASURES FACILITATING THE REMOVAL OF COMPONENTS AND STRUCTURES

These measures reduce on-site work which is not productive and incurs dose, by facilitating the removal of activated and contaminated waste to the conditioning workshops [Ref-1].

A review of the installation of some large components, particularly the steam generators, reactor coolant pumps and the pressuriser, has been complemented by a review of their disassembly, including their reverse handling and transportation operations, thereby ensuring the possibility of removing them from the reactor building in one single piece, if appropriate. Feedback from the replacement of steam generators in the PWR plants provides guidance and is taken into account in the design. For example, a protected area behind the equipment hatch is created in which an entire steam generator can be handled

The measures adopted to enable maintenance during operation facilitate the removal of waste. These measures, associated with an approach to decommissioning which is based on starting from the access points, provide the necessary areas for the deployment of machinery, the disassembly, the placement and processing (decontamination, cutting, etc.) of the components, and the implementation of waste measurement, packaging and characterisation facilities.

2.3. MEASURES FACILITATING PERSONNEL ACCESS DURING THE DISMANTLING PHASE

The reactor design facilitates access at minimal dose rates in nearly all of the controlled area. As such, the active components have been enclosed in bunkers or isolated behind screens. This includes for example:

- the floor separating the pressuriser spray function from the pressuriser pressure relief function;
- the walls separating the hot legs from the cold legs;
- the bunkers in which the most active valves are placed.

Furthermore, measures have been taken to facilitate access to equipment and to create protected working and emergency shutdown areas, for example:

- the strengthening of the biological shielding of the annular region;
- the implementation of shielding baffles in front of the reactor coolant pumps;
- the implementation of shielded doors in front of the steam generators;
- the operating floor above the cavity (pool), permitting the installation of an in-situ dismantling workshop;
- the access areas introduced around the main components.

All of these measures help to reduce exposure level and time of staff undertaking manual operations and they also facilitate the use of remote controlled equipment.

2.4. REMOVABLE NEUTRON SHIELDING

The reactor design includes neutron shielding. This shielding reduces the activation of materials and thereby facilitates the clean-up of the structures while reducing the volume of active waste.

This involves:

- the neutron shield (also referred to as 'heavy reflector' in other chapters) surrounding the core, made of a dozen circular elements joined together by vertical tie-rods;

- the slab positioned above the vessel, made of removable concrete plates.

This shielding is unavoidably activated during reactor operation to a significant degree, but is designed to be dismantled in sections. This makes it possible to remove it once commercial operation of the reactor has ceased, while exposing workers to the minimal dose.

2.5. BUILDING ARRANGEMENTS

The reactor and nuclear auxiliary buildings have a basemat (i.e. foundation raft) which is different from that of the turbine hall: a common basemat for the reactor building, the safeguard buildings and the fuel building, and a separate basemat for the nuclear auxiliary building.

This facilitates the phased dismantling of the plant, as the demolition of the turbine hall does not affect the stability of the nuclear buildings.

The location of the gaseous waste discharge stack, on the roof of the fuel building, means that it can be kept in service while the reactor is dismantled.

3. ARRANGEMENTS RELATING TO THE CIRCUITS

The design of the systems can have a significant impact on their radiological inventory and, consequently, on the dose uptake during final dismantling, as is the case for extensive maintenance operations.

3.1. MEASURES TO LIMIT THE CONTAMINATION OF SYSTEMS

Specific measures have been taken to eliminate retention areas, which are likely to attract radioactive deposits and be a possible source of corrosion particularly once the power unit ceases to operate. These include in particular:

- a failed fuel assembly fast detection system, which is an essential factor in limiting contamination of waste with alpha emitters;

- processing facilities (e.g. reactor coolant chemistry control and particulate filters) which limit both corrosion and deposits in the systems;

- the design of systems and tanks avoiding, as far as possible, vortex areas, undrained low points even of a small volume (e.g. in valves), low velocity areas and dead cavities;

- the complete drainage of systems, facilitated by an adequate slope, as well as appropriate provision and positioning of drainage valves and vents;

- ventilation systems, designed according to segregated zones, to limit the spread of contamination, the minimisation of air ducts likely to transport contamination, the removal of contamination from as close as possible to its source, and the mounting of filters as far upstream as possible.

These measures limit the deposition of contamination in the systems and tanks as well as the transport and deposition of activated material. In both cases, the main aim is to reduce the dose. During decommissioning, these measures reduce the dose to workers, the risk of internal exposure and the activity of the waste. Chapter 5 of document "GDA UK EPR – Decommissioning" [Ref-1] provides additional information regarding the minimisation of activation and corrosion products, and the minimisation of the transport of these products throughout the plant.

3.2. MEASURES TO LIMIT THE SPREAD OF CONTAMINATION

The aim is to reduce the risk of contamination of rooms by fluids contained in systems and prevent land and groundwater contamination. In particular:

- through cleanliness/waste zoning defined at the design stage. Areas which could be contaminated in normal and accident situations have been identified;
- systems are fitted with isolation valves;
- contaminated fluid tanks are fitted with retention tanks, with drains which can be monitored. Floors are equipped with a drainage and collection system;
- leak tight seals prevent contaminated liquids from leaking to ground;
- pipes enclosed in concrete slabs or rafts are double-walled thereby excluding any accidental contamination, which is difficult to remove from the slabs;
- the waste building attached to the nuclear auxiliary building allows the treatment of a part of the waste before its final conditioning without leaving the controlled area;
- automatic monitoring of the sump levels and alarms are implemented in the design.

These design measures will be completed during operation by periodic visual inspections and ground / groundwater monitoring of the site.

This is further described in Chapter 5 of Document "GDA UK EPR – Decommissioning" [Ref-1].

3.3. ARRANGEMENTS TO FACILITATE THE DECONTAMINATION OF ROOMS AND EQUIPMENT

Decontamination of systems and components prior to their dismantling is one means of reducing worker exposure. In certain circumstances, it simultaneously reduces the quantity and activity of final waste. The design has therefore, as far as possible:

- taken into account decontamination requirements by placing injection seals in such a way as to maximise the wetting of the internal surfaces, and by including drainage lines and tanks, and sampling points;

- provided for the protection, if required, of floors and walls with surface coatings, which can be decontaminated or removed;
- provided for the coating or lining of the walls of submerged enclosures;
- on a case by case basis, provided for the treatment of metal surfaces to avoid the deposition of contamination and facilitate the removal of contaminated deposits.

The presence of a metal liner on the internal wall of the reactor building greatly eases the clean-up operations and the subsequent demolition of the Reactor Building. The concrete will be protected against any contamination and will be reusable by design; the liner will be cleaned and then declassified.

3.4. MEASURES TO FACILITATE THE ELECTRICAL ISOLATION OF THE BUILDINGS

Experience from permanent facility shutdown work reveals that the uncertainties related to the actual state of the electrical cabling, and thereby the ability to isolate them, present considerable difficulties.

The EPR reactor has four safety trains. The allocation of one cabling system to each safety area improves the clarity and ability to uniquely identify the systems.

3.5. MEASURES PREVENTING CHEMICAL CONTAMINATION

Problems presented by the collection and management of considerable quantities of waste from the chemical pollution of the ground and the buildings have been experienced during the maintenance of previous facilities.

The loading and unloading areas for tankers and vehicles transporting equipment containing this type of liquid are fitted with collection systems, as are the storage tanks. The drains can be monitored and emptied.

Cavities enable the recovery of water used in fighting fires.

4. ESTIMATION OF DECOMMISSIONING WASTE

The estimation of nuclear waste (total amount, amount of various types) arising from dismantling and its preparation for final disposal depends on a number of different assumptions:

- decommissioning strategy;
- treatment strategy for the radioactive waste;
- and conditioning of waste.

4.1. DECOMMISSIONING STRATEGY

Two viable strategies are usually considered for decommissioning of a NPP.

- Immediate dismantling of the whole plant;
- Safe enclosure of the reactor and adjacent buildings with radioactive inventory followed by deferred dismantling.

If the strategy includes a safestore period of decades, the natural decay of 60Co, the dominant radionuclide in activation and corrosion products, will reduce the radiation level and thus the amount of intermediate level radioactive waste for final disposal.

Further discussion on the UK EPR decommissioning strategy can be found in Chapter 3 of document “GDA UK EPR - Decommissioning” [Ref-1].

4.2. TREATMENT STRATEGY FOR THE RADIOACTIVE WASTE

By treatment of the surface of contaminated material, the amount of waste, which has to be provided for final disposal, can be reduced considerably.

By chemical cleaning or blasting of the surface and melting of metallic material, the amount of material for unrestricted or restricted release can be affected.

Further details on the decontamination techniques currently available and foreseen for decommissioning are described in document “Decontamination processes and techniques for the UK EPR” [Ref-1].

Besides the handling and treatment expenses, the specific cost structure for storage of waste in the final repository is an important factor. Therefore, selection of the treatment measures may also be influenced by cost-effectiveness considerations.

4.3. CONDITIONING OF WASTE

Conditioning involves transforming radioactive waste into a form that is suitable for handling, transportation, storage and disposal. This might involve immobilisation of radioactive waste, placing waste into containers or providing additional packaging. Common immobilisation methods include solidification of LLW and ILW liquid radioactive waste in cement. Immobilised waste may be placed in steel drums or other engineered containers to create a waste package.

4.4. ESTIMATION OF WASTE

4.4.1. Waste from the EPR unit decommissioning

In view of all these assumptions that need to be made, it is difficult to estimate the volume of the radioactive decommissioning waste to be expected after a designed service life of 60 years.

Nevertheless, the total amount of nuclear waste which will have to be disposed of in repositories for LLW and ILW as a result of decommissioning an EPR has been estimated, based on extrapolation from the decommissioning plan of a French PWR. The exact split between the ILW, the LLW and the VLLW waste streams, and a detailed characterisation of the LLW, will only be determined at the time of decommissioning.

In the early stages of GDA, a first evaluation of solid radioactive waste was made considering the characteristics of existing French plants (900 MWe PWR), and with the application of a ratio (16/9) in order to take into account the increased power and size of the EPR.

The substantial part (in terms of radiation) of decommissioning waste for disposal originates from the areas where the core has activated the surrounding material. These are mainly the core internals, the reactor pressure vessel and the biological shielding. The remaining primary system with auxiliary systems and waste treatment systems may also be contaminated with α waste originating from defective fuel assemblies.

Therefore, a more detailed evaluation has been made and is reported in the UK EPR Decommissioning waste inventory report for the EPR unit [Ref-1], and is further discussed in Chapter 6 of document "GDA UK EPR – Decommissioning" [Ref-2], in particular with respect to decontamination waste.

Herein estimates of solid radioactive waste arisings have been refined considering the specific characteristics of the EPR core, in addition to taking account of feedback on decontamination methods and the methodology used for the original 900 MWe PWR detailed study.

Components that are not in contact with primary fluid will be considered as VLLW. Cable trays and supports located in Controlled Areas are considered as VLLW whereas cable trays and supports located in Non Controlled Areas are considered as conventional wastes.

Raw waste estimations based on the assumptions presented are detailed in the following table.

	ILW (tonnes, m^3)	**LLW (tonnes)**	**VLLW (tonnes)**	**Conventional (tonnes)**
Primary Circuit	623	2,735	1,898	
Decontamination	40 m^3			
NSSS Equipment		2,259		
BNI Equipment		2,824	2,605	978
Concrete due to clean up of BNI		75	455	
	623 tonnes, 40 m^3	**7,893**	**4,958**	**978**

An indicative assessment of the volume of final packages has been made based on the above data. This analysis was carried out assuming UK Packaging specifications compatible with immediate dismantling and export, as follows:

- shielded 4 metre boxes with an additional shielding of 400 mm of concrete for the core shells of the reactor vessel (ILW);
- 3 cubic metre boxes with an additional 100 mm steel shielding for the other metallic wastes (ILW);
- 4 metre boxes for concrete (ILW);

- 500 litre solids drum for Ion Exchange Resins (ILW);
- HHISO 20‘ container for LLW (metallic and concrete wastes).

Ignoring the mass of the package and any associated shielding, the typical waste package parameters are given as follows:

- the shielded 4 metre boxes with an additional shielding of 400 mm of concrete are expected to comprise 38% of ferritic steel waste, 2% of stainless steel cladding waste and 60% of mortar;
- the 3 cubic metre boxes are expected to comprise stainless steel waste and mortar;
- the 4 metre boxes for concrete (ILW) are expected to comprise concrete waste and mortar matrix;
- the 500 litre drums for Ion Exchange Resins are expected to comprise 20% of resin and 80% of polymer matrix.

This leads to the following volume for ILW and LLW packages:

	ILW (m^3)	LLW (m^3)
Primary Circuit	1,180	4,036
Decontamination	220	
NSSS Equipment		4,170
BNI Equipment		3,348
Concrete due to clean up of BNI		115
	1,400	**11,669**

Thus, the final total volume of low and intermediate level waste packages is about 13,100 m^3.

The difference between this new volume as compared to the first evaluation (7,000 m^3) can be explained by the fact the earlier GDA assessment was based on French Packaging specifications and specific compaction techniques used in conditioning the waste. In this new study, present UK Packaging specifications have been applied.

The amount of Very Low Level Waste (VLLW) is too dependant on management and packaging options to allow a simple estimate at the GDA stage. It can be noted that, on the basis of the specific EPR evaluation, an average of 5,000 tons of VLLW have been estimated. In the first evaluation, a volume of 13,000 m^3 for the VLLW based on volume was established.

The impact of radioactive decay during storage on the categorisation of decommissioning waste is shown in the Solid Radioactive Waste Strategy Report [Ref-3].

4.4.2. Waste from interim storage facilities decommissioning

Waste arising from the interim storage facilities for ILW and spent fuel is presented and discussed in Chapter 6 of document GDA UK EPR – Decommissioning” [Ref-1].

It is concluded that:

- for the ILW storage facility, any decommissioning waste is expected to be conventional waste;
- for a wet fuel storage facility, all metallic wastes are considered LLW. Regarding the concrete, only the top layer of concrete may be cleaned if monitoring shows contamination. The quantity of contaminated concrete produced would be limited, and categorised as LLW. All the remaining concrete would be conventional waste;
- for a dry fuel storage facility, most of the casks can be disposed of, after decontamination, as exempt waste leaving less than 10% radioactive waste. In the case of dry storage in a vault, a high proportion of the vault type storage decommissioning wastes are anticipated to be classified as LLW and VLLW, although a very limited volume of ILW cannot be excluded.

4.4.3. Secondary waste arising from decommissioning

Secondary waste arising from decommissioning is discussed in Chapter 6 of document GDA UK EPR – Decommissioning" [Ref-1]. It is important to note that all the resulting waste from decontamination operations has the same characteristics as waste created during plant operation and can be treated by the plant itself.

4.5. DISPOSABILITY

The Nuclear Decommissioning Authority (NDA) currently assesses the disposability of ILW and some LLW through the Letter of Compliance (LoC) assessment process. As part of the GDA process, the NDA has developed a conceptual LoC process and is conducting a 'nature and quantities' assessment of the conditioned ILW packages that are currently proposed to be produced from the eventual decommissioning of the UK EPR. The first step of this assessment has been performed and the results have been published by NDA in a Disposability Report [Ref-1].

This report concludes that ILW and spent fuel from operation and decommissioning of an EPR should be compatible with plans for transport and geological disposal of higher activity wastes and spent fuel. It has also concluded that compared with legacy wastes and existing spent fuel, no new issues arise that challenge the fundamental disposability of the wastes and spent fuel expected to arise from operation of the UK EPR.

Chapter 6 of document "GDA UK EPR – Decommissioning" [Ref-2] confirms how the disposability assessment aligns with the baseline decommissioning plans covering the radioactive waste generated during the decommissioning of the nuclear facilities of an EPR site (one single EPR plant and associated Interim Storage Facilities (ISF for ILW and Spent Fuel).

As mentioned in section 4.4 above, waste arising from the decommissioning of interim storage facilities is expected to be LLW, thus having no impact on the data provided to the NDA for their assessment. Chapter 6 of document "GDA UK EPR – Decommissioning" [Ref-2] further discusses how decommissioning LLW and/or VLLW are not considered in the scope of the Disposability Assessment. The waste arising from decommissioning operations will be monitored and classified in the same manner as the operational phase. As a consequence, it is reasonable to assume that such LLW/VLLW would be acceptable to the LLWR, as the waste will also have been demonstrated to be compliant with the LLWR acceptance criteria.

5. DOCUMENTATION

As set out in PCER Sub-chapter 5.1 section 6, the existence and availability of comprehensive design, construction and operation documentation is a major factor which ensures efficiency and the reduction in the number of unanticipated situations during decommissioning.

Documentation considered necessary for decommissioning mainly includes:

- drawings and diagrams relevant to operations, including: mechanical and electrical, cabling drawings, isometric piping drawings, layout drawings, penetration drawings, component details, reinforcements, drawings for special tools used during assembly, and 3D digital model of all of the equipment and the reactor plant;

- additional documentation permitting the use or modification, for alternative operations, of equipment and structures (e.g. design of handling machines, special tools, floors, load-bearing structures, manufacturing and equipment specifications, geo-technical test results);

- photos and videos (with captions, dates and comments), useful to illustrate the assembly and erection of components, the carrying out of the earthworks and the parts of the structures which are subsequently hidden, the means for handling components, the routing plans, while focusing on those parts which are to become highly activated and contaminated;

- quantitative inventories: concrete quantities, steel tonnage, cable lengths, etc. acceptance documents, samples of the materials used in construction, which enables the identification of impurities, strength data for irradiated materials, corrosion resistance, etc. as well as the distinction between initial radioactivity and that which arose from reactor operation, particularly for materials used in construction with an artificial initial radioactivity;

- a record of all of the operating incidents together with their assessment and a record of all modifications made to the original facility;

- all of the documents providing traceability in the areas of radiological characterisation and the radiological inventory (mapping, smear tests, various samples, etc).

These last two points will be ensured in particular through the monitoring of the development of cleanliness/waste zoning.

- The retention of samples and specimens of reactor construction materials (steels, concretes, etc) in an archive for later testing and examination.

A radio-ecological reference survey of the site (ground and marine environments) would also be useful to the final decommissioning file.

This is further developed in Chapter 8 of document "GDA UK EPR – Decommissioning" [Ref-1].

6. DECOMMISSIONING PLAN

The Decommissioning Plan brings together all the activities that are required to move from an operational site back to a state that is suitable for the agreed future use of the site. The plan is developed to align with the adopted decommissioning strategy and to show that decommissioning is feasible.

6.1. TIMINGS OF DECOMMISSIONING

The timing of decommissioning (i.e. deferred or immediate) will have a major effect on the baseline decommissioning plan and programme, and could affect other aspects of the decommissioning, e.g. the methodologies proposed. Considering the timescales concerned it is reasonable to expect a degree of uncertainty over the commencement of decommissioning. At present EDF / AREVA have set out baseline assumptions on the timing of decommissioning of the UK EPR.

The preferred strategy to be adopted for the decommissioning of the UK EPR and the justification for this choice are detailed in Chapter 3 of document “GDA UK EPR – Decommissioning” [Ref-1], together with the effect of changing the baseline strategy.

The strategy describes the effect on timings of the choice of interim storage technique for spent fuel, i.e. the time during which the spent fuel need to be stored in the at-reactor fuel pool after operations, and the effect on other decommissioning activities of storing spent fuel assemblies in the at-reactor fuel pool.

6.2. ASSUMED PLANT STATUS AT DECOMMISSIONING

To produce a baseline decommissioning plan a suitable prediction of the plant status at the end of operations is needed. For example the radiological conditions will influence the decommissioning methodology, shielding or containment requirements.

Chapter 5 of document “GDA UK EPR – Decommissioning” [Ref-1] presents and discusses:

- the plant status assumed to exist at the cessation of power operations (e.g. radiological conditions, contamination, activation, allowances made for any reasonably foreseeable abnormal operations); this has been established at the design stage for the purpose of defining the decommissioning plan;

- how this is expected to evolve or remain unchanged until reactor cessation of operation depending on operation history and the impacts of a different decommissioning start-time compared to the baseline scenario (e.g. early plant shutdown, life extension or deferment);

- methods for confirming plant conditions in the future by the operator, for example through surveys and calculations at the time of cessation of operation.

6.3. DECOMMISSIONING TECHNIQUES AND LOGISTICS

Chapter 2 of document "GDA UK EPR – Decommissioning" [Ref-1] presents the baseline decommissioning scenario using currently available techniques and tools which will allow to progressively dismantle the main components, circuits and structures. The chapter focuses on the dismantling of heavy components and major civil structures.

6.4. DECOMMISSIONING PLAN

Chapter 7 of document "GDA UK EPR – Decommissioning" [Ref-1] presents the UK EPR baseline decommissioning plan. The plan level of detail is commensurate with the stage of the lifecycle and takes cognisance of the work that is being carried out to prepare a costed decommissioning plan for PWRs in France and to prepare a site specific Decommissioning Plan for an EPR which would be built in the UK.

The assumptions underpinning the plan are consistent with the other chapters of the document [Ref-1], i.e. the baseline decommissioning scenario and techniques considered and the whole decommissioning, including the decommissioning of interim waste stores. It covers phases such as achieving operational shutdown, Post Operational Clean Out, and spent fuel cooling before transfer to the interim storage facility.

The timescale covers the operational lifetime of the reactor, the relevant safety and environmental submission schedule and the technology choice for fuel storage. The impact on the program of any necessary fuel storage period in the at-reactor fuel pool is considered and consistency with Government policy and the disposability assessment is addressed.

7. SITE

The site layout, by considering its subsequent development, sets aside the space needed for dismantling, in particular for:

- extension of the processing facilities for normal operating waste;
- modification of the ventilation systems so as to ensure, on the one hand, the integrity of the structures and equipment after permanent shutdown and partial dismantling, and, on the other hand, the containment of contamination during dismantling operations;
- building additional and specific facilities after permanent shutdown (e.g. in-line treatment of large volumes of water, maintenance and decontamination of machinery, secondary cutting of large components, management of larger stream of waste containers, etc.);
- temporary storage of waste, whether to reduce activity levels or to authorise the declassification of certain waste through decay;
- movement of waste and machinery;
- contractors' premises on-site.

8. CONCLUSION

The design of the EPR reactor includes measures which minimise the volume of radioactive structures, reduce the toxicity of the waste, lower the activity level of irradiated components, restrict the spread of contamination and permit easier decontamination, facilitate the access of personnel and machines and the removal of waste, and ensure the collection of building and operating data needed to prepare properly for decommissioning.

These measures facilitate the dismantling of the reactor, limit the dose uptake for the corresponding operations and limit the quantity and activity of the nuclear waste produced in comparison to existing PWRs, which did not consider decommissioning at the design stage.

All of these benefits of reducing the source of radioactivity, optimising its treatments, reducing the requirements for uranium natural resources will be accumulated over the extended design and plant operational life of the EPR of 60 years.

Long design life is built in via features such as lower neutron influence on the reactor pressure vessel or improved SG performance.

With reference to dismantling, numerous provisions have been made regarding the EPR at the design stage to reduce the volume of radioactive waste generated during decommissioning via choices regarding aspects such as the composition of materials in order to reduce the activation, the design of the systems to limit radioactive deposits, cleanliness of systems, the definition of the primary circuit chemistry in order to prevent build up of crud in the reactor and SGs, and use of decontaminable surfaces.

Management, maintenance and operational activities and documentation, throughout the lifecycle, of information relevant to decommissioning preparation, will also minimise legacy issues associated with decommissioning.

A baseline decommissioning strategy has been established, using the current level of knowledge on decommissioning worldwide. This shows that the UK EPR and associated waste and spent fuel interim storage facilities can be safely decommissioned using current technologies, after 60 years and 100 years of operation respectively, and that the site can be restored to a state that is suitable for its agreed future use.

SUB-CHAPTER 5.2 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

[Ref-1] Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs. The Environment Agency. January 2007. (E)

2. DESIGN MEASURES

2.2. MEASURES FACILITATING THE REMOVAL OF COMPONENTS AND STRUCTURES

[Ref-1] Decontamination processes and techniques for the UK EPR. UKEPR-0017-001 Issue 00. EDF/AREVA. March 2011. (E)

3. ARRANGEMENTS RELATING TO THE CIRCUITS

3.1. MEASURES TO LIMIT THE CONTAMINATION OF SYSTEMS

[Ref-1] GDA UK EPR – Decommissioning. Chapter 5 - Assumed plant status at decommissioning. UKEPR-0016-001 Issue 01. March 2011. (E)

3.2. MEASURES TO LIMIT THE SPREAD OF CONTAMINATION

[Ref-1] GDA UK EPR – Decommissioning. Chapter 5 - Assumed plant status at decommissioning. UKEPR-0016-001 Issue 01. March 2011. (E)

4. ESTIMATION OF DECOMMISSIONING WASTE

4.1. DECOMMISSIONING STRATEGY

[Ref-1] GDA UK EPR – Decommissioning. Chapter 3 – Timings of Decommissioning. UKEPR-0016-001 Issue 01. March 2011. (E)

4.2. TREATMENT STRATEGY FOR THE RADIOACTIVE WASTE

[Ref-1] Decontamination processes and techniques for the UK EPR. UKEPR-0017-001 Issue 00. EDF/AREVA. March 2011. (E)

4.4. ESTIMATION OF WASTE

4.4.1. Waste from the EPR unit decommissioning

[Ref-1] EPR UK – Decommissioning waste inventory. ELIDC0801302 Revision A. EDF. November 2008. (E)

[Ref-2] GDA UK EPR – Decommissioning. Chapter 6 – Disposability assessment. UKEPR-0016-001 Issue 01. March 2011. (E)

[Ref-3] Solid Radioactive Waste Strategy Report (SRWSR). NESH-G/2008/en/0123 Revision A. AREVA NP. November 2008. (E)

4.4.2. Waste from interim storage facilities decommissioning

[Ref-1] GDA UK EPR – Decommissioning. Chapter 6 – Disposability assessment. UKEPR-0016-001 Issue 01. March 2011. (E)

4.4.3. Secondary waste arising from decommissioning

[Ref-1] GDA UK EPR – Decommissioning. Chapter 6 – Disposability assessment. UKEPR-0016-001 Issue 01. March 2011. (E)

4.5. DISPOSABILITY

[Ref-1] Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK EPR. NDA. Radioactive Waste Management Directorate. Technical Note no. 11261814. October 2009 (https://www.nda.gov.uk/documents/upload/TN-17548-Generic-Design-Assessment-Summary-of-Disposability-Assessment-for-Wastes-and-Spent-Fuel-arising-from-Operation-of-the-EPWR.pdf.) (E)

[Ref-2] GDA UK EPR – Decommissioning. Chapter 6 – Disposability assessment. UKEPR-0016-001 Issue 01. March 2011. (E)

5. DOCUMENTATION

[Ref-1] GDA UK EPR – Decommissioning. Chapter 8 – Knowledge Management. UKEPR-0016-001 Issue 01. March 2011. (E)

6. DECOMMISSIONING PLAN

6.1. TIMINGS OF DECOMMISSIONING

[Ref-1] GDA UK EPR – Decommissioning. Chapter 3 – Timings of decommissioning. UKEPR-0016-001 Issue 01. March 2011. (E)

6.2. ASSUMED PLANT STATUS AT DECOMMISSIONING

[Ref-1] GDA UK EPR – Decommissioning. Chapter 5 - Assumed plant status at decommissioning. UKEPR-0016-001 Issue 01. March 2011. (E)

6.3. DECOMMISSIONING TECHNIQUES AND LOGISTICS

[Ref-1] GDA UK EPR – Decommissioning. Chapter 2 – Decommissioning plans. UKEPR-0016-001 Issue 01. March 2011. (E)

6.4. DECOMMISSIONING PLAN

[Ref-1] GDA UK EPR – Decommissioning. Chapter 7 – Decommissioning plans. UKEPR-0016-001 Issue 01. March 2011. (E)