

# **The Management of Large Components from Decommissioning to Storage and Disposal**

A Report of the Task Group  
on Large Components of  
the NEA Working Party  
on Decommissioning and  
Dismantling (WPDD)



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## **Radioactive Waste Management Committee**

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## 1. Introduction

During the decommissioning operations of a nuclear facility or during the maintenance activities of an operating nuclear facility, dismantled components may either be segmented (i.e., reduced in size) in order to put the pieces in standardised containers or removed as single or multiple large pieces for treatment or transportation to a disposal facility. Both options have been used and experience exists in most countries with mature nuclear programmes. The considerations and criteria leading to such decisions are multifaceted and include both legal and regulatory aspects dealing notably with transportation, disposal and waste-acceptance criteria (WAC), as well as the availability and acceptance of sized transport containers and dose limits.

The final management option may not be selected solely by the decommissioning entity. In any case, radioactive waste will be generated and will need to be processed through a sequence of operations, including deconstruction, conditioning, extraction, short- or long-term storage on site, transport conditioning, transportation to a waste-management facility that may be a storage facility, a treatment facility or a disposal facility.

The different actors involved play a significant role in choosing the most relevant management option throughout the entire process, since a single option may not be the most appropriate for every stage of the process. If the removal of large pieces raises very complex transportation issues, for instance, it may be preferable to cut components into smaller pieces; in some cases, the disposal of large components may also generate an unacceptable or less than optimal capacity of the repository. For such reasons, integration is required throughout the entire project. The proposed management option for large components should be described in the facility's decommissioning plan and should explain why a particular option was selected. In choosing the proposed option, the decommissioning organisation needs to take into account the respective requirements not only of the waste transporters and of the repository operator, but also of those of the relevant safety and transport authorities.

The objectives of this study are:

- to provide the basis for the different involved parties to reach convergence on the most relevant management option from an overall point of view;
- to identify which criteria should be assessed in order to appreciate that relevancy, and
- to promote a communication tool that benefits from the experience gained by the different countries dealing with that issue.

As well as providing a tool for dialogue between all involved parties, the objective also provides a tool for assessment bodies (e.g., regulators) and stakeholders (the public) in order to appreciate the merits and the disadvantages of a given management option.

Hence, this technical guide promotes an integrated approach encompassing the interests of all actors involved (e.g., decommissioners, regulators, the public at large, waste-management agencies, transporters, waste owners, etc.). Its purpose is to facilitate the review of the issues at stake through a case-by-case approach, addressing all intermediate steps, such as treatment and conditioning, transportation and relevant



decision-making parameters, in order to determine the overall relevancy of potential management routes depending on given circumstances.

## **2. Recent national experience in the management of large components**

### **2.1 General overview**

The meaning of the term “large components” may vary greatly in different countries, either in terms of volume or weight. In Sweden, for example, it applies to items that may not be transported in 20-ft ISO containers or weigh more than 20 Mg. In order to provide a common definition that is valid in all countries, any large component will be considered here as any part of a nuclear facility that may be removed without being cut, that is conditioned in a non-standard package for disposal or storage and that requires specific consideration by local regulators due to its weight, its volume or the extent of its radiological contamination. It means that the related standard process involved by the operator to manage transport, storage or disposal cannot be applied without any modification.

Obviously, the notion of “non-standard package” is relative and is only valid at the scale of a single country, depending on the licensing framework of the involved facilities, and it may change in time, if that licensing framework evolves. Generally, the topic addresses items, such as steam generators, pressurisers, reactor vessels and heads, or transportation casks.

The way to manage large disused components is of wide interest, especially among operators of nuclear facilities, decommissioning organisations, waste transporters and waste-management agencies, as well as safety regulators and other national authorities. Managing and disposing of large components have been successfully carried out in various countries and the experience gained from it provides the baseline for optimising those decisions.

### **2.2 Recent national experience**

This Chapter provides a brief overview of recent national experience in the management of large components for specific countries. More detailed examples are also provided in Annexes 1 to 6c.

#### **Spain**

In Spain, criteria for optimising the management of large components include safety, technical, waste-management, socio-political, regulatory and economical issues. Overall, optimisation must address the impact of the different dismantling options (e.g., removal of components, either intact or in large pieces) during subsequent waste-management operations. Of particular importance are aspects such as the need to develop new waste containers (and their acceptability at disposal sites), egress routes for component removal, the extent of anticipated decontamination operations (on or off site) and the number and type of shipments.

An integrated approach for optimising decommissioning and waste management is currently pursued by the Spanish Agency for Radioactive Waste (ENRESA – *Empresa Nacional de Residuos Radioactivos*), thus involving a dialogue with interested parties. Ultimately, regulatory approval of the selected management option is necessary as part

of the approval process for the overall decommissioning programme of any particular nuclear facility. Studies on the management of large components have been conducted for the José Cabrera Nuclear Power Plant (NPP) (see Annex 3) and will be performed in the future for the other NPPs to be decommissioned.

## Belgium

The Belgian strategy for managing all large components from the decommissioning of the 10-MWe BR3 pressurised-water reactor (PWR) is based on cutting operations *in-situ*. The level of *in-situ* segmentation depends on the acceptance criteria of the transportation itinerary selected for every large component.

For activated components (e.g., thermal shields, pressure vessels, internals), extensive use is made of remote-controlled underwater cutting by mechanical sawing (e.g., band and circular saws) with thermal cutting techniques (e.g., plasma torch, electrical discharge machining [EDM]) used as a backup or directly for specific applicable tasks. Activated components have to be disposed of as radioactive waste. The standard packages accepted by the National Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS – *Organisme national des déchets radioactifs et des matières fissiles enrichies*) are the 200-L or 400-L drums. That choice requires components to be segmented in pieces having a maximum length of ~500 mm and a maximum weight of 560 kg. After packaging, the activated pieces are conditioned into a cement matrix and are currently held in storage. Eventually, the cemented packages will be emplaced in an overpack before being sent to a geological disposal facility.

Large contaminated components, such as the pressuriser or the steam generator, are first decontaminated using an in-loop process (Metal Decontamination by Oxidation with Cerium – MEDOC), and then segmented into large pieces using high-pressure water-jet cutting and diamond-wire cutting. The tube bundles of the steam generator are segmented using a diamond-wire cutting process. After decontamination, components are segmented in order to demonstrate their compliance with clearance levels.

## Sweden

In Sweden, Barsebäck Kraft AB (BKAB) has examined the option to remove the reactor's pressure vessel in one large single piece at the two shutdown reactors (615-MWe BWR) at Barsebäck, and has presented the conclusions to the Swedish Nuclear Fuel and Waste Management Company (SKB). That option is included in a parallel study where SKB is examining options for expanding the SFR repository for low-level and intermediate-level radioactive waste in order to accommodate decommissioning waste, including the disposal of large components and the interim storage of long-lived operational and decommissioning waste. SKB is also undertaking feasibility studies for the shallow disposal of very-low level waste (VLLW) and for the interim surface storage of long-lived components. All long-lived waste will eventually be disposed of in an underground repository scheduled to open in components in 2045.

Among the issues being considered by BKAB are the implications of removing the vessel with its internals still inside, thus requiring additional shielding during transportation and special measures to anchor the internals. Both the radiation and conventional risks of the different options are important considerations. It is clear that, in the event of removing the vessel and its internals in one single piece, a period of interim storage will be needed prior to disposal in the future geological repository for long-lived waste (currently scheduled to open in 2045). That option is expected to be very expensive; it is more likely that, due to the likely high relative cost of geological disposal, an approach based on emplacing the vessel (minus its internals) in the SFR will be adopted.

As regards transportation, a roll-on/roll-off ship would be needed for most reactor pressure vessels (RPV), and the largest ones of Oskarsham 3 and Forsmark 3 would need to be transported by barge. In either case, new transport regulations would be needed for transportation of the vessel with its internals. The transportation of RPVs without their activated internals is assumed to be possible in accordance with the existing *Regulations* of the International Atomic Energy Agency (IAEA), but under special arrangement.

Shipments of large components have been performed successfully in Sweden (e.g., PWR steam generators and BWR steam turbines, from NPP sites to Studsvik for decontamination, volume reduction and release of material for free use).

## Germany

An emerging decommissioning practice in Germany is the removal of complete (unsegmented) large components and their transportation to interim storage facilities (see text below). Following that approach, components are placed in storage and radioactivity is allowed to decay until segmentation may generally be undertaken without using remote techniques, thus offering a greater possibility for the material to be cleared and reused, rather than being sent for disposal. The need for interim storage facilities is an important factor, requiring large investment costs, since those facilities may have to remain in operation for an extended period of time. With regard to any subsequent segmentation after storage during an appropriate period, it must be sure that any resulting radioactive waste will be brought to a repository. It is currently envisaged that RPVs deposited in the interim storage facility at Lubmin (ZLN) will be segmented after a longer storage period and then emplaced into standard waste containers at the Konrad repository, because it is not designed for the disposal of large components (see Annex 2).

In the following paragraph are presented some examples of the removal of large components.

In October 2007, the RPV from the Rheinberg NPP was transported unsegmented to the interim storage facility at Lubmin (ZLN). In addition, the complete RPVs of the Greifswald NPP were transported internally to the nearby ZLN, in November 2007 (Units 1 and 2) and September 2009 (Units 3 and 4). The ZLN is a large storage facility (measuring 240 m in length by 140 m in width and by 18 m in building height) for storing spent fuel and radioactive materials (either conditioned or in the form of large components) and serving as an infrastructure for treating and conditioning radioactive materials (e.g., segmentation techniques). Another example of removing large components is the high-temperature reactor in Jülich (*Arbeitsgemeinschaft Versuchsreaktor – AVR*). Dismantling the reactor tank in today's installed position would be possible only at the cost of unreasonable effort from a radiation-protection standpoint. Hence, the reactor tank of the AVR was filled with light-weight concrete in November 2008 in order to fix the contamination and to stabilise internal structures. It is planned to lift the complete reactor tank (weighing about 2 000 Mg and measuring about 26 m high) out of the reactor building and to store it in a nearby interim storage facility. After letting the component decay in storage for about 30 to 60 years, the plan is to extend the storage facility and to equip it with the required technical infrastructure to cut the reactor tank into pieces that meet the regulatory waste-acceptance requirements of a disposal site. The operator of the facility has demonstrated, via an exemplary prototype concept, that technical options for later segmentation with regard to safety and radiation protection were available.

Several shipments of large components were authorised in Germany in 2007 and 2008: those involved transportation by road and railway, as well as by sea and inland waterway. In general, two approvals are required: a special agreement under the dangerous goods legislation (which is the responsibility of the Federal Office for Radiation Protection - Bundesamt für Strahlenschutz – BfS) and a licence under the radiation-

protection legislation (which is the responsibility of the Länder authorities or of the Federal Railway Authority (*Eisenbahn Bundesamt* – EBA).

### **United States**

The United States Nuclear Regulatory Commission (USNRC) defines “large components” as including reactor vessels and heads, steam generators, pressurisers, feedwater heaters and turbine rotors. In general, the disposal of RPVs in one single piece is the preferred management solution in the country and a number of pressure vessels have already been emplaced in final disposal facilities. In two recent decommissioning projects, Shippingport and Trojan, the internals remained inside the vessel and were surrounded by a light-weight concrete. The basis for that approach is that the risk of potential human intrusion is small and that the overall waste package may avoid being classified as greater than Class C (GTCC). It should be noted that internals are decontaminated prior to being stabilised in concrete.

Important regulatory issues are waste classification and transportation: USNRC does allow volumetric averaging, except in cases of intentional dilution, when determining the appropriate waste class. Given the very long itineraries typically at stake and the complex involvement of the different local transport authorities to obtain movement agreements, the Trojan RPV travelled by rail and barge, thus involving a journey of about 300 miles (500 km) down the Columbia River.

An example of removing a large component sponsored by the United States Department of Energy (USDOE) was the decommissioning of the Heavy Water Component Test Reactor (HWCTR) located at DOE’s Savannah River Site (SRS), Aiken, South Carolina. In order to determine which decommissioning process was best, four decommissioning alternatives were under study. Those alternatives included dismantling, partial and interim safe storage, conversion for beneficial reuse and entombment. Dismantling was chosen after evaluating potential effects on the environment, risks, effectiveness, ease of implementation and cost. Dismantling was also the most compatible option with the site-property reuse plans for the future as it would restore the site to its original condition.

The HWCTR was an excellent model of removing a large component. In order to remove the reactor’s 87-ton dome, three lifting lugs were attached to its surface and the upper portion was cut with a welder’s torch. A 660-ton crane with a 200-ft boom was used to lift the massive dome off its base. The dome was placed on the ground where it was cut into smaller pieces and disposed of at an approved burial facility. The removal of the dome facilitated the removal of two 21-ton steam generators and one previously-defueled 110-ton RPV as single lifts. Before removing generators and the reactor, their pipes were cut and prepared for transportation without reducing them in size. Once those components were laid down horizontally, they were also secured for interment at SRS burial facility on site. Availability of on-site disposal facilities and stringent demonstration through migration-to-groundwater analyses showed that regulatory imposed protective waste-acceptance criteria were met for on-site disposal without size reduction. Moreover, with the HWCTR facility emptied of its steam generators and of its RPV, the surrounding 29-ft cylindrical base was demolished and the underground portion of the building was entombed in grout.

Another example of removing a large component at a DOE facility was the decommissioning of the Engineering Test Reactor (ETR) located at DOE’s Idaho National Laboratory (INL), Idaho Fall, Idaho (see also Annex 6a). Once the building structure was dismantled, the 82-ton defueled RPV was lifted as a single component and disposed of as a single unit at the INL disposal facility on site. Similarly to the HWCTR at SRS, the void spaces between the ETR Facility’s empty RPVs were encapsulated in grout.

## France

The purpose of the National Management Plan for Radioactive Materials and Waste (*Plan national de gestion des matières et des déchets radioactifs* – PNGMDR) is to identify long-term management solutions for all radioactive waste and materials, including dismantling waste. The Plan provides means to ensure the consistency of the overall waste-management programme and the optimisation of individual waste-management steps, including storage. In general, the re-use and recycling of waste is preferred to disposal, and operators are expected to follow an early dismantling strategy, subject to the availability of waste-management venues.

However France has a specific regulatory framework for waste materials that are generated in part of a facility where they may be, may have been or likely to have been activated or contaminated by radioactive substances, thus requiring that they be managed with reinforced traceability. Consequently, a waste zone has to be implemented in order to segregate parts of the facilities with nuclear waste (radioactive or potentially radioactive waste) from parts with conventional waste (no possibility of contamination or activation).

The PNGMDR reflects the overriding need to reduce the volume of waste for disposal, given the need to optimise the use of national disposal facilities and the different waste-management steps within a overall consistent approach. Considerations in achieving such a level of optimisation include technical options for recycling steel and concrete, decontamination processes and issues regarding the disposal of large components.

Électricité de France (EDF) has considered options for the long-term management of the steam generators and the RPV from the Chooz A NPP using a multi-criterion analysis technique. For steam generators, a reference option involving the de-categorisation from low-level waste (LLW) to VLLW, followed by disposal in one single piece, was compared with an option involving segmentation (i.e., thermal cutting of walls and mechanical cutting of tube bundles). The reference option required not only a greater level of decontamination than the latter option, but also a parallel study by the French Radioactive Waste Management Agency (*Agence nationale pour la gestion des déchets radioactifs* – ANDRA), to confirm that the disposal of steam generators as single pieces at the VLLW Repository was feasible. The reference option was selected for implementation, because it yielded significant benefits in terms of professional dose, removal time, waste volume and decommissioning costs, although that factor was balanced by an increase in disposal costs.

For the pressure vessel, segmentation, except for the vessel head and the vessel bottom, was compared with removal as a single piece. It was assumed that the least activated internals would remain in the vessel, whereas the others would be placed in interim storage. It should be noted that, in France, the vessel head and bottom may, in principle, be disposed of as LLW, but not vessel internals, for which only geological disposal is authorised. Although many factors favoured disposal as a single piece for steam generators, for instance, the assumed level of alpha contamination in the internals made it difficult justify disposal at ANDRA's LLW repository, due to the risk of potential human intrusions. Because of the time needed to undertake a more extensive characterisation of the internals, the segmentation option was preferred.

The safety report and the general operating rules for ANDRA's disposal facilities already included the emplacement of certain types of large components, and ANDRA has already accepted a limited number of PWR vessel heads at the *Centre de l'Aube* (LLW) and heavy metallic items and concrete blocks (up to 24 t in weight) at Morvilliers (VLLW). The inventory of large components that may require disposal over the next 20 years has been estimated at 2 500 m<sup>3</sup> and 11 000 m<sup>3</sup>, respectively for LLW and VLLW. It is planned to seek generic authorisations from the French Nuclear Safety Authority (*Autorité de sûreté nucléaire* – ASN) for any facility changes that will be needed in order to facilitate the

disposal of those large components, including a revised safety case for the LLW facility at the *Centre de l'Aube* and the availability of dedicated disposal cells for large components at Morvilliers.

The main issues bearing on the feasibility of disposing of large components at the *Centre de l'Aube* are the impact on the operation of the facility and characterisation requirements (in order to meet the requirements derived from the safety case) and the impact on long-term risk (particularly, in relation to intrusion scenarios).

### **United Kingdom**

In the United Kingdom, large components contaminated by radioactivity are managed in the same fashion as other contaminated waste. Decisions about the way specific waste types will be managed need to be undertaken on a case-by-case basis, with due account of the nature of the waste. The national policy and strategy for LLW provides guidance and the framework according which those decisions are made. In the past, large components have been stored on site awaiting a solution, as in the case of the large boilers at Berkeley, or disposed of directly at the LLW Repository (LLWR) in Cumbria.

Large components disposed of at LLWR were grouted directly into the facility without reducing their size, thus using up valuable space in the facility. In recent years, the U.K. has developed its strategy for the management of solid LLW from the nuclear industry<sup>1</sup>. That strategy will ensure that the space capacity of LLWR will be used more wisely through a better application of waste hierarchy and the use of alternative venues for waste management. Those principles are applied to large components as well as to other types of waste. For large metallic components, that means a better use of size reduction and metal recycling waste venues. The British policy for LLW also expresses a preference for early solutions, which means that long-term awaiting a solution is not a favourable option.

LLW strategy in the U.K. is being implemented through a number of initiatives. One of those is changing the role of LLWR Ltd, which now provides a wider range of waste-management services than just disposal. They also have a role in co-ordinating LLW management in the country. Under those new arrangements, the management of large items will benefit from a collaborative way of working. The decommissioning and waste-management teams at the site generating waste in the form of large components will assist LLWR closely in order to devise the best way to manage the waste. That is already happening at Berkeley, where Magnox Ltd. is working with LLWR Ltd. in order to provide a solution for boilers involving metal recycling.

In practice, many of the solutions for managing large components are already available. Collaborative work will be the key not only to ensure that the best management solution is achieved for them, but also to preserve Britain's capability to manage LLW.

### **2.3 Key drivers of management strategies**

The strategy that various countries follow for managing large disused components is influenced by key drivers, although there are some shared international positions arising from the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA) and the IAEA's good practice, some countries have some specific constraints that may alter the importance of some of the drivers identified in this document.

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1. ([www.nda.gov.uk/documents/upload/UK-Strategy-for-the-Management-of-Solid-Low-Level-Radioactive-Waste-from-the-Nuclear-Industry-August-2010.pdf](http://www.nda.gov.uk/documents/upload/UK-Strategy-for-the-Management-of-Solid-Low-Level-Radioactive-Waste-from-the-Nuclear-Industry-August-2010.pdf)).

One of the major issue that impacts on the chosen management strategy is the clearance (or de-categorisation) and recycling strategy, depending on the national regulations involved. The purpose of that strategy, when implemented, is generally to minimise the volume of radioactive waste to manage by:

- treating decommissioned materials in order to clear them or de-categorise them, for instance by decontaminating disused components, or
- segregating the waste according to available management venues, which means either disposal for the different categories of radioactive waste with regard to the local classification, or recycling.

Depending of the selected strategy, the option for the management of large components will be influenced by another key driver, which is the availability of waste storage and treatment facilities. For instance the recourse to radioactive decay may avoid the use of expensive remote-controlled segmentation techniques or cutting may possibly be carried out manually with less radiation-protection requirements. Through radioactive decay, clearance may be granted and result in either free release or de-categorisation of the waste, thus decreasing the amount of radioactive waste in a particular category. An example of that option may be found in Germany (see Chapter 2.2). It is crucial to know before making a decision, whether an interim storage facility is already available or if it needs to be constructed specifically. On the other hand, the necessity for interim-storage capacity is a disadvantage due to its large investment costs and to the long-term operation of such facility. Furthermore, the treatment capacity for large components in a dedicated external facility may be very useful in order to optimise decommissioning works.

The final form of radioactive waste will be specified by a third key driver, which is the capacity of the disposal facility to accommodate large components. If such a capacity is proposed (as in the case of the U.S.A., France and Sweden) there will be no need for total segmentation in order to standardise conditioning. That may avoid costs and doses to workers. Nevertheless, disposal facilities for radioactive waste represent a scarce and valuable resource in all countries, thus always giving waste reduction and categorisation a high priority.

However, the use of an external storage or treatment facility associated with a disposal facility will not be considered if an additional, but major, key driver, that is the feasibility of transportation, prevents those options. The transportation of large components may require suitable rail, road, sea or river transport systems and the development of suitable transport containers. Where there is a need to develop the elements of waste-management or transportation systems, that may cause significant delays to decommissioning projects, which, in turn, may have a significant impact on cost. The situation, however, may be very different depending on the national framework. In the United States, for instance, the existing infrastructure enables the relocation of large items from the decommissioning site to the interim storage and final disposal facilities. That is also the case in Sweden, where most facilities are located close to the sea, thus making maritime transportation possible. In other countries, as in France, the transportation issue may be more critical.

Economic issues are also key drivers, since they need to reflect the technical difficulties of all phases throughout waste management, including both safety and radiation protection issues. The economic optimisation of decommissioning and decommissioning waste management should also reflect the overall technical optimisation of the selected decommissioning process.

The minimisation of the timeframe for the implementation of dismantling has to be considered and may be a key driver for the selection of a management option for large components. Usually, the dismantling of large components is on the critical path of a decommissioning project and there is considerable interest in finding an alternate



solution to the standard option, which is full segmentation and conditioning in standard packages. Considerable time may be saved by reducing segmentation activities on site. Furthermore, because cutting large components is a complex process, many technical and safety hazards may be avoided when segmentation activities are limited or even better excluded. Finally, the early removal of large components would also improve in-plant logistics for future decommissioning activities. On the other hand, preparatory works may also be required, especially if the installation was not originally designed for handling and removal large components, and the necessary timeframe for those activities has to be taken into account. Normally speaking, any schedule reduction would likely result in a limitation of professional doses as well.

### 3. Main relevant actors in the technical process of managing large components

As set out in previous Chapters, managing radioactive waste involves many actors at various stages, including operators, regulators and a range of stakeholders. The following is a summary of the actors considered in this document, based on the experience with a short questionnaire and some judgements of the Working Group.

- The operator of the nuclear facility.

Not only in the case of large disused components, such as steam generators, generated during the operation of a facility, but also in the case of a decommissioning project:

- the operator is able to provide the most accurate information about the characterisation of the waste (e.g., radioactive content for instance),
- there may be co-activity issues in a facility, when large components are removed during operation.

- The decommissioning organisation.

The decommissioning organisation may be the operator himself or a dedicated agent within the operator's organisation. The involvement of subcontractors should be taken into account. Depending on the specific contractual framework, subcontractors may have more or less flexibility in managing the waste.

In some countries, such as the United States or Spain, the responsibility of the facility has been or may be transferred from the operator to another organisation.

- The transportation organisation.

Generally, the transportation organisation is a subcontractor of the decommissioning organisation who is qualified for the transportation of radioactive material, depending on the selected method of transportation and the nature of travel to be undertaken. That may include transportation across national borders and involve options, such as road, rail, river or sea itineraries. Hence, it may consist of a company from another country than that of the decommissioning organisation.

In general, the consignor is responsible for regulatory compliance, whereas the carrier has to ensure the use of qualified personnel and equipment.

- The treatment or storage organisation.

This study considers the possibility of a treatment or storage facility to be located outside the decommissioning site.

The operator of the treatment facility may provide services, such as, but not limited to, cutting, decontamination, incineration and melting. Recycling part of the treated waste is also possible.

- The operator of the disposal facility.

The operator of the disposal facility is in charge of ensuring that the disposed waste complies with all specific regulations and waste-acceptance criteria of the repository. Additional conditioning services on the site may also be made available.

The operator is also responsible to demonstrate that all disposed waste meets the requirements regarding operational safety and the long-term safety of the repository.

For the purposes of this report, mostly LLW or VLLW repositories are addressed, but it may also apply to landfills, if they are licensed for the disposal of radioactive waste.

The various actors mentioned above are involved in the operational aspects of the different waste-management phases. Their responsibilities may be extensive, since they have to prepare applications and to obtain the respective licenses from regulatory bodies.

There is also a number of important stakeholders, including the public at large, that may influence the waste strategy. Some of those stakeholders may interact with waste-management projects within a legal or regulatory framework, as in the case of local information commissions (*Commission locale d'information* – CLI) in France. They may also include local representatives. Other stakeholders may interact through non-structured or informal processes, such as environmental associations. All stakeholders pay particular attention to the impact of decisions on the quality of life according to their respective sensitivity.

That pattern is common to all countries, although the structure may vary significantly between countries. Annex 7 describes the waste-management organisation in different countries and the role various actors play:

- the responsibilities for the decommissioning process (e.g., liability management, decommissioning operations, transport, waste treatment/storage and waste disposal);
- the control mechanisms existing within and/or between the institutions involved, and the responsibility for the choice of the decommissioning strategy;
- the responsibilities in terms of on-site safety regulations, discharges and disposal;
- the ownership of the facilities; and
- the responsibilities for funding the decommissioning and disposal plans.

Very often, distinct actors are involved. However, in some countries, such as Spain, there is a transfer of responsibility and of ownership from the operator of the decommissioned facility to a single organisation, which may be in charge of decommissioning, waste treatment, storage, transportation and disposal altogether. That approach may integrate a number of operations, thus reducing the number of individual actors with different responsibilities within the process.

Practices in regulating nuclear activities may differ significantly from one country to the next. In some of them, it is the responsibility of the nuclear operator to demonstrate in his application that processes he selected will meet the safety objective. The operator may then select the means, such as long-term safety scenarios, to be used to perform the assessment. The application is reviewed and approved by the regulatory authority, notably in Spain and in France, where a general framework of “obligations of objectives” for the operator is applied. In other countries, such as the United States, the regulatory body may issue the methodology, and sometimes even the tools and standards to be used by the nuclear operator in support of his

application. In that case, the rules are completely clear for the operator, although there might be less flexibility, since the rules may not cover all situations.

The different waste-management processes being implemented involve different regulatory authorities. Those authorities may vary depending on the activity (e.g., decommissioning, transportation). They may also pertain to different regulatory hierarchy levels at the national, State or regional scale. Furthermore, there may be different national levels, if some operations are performed in a different country (i.e., melting of German steam generators in a Swedish facility), thus leading to complex situations when those countries fail to share the same waste-management strategies, such as different clearance levels for radioactive waste. Transboundary transfers may also be regulated by an international convention, as in the case between the different countries of the European Union.

The selection of a waste-management strategy may also be influenced by the national funding system. In some countries, a third-party organisation manages the dedicated funds for decommissioning, while in others, operators are responsible for their own funds, even if some external control may check if the funds are well secured. Since the justification of the funds is provided by a reference decommissioning scenario, any change in that scenario may involve a new financial assessment. Depending on the funding system and on its controlling organisation, there may be more or less flexibility in the choice of decommissioning and waste-management strategies.

National frameworks represent a significant driver and there may be several situations with different bodies to consider as part of the selection process for a decommissioning and waste-management strategy. The dialogue between the relevant regulators and the stakeholders has to be adapted to each specific situation. However, the technical work to be performed does not differ in every country, and it is possible, despite those differences, to propose some general principles and good practices for the management of large disused components.



## 4. Overview of relevant issues

### 4.1 Management stages for large disused components

In order to assess the relevancy of a waste management option for large disused components, different aspects have to be investigated, such as:

- technical aspects;
- regulatory aspects;
- stakeholder aspects, and
- economic aspects.

Those aspects must be considered at every stage throughout the management of disused large components:

- decommissioning, when the handling option is implemented;
- transportation;
- waste treatment or storage, either performed at or away from the decommissioned site, and
- disposal.

### 4.2 Decommissioning issues

In general, the decommissioning organisation has to establish a strategy that covers all waste-management issues. The decision on how to proceed with decommissioning, segmentation and the packaging of large components, for instance, depends on a number of factors, including:

- a) the disposal policies for primary and secondary waste;
- b) safety issues, the ALARA principle to maintain doses as low as practically achievable and limitations of operational dose exposures;
- c) the availability of mature and previously- tested technologies;
- d) the original plant design;
- e) the physical and radiological conditions of the plant at the time of the project;
- f) the overall decommissioning and dismantling schedule of the project;
- g) financial aspects;
- h) regulatory and licensing issues, and
- i) public opinion and stakeholder considerations.

Every factor must be examined with regard to the specific conditions to the facility at stake in order to reach a satisfactory dismantling/segmentation plan for large components. Each factor is briefly discussed below.

In addition, waste may be treated, notably for decontamination. That operation may take place on or off site. Treatment-related issues are discussed in Section 4.4.

**a) Disposal policies for primary and secondary waste**

There may be large differences between countries regarding the legal framework for the disposal of products resulting from the segmentation of large components. Those differences may be tracked down to the specific waste-acceptance criteria of the licensed waste repositories in every country. Besides, different considerations come into play whether primary or secondary waste is involved.

Notwithstanding, some key principles are common to the different approaches and relate to the minimisation of the final waste volume for disposal.

In the case of primary waste, minimisation involves mainly a detailed and accurate radiological characterisation and packing optimisation, including the design of new packages and the licensing and optimisation of cutting strategies.

For secondary waste, efforts focus primarily on minimising the generated waste and optimising their disposal.

Since, in some instances, there may be compliance conflicts between the objectives for primary and secondary waste (e.g., more cutting, resulting in better packing may result in more secondary waste), some kind of equilibrium must be reached, thus taking into account all intervening technical and cost factors.

The following paragraphs address such considerations and factors.

**Primary waste**

Primary waste consists of direct segmentation products, which are usually in the form of metal pieces and components.

It is worth noting that, in many instances, the decision has already been made to defer the dismantling of activated reactor components until several decades after shutdown, thus reducing the inventories of short-lived activation products via radioactive decay. Although that is a sensible measure from the ALARA point view, it may have a more limited effect on waste disposal, which is greatly influenced by the presence of longer-lived nuclides.

International experience, so far, shows that most primary waste resulting from the segmentation of large components may be managed and disposed of as low and intermediate-level waste (LILW). The exception concerns long-lived activation products, such as those that are present in parts of reactor vessels and internal components exposed to a high neutron flux; and most countries, in that case, have agreed to establish specific management criteria, usually based on long-term scenarios for repository performance. In countries that selected the disposal option, those components may only be disposed of in near-surface LILW repositories, if the specific activity of radionuclides, such as Ni-59, Ni-63, Nb-94, C-14, etc., is below the acceptance-criterion limits established by specific regulations (e.g., 10 CFR 61) or by repository operators.

The consensus for managing any residues exceeding those limits, which are usually referred to as LL/ILW (long-lived intermediate-level waste), is to store them at dedicated interim locations, pending their final disposal in geological repositories, along with high-level waste (HLW) from the end of fuel cycle.

Usually, interim storage is carried out within storage casks, similar to those used for the spent fuel stored at the same facility (interim spent-fuel storage – ISFS). In other cases, it is usually performed within specific, but smaller, containers. In all cases, the primary waste is placed inside insert trays, whose internal structure,

dimensions and loading capacity have a decisive influence during the preparation of the corresponding segmentation plan.

The rest of primary waste, which may be classified as LILW and disposed of at near-surface repositories, are managed and disposed of in accordance with the relevant acceptance criteria.

One of the primary issues to be addressed when delineating a dismantling strategy for the LILW portion of large components relates to the extent of the segmentation effort.

One possible option, favoured mainly in the United States and in France, is either to dispose of the components in a more or less intact form within large dedicated packages or to prepare the components as to form the packages themselves, notably by using dismantled reactor vessels as containers or by housing LILW internals or other large components, such as steam generators and pressurisers, as single pieces after grouting and sealing.

Another option implies the extensive dismantling and segmentation of the components in order to use standard packaging and immobilisation/sealing procedures, with available licensed and repository-approved containers.

It may be stated that a limited segmentation approach, resulting in large items for disposal, offers substantial advantages, in principle, by minimising such aspects as:

- programme risks and uncertainties;
- the number of heavy lifts and off-site shipments;
- radiation exposures throughout the operations;
- the overall schedule, and
- the total cost.

On the other hand, it is also true that such an approach presents challenges, the severity of which will usually depend on country-specific factors. Examples of those drawbacks include:

- the design and licensing of new types of large “first-of-a-kind” waste containers or the qualification of any component as self-container may be required, thus requiring more or less time depending on the country’s regulatory framework;
- dedicated heavy lifting devices and new waste venues may be required, depending on the original plant design (e.g., roof openings may be required for the top removal of steam generators);
- extra-large containers may require special transportation arrangements (e.g., weight, height, avoidance of public areas, etc.);
- the final licence for the disposal site may need to be modified and new acceptance-criteria to be developed in order to allow the disposal of new containers or waste types;
- waste-handling facilities and procedures on the disposal site may need to be adapted to the requirements imposed by new containers or waste types, and
- depending on the geometry of new packages and the effective filling factors achieved, the expected reduction of the final storage volume may never occur or remain marginal.

In brief, it may be said that both the repository’s acceptance criteria and the availability and design characteristics of the final disposal containers will be key factors when setting up a nuclear facility’s segmentation plan for large components.



### **Secondary waste**

Secondary waste consists of segmentation sub-products, including any eventual prior decontamination residues, usually in form of disaggregated material, filters, or ion-exchange resins.

The acceptance criteria of the LILW repository are usually one of the main factors to be considered, when setting up a segmentation plan, since they establish specific requirements regarding the final conditioned form and activity levels for those wastes.

More significant challenges result from the debris generated during the segmentation of highly-activated components, such as the internals of the reactor vessel. Depending on the cutting techniques used, debris may consist of metal-only particles (e.g. chips and turnings from mechanical cutting) or of a mixture of metal and abrasive material. Practically speaking, all segmentation techniques also generate secondary waste in the form of cartridge filters and ion-exchange resins, which are used to capture the smallest particles and dissolved materials.

Handling and disposal of debris may be complicated by their high specific activity, which, in some cases, may jeopardise its entire disposal as LILW without dilution (e.g. mechanical-cutting chips) or may require significant shielding requirements with regard to disposal containers, in order to comply with the dose-rate limitations for transportation and on the disposal site.

As an example, one of the options for the disposal of grit in the segmentation project for the internals of a reactor vessel is to store them, dewatered (i.e. without free-standing water), inside large certified “high-integrity containers” (HIC). However, that approach may not be applicable in countries whose repositories require that such waste type be immobilised (e.g., in a cement matrix). That factor, for instance, may imply that the disposal of the same amount of secondary waste may result in an increase in the volume of final packages.

As another example, some countries, allow the storage of metal-only secondary waste inside the same containers used to store LL/IL primary waste, subject to the same conditions and limitations, such as dryness. That approach is logical, since the same material is involved, but in different physical form.

Consequently, before selecting any segmentation technique, it is necessary to assess the implications that the physical form and other characteristics of the associated secondary waste may represent for its disposal at the designated repository with regard to the waste/package-acceptance criteria.

The expected production of secondary waste may be another key criterion during the preparation of the segmentation plan for large components, and, especially, in the decisions between limited or extensive segmentation. It is clear that the first option will usually result in the smaller production of secondary waste, and, thus, lower cost for waste processing, packaging and disposal. However, those benefits will have to be balanced by potential drawbacks in other areas.

In brief, the following list includes some of the most important issues to be investigated with regard to the disposal of both primary and secondary waste, and which may have a large influence on the selection and preparation of an adequate segmentation and packaging plan for large components:

- the classes of waste to be accepted in each potential disposal facility;
- the physical characteristics and waste class of waste packages that are currently approved in each repository;
- any acceptance criterion for final packages, such as waste conditioning, external dose-rate limits for packages, handling limitations, etc.;

- identification of the potential for the use of exemption criteria for waste, and
- the effect of selecting any cutting technology on the volume of secondary waste for final disposal and compliance with general waste-minimisation criteria.

**b) Safety issues, ALARA principle and limitations of exposures due to operational dose**

Risk avoidance and optimisation are important drivers first in the selection of any segmentation technology and strategy for large components, and afterwards during their practical implementation.

The segmentation of large components implies dealing with heavy pieces of equipment, which are activated and/or contaminated internally or externally. Hence, any intervention on them, as part of the dismantling or segmentation process, may include different radiation risks at varying levels, such as:

- external exposures to gamma radiation;
- internal exposures, including the risk of alpha radiation;
- uncontrolled releases of radioactive materials in the atmosphere, and
- spread of contamination.

The segmentation of large components may include conventional (i.e., non-radiological) risks, such as:

- heavy- load drops;
- fires and explosions;
- equipment malfunctions or ruptures, and
- personnel injuries, such as falls, electrocution, asphyxia, etc.

Besides compliance with established regulatory dose-exposure limits for the project, ALARA considerations also have to be taken into account.

Examples of good practices to minimise the above-mentioned risks and to demonstrate compliance with the ALARA principle include:

- the preparation of 3-D models in sufficient detail for large components and all surrounding plant structures and facilities;
- the use of those 3-D models as an essential tool for the design of segmentation strategies and dismantling sequences;
- the optimisation in the number and length of cuts in order to minimise the number and duration of interventions, while considering the potential constraints derived from the design of available containers;
- the preferred use of cold rather than thermal cutting methods, when dealing with activated or highly-contaminated elements;
- the design of cutting equipment for efficient and safe operation, as well as easy maintenance and repair;
- the underwater segmentation of activated components, if possible, with sufficient water to act as shielding;
- the use of temporary confinement or high-efficiency particulate-air (HEPA) filtration structures for all on-air segmentation activities on contaminated components;
- the minimised use of liquid or gas fuel cutting equipment;

- adequate job planning, including training, work-team composition, detailed work procedures, etc., before starting the work, and
- the review of lessons learnt from previous similar projects should also be considered of paramount importance for both, operators and regulators.

The following are some of the most important issues to be investigated, from the point of view of risk management, the ALARA principle and radiation protection, and which may have a great influence on the selection and the preparation of the segmentation and packaging plan:

- the availability of as-built or original construction drawings for large components;
- the radiological characterisation of the large components with regard to activation and/or contamination, and
- the actual status of the plant's handling equipment for heavy loads (e.g., cranes, working platforms, etc.), as well as equipment replacement or re-certification.

The assessment of radiological and conventional risks should also be one of the key factors affecting the decision-making process between limited and extensive segmentation options. In principle, the limited-segmentation option should offer some advantages, due to smaller expected operational and public doses, but they must be balanced off against the expected increase in conventional risks, such as those relating to the lifting and handling of heavy loads.

### ***c) Availability of mature and previously-tested technologies***

The segmentation of large components implies a large number of cutting operations on thick stainless or carbon steel pieces under difficult access and handling conditions. Besides, highly-irradiated stainless-steel components may have radiation-hardening effects that may affect the performance of standard cutting tools.

On the other hand, packing-optimisation criteria usually aim at minimising the final volume of direct segmentation waste. The application of those criteria usually results in the preparation of precise cutting plans, with limited margin for deviations.

In addition, aspects such as the reliability, durability and resilience of the different components of the cutting systems must also be taken into account due to their possible impacts on schedule, on risks and on their radiological impact that equipment failure and/or maintenance may have.

Consequently, it is very important to perform a survey of the different segmentation techniques and of the available equipment from potential suppliers of that type of services. One important aspect of that survey would be to collect and to evaluate information about the previous use of the technology in similar or related projects.

Examples of the main aspects to be considered and evaluated in the survey include:

- the performance and limitations of the cutting equipment (e.g., maximum cut width, cutting rate in relation to thickness, heat and gas generation, etc.);
- the expected life of wearable parts, such as saws, disks, nozzles, electrodes, etc., in relation to the thickness of cut pieces;
- the positioning and restraining requirements of the cutting equipment for cut accuracy and stability purposes;

- the design for easy-maintenance and decontamination purposes, and
- the characteristics for cutting sub-products, including any required adjuvant material, such as abrasive grit.

The following list includes some of the most important issues to be investigated, from the standpoint of cutting technology maturity and requirements, since they may have a huge influence on the selection and preparation of the segmentation and packaging plan for large components:

- the availability and analysis of detailed reports on experience with previous use, addressing actual *versus* cutting performance parameters (e.g. cutting speed, secondary and induced waste generation, etc.), as well as any significant problems encountered, including root-cause analyses;
- the scope of the specific test programmes required to validate the use of selected method or methods at the facility (e.g. representative mock-ups);
- compatibility between the characteristics of secondary waste with currently-accepted waste-management practices at the installation, and
- the requirements imposed by the selected cutting technology, such as space, support, positioning and control equipment, auxiliary installations, confinement, etc.

#### **d) Original plant's design and load-handling systems**

Decommissioning and dismantling considerations were not usually considered in the design of old nuclear power plants and other facilities. As an example, old PWRs were not designed for easy removal or the replacement of some large components, such as steam generators, contrary to newer designs.

Consideration of the ALARA principle during the periodic inspection and maintenance of some components (e.g., reactor internals) had a smaller influence on the design of older plants. As another example, the design of reactor's auxiliary cavities in some older PWR plants implies that part of the lower internals will be out of water during the decennial inspection. That is the reason why new plants incorporate cavity designs with higher flooding depths. That lesson resulted from experience in altering the design and is a significant feature that impacts on dismantling approaches.

Older plants may also lack some handling features that are now standard in newer ones, such as high-capacity polar cranes and large equipment hatches.

It is then clear that plant design, especially from the layout and structural standpoints, may have a decisive influence on the preparation of a successful segmentation plan for large components. That is especially the case when considering options such as the removal of large and heavy components, such as steam generators, as single pieces.

Hence, it is very important to review the plant design, since it may in turn affect the removal and the segmentation of large components, before a sensible planning may be drawn. As a result of that review, the requirements for any structural modifications and new handling equipment in the plant will be identified.

Examples of the main aspects to be considered and evaluated in that review include:

- the plant's lifting and handling systems for heavy loads, including maximum load capacity and operability assessments;

- the accessibility to compartments housing large components (e.g., removable block walls, hatches, platforms, etc.);
- a re-evaluation of cavity flooding levels, and
- the current design of plant systems considered as auxiliary equipment for large components, such as the clean-up of cavity water, and the assessment of possible upgrades.

The following list includes some of the most important issues to be investigated, from the standpoint of the original plant design, since they may have a large influence on the selection and preparation of the segmentation and packaging plan for large components:

- the availability of as-built or original construction drawings for existing plant structures and facilities;
- the feasibility of upgrading existing lifting and handling systems, if required;
- a feasibility analysis for new entranceways and handling systems and itineraries, including structural re-analyses, if they are required by any of the options under consideration;
- the availability of as-built or original design information about plant systems of interest;
- the availability of detailed records documenting previous design changes, and
- a comprehensive plant walk-down is usually required in order to confirm design data.

***e) Physical and radiological state of the plant at the time of the project***

The physical and radiological state of the plant at the time when the project is performed will also have a significant influence on the scope of a suitable segmentation and packaging plan.

Hence, it is very important to perform a survey of the expected physical and radiological state at the time the project is performed. That survey should consider, as a minimum, such aspects as:

- any potential obsolescence and/or degradation of any segmentation system and equipment;
- any degradation of leak-tightness features in cavities and pools;
- background radiation levels in compartments and general access areas, and
- the existence of additional non-properly characterised items to be included in the scope of the project, such as reactor operational waste, which may require specific treatment (e.g., Zircaloy items).

Some of the most important issues to be investigated, with regard to the plant's physical and radiological state, since they may influence the segmentation and packaging plan, are:

- the certification and inspection of load-handling equipment;
- the plant's system maintenance records being affected;
- recent plant-wide radiological survey data, and

- a comprehensive plant walk-down is usually required to evaluate the overall state of the plant and it may be supplemented by electronic surveys, such as 3-D laser scanning.

**f) Overall decommissioning and dismantling schedule of the project**

Overall schedule requirements may also influence the selection of the segmentation and packaging strategy and technologies for large components.

**g) Financial aspects**

Although financial aspects and constraints are of no or limited concern with regard to application from a regulatory standpoint, it should be recognised that they are a key driver in terms of overall business decisions, and may have a decisive influence in the selection of suitable segmentation and packaging technologies and strategy for large components.

That influence is usually due to the following factors:

- some cutting technologies may result in higher up-front costs than others, due to the use of advanced and expensive equipment;
- however, since they may represent definite advantages in other areas, such as radiological impact, reduced secondary waste, cutting time and precision, etc., their higher cost may be balanced off by those other considerations;
- the impact on the costs and schedule of the required plant modifications must also be addressed and taken into account, notably when comparing different alternatives. Some modifications, especially those involving the set-up of new handling structures or requiring the use of external heavy load cranes, may represent a substantial part of the overall cost;
- some cutting technologies may have higher risks, which, if proven, may result in extensive delays or clean-up efforts, thus generating financial risks to the vendor, supplier or entity responsible for the plant, and
- the design, licensing, procurement, transportation and handling of the type of specialised containers required for the disposal of direct segmentation waste may represent a very substantial part of the total project budget. It is clear, as mentioned above, that the approach used for the segmentation and packaging plan will have a decisive influence on that aspect.

Consequently, a detailed financial assessment, with due account of those types of factors, should also be an integral part of the overall decision-making process.

**h) Regulatory and licensing issues**

The segmentation and packaging plan for large components is an integral part of the total decommissioning and dismantling (D&D) safety plan for the facility concerned, and, as such, is subject to review and approval by the licensing authorities. The most important issue for that review is compliance with applicable regulations about:

- the radiological protection of workers and the general public;
- the ALARA principle;
- routine and accidental radioactive releases;
- non -radiological risks and safety issues;
- the quality assurance of components and systems;

- leadership and management for safety;
- human performance, and
- operational feedback.

New designs for specific containers, which may be required by the segmentation and packaging plan, shall be subject to review and approval by licensing authorities, prior to use. Depending on the type of container involved, the following three types of licences may be required, each one with its own criteria and prerequisites:

- interim storage on site;
- transport to the disposal facility, and
- final disposal.

Licensing authorities will usually review and approve specific interface processes, such as:

- container loading, conditioning and closure at production site;
- re-packaging operations before transport and conformity with applicable transport regulations, and
- re-packaging operations at disposal site.

Interactions between licensing and the selection of options are particularly important when new 'first-of-a-kind' packages or processes need to be approved, (e.g., when large components are to be disposed of in one piece). The long lead-time usually associated with that approval means that licensing authorities must be approached well in advance in order to minimise project risks, or the refusal of or the request for substantial changes to the proposed plan.

#### ***j) Public-acceptance considerations***

At times, and depending on the sensitivity of the general public to nuclear-related issues, it may be sensible to address such aspects, as the examples shown below, when selecting a segmentation and packaging plan for large components:

- public aversion to (radiological) risk may be aggravated, if conspicuous large radioactive-labelled containers are used to transport large pieces away from the site (reduced segmentation);
- people tend to accept more easily a number of 'normal-size' containers spread in different shipments, although, in fact, the impact and risk might be slightly higher;
- for sites close to populated areas, the sight of large components being extracted through large openings in containment buildings may generate uneasiness among some people, and
- the use of segmentation technologies and strategies, that are obviously more beneficial than recycling (e.g., via extensive segmentation and segregation), might be preferable for public acceptance.

### **4.3 Transportation issues**

#### **4.3.1 Regulatory issues**

Previous Chapters illustrated the importance of transportation and the need for early consideration. Regulatory issues arise from the application of IAEA regulations

and, particularly, the *Safety Standard Series No. ST-1* issued in 1996: *Regulations for the Safe Transport of Radioactive Material*. All international transport regulations concerning every transport mode are established on the basis of those regulations, and all shipments of nuclear waste, including large components, shall be performed in accordance with them.

The main difficulties concerning large components, according to those provisions, include:

- activity limits and, particularly, their situation with regard to A2 values (0.4 TBq for Co-60), and contamination limits. For instance, the maximum authorised activity for components, such as cover caps or steam generators, to be transported as industrial packages is 40 MBq/g, and non-fixed contamination on inaccessible surfaces shall not exceed 800 kBq/cm<sup>2</sup> for  $\beta\gamma$  emitters, and
- dose rate limits:
  - $\leq 10$  mSv/h, at 3 m from the waste, without any protection;
  - $\leq 2$  mSv/h, at the point of contact of the package or transport container, and
  - $\leq 0.1$  mSv/h at 1 m from the package/container or 2 m from the vehicle.

Compliance with those criteria facilitates transport with industrial packages (IP1 or IP2). If one or several of those criteria is not possible, Type-B packages shall be used (e.g., transport of spent-fuel casks), but that method is not relevant, because it is too complex and expensive when transporting only one or a few large components.

The transport of large components in industrial packages, as “surface contaminated objects (SCO)” or, “low specific activity (LSA) material” (in cases where the activity results from activation), according to the classification range, is not technically difficult. Test procedures to demonstrate compliance with the containment objective under normal conditions are not too stringent and, in case of difficulty to ensure that demonstration, special arrangements are negotiable with regulatory authorities.

It is possible to transport a component without any packaging, if it is classified SCO1 (according to *IAEA Transport Regulations*) and is subject to dose and surface-contamination limits.

#### **4.3.2 Technical and operational issues**

Technical and operational issues, due to the size and/or the weight of large components, involve the various equipment for packaging, handling and infrastructure.

##### *Packaging*

The main issues include:

- the design of the package in compliance with *IAEA Transport Regulations* (mainly with the objective to be reached after the different tests) and adapted to the characteristics, such as size and weight (sometimes over 100 t), of the different pieces;
- compatibility between the size and the weight of the items to be transferred with the transport means. Those restraints may require components to be cut or parts of them removed (e.g., core components), and
- the design, if necessary, of the shielding to be both suitable for limiting dose rates and consistent with the weight limits of the transport means.



### *Handling*

The different issues result mainly from the transport means (i.e., transport mode, multimodal transport, etc.):

- flexibility: according to the weight of large components after packaging, the different means shall be available at the different transportation stages (loading, transshipment, unloading). In case of multimodal transport (road/rail, road/sea, etc.), handling means shall be adapted to the different transport means, and
- security: in case of accident, it will be necessary to remove the package and that may be a condition to obtain a shipment authorisation. Hence, the different intervention conditions and means shall be defined, but handling means for heavy loads may not be necessarily easily available within short delays.

### *Transport means and infrastructure equipment*

The different issues regarding transport means and infrastructure equipment result also from the transport mode. Each has its own advantages and disadvantages, as described in Table 4.1.

#### **4.3.3 Economic issues**

Economic issues shall be estimated regarding the following considerations relating to transportation, such as the development and construction of specific packaging, including programme tests, in order to demonstrate compliance with transport regulations and the development of specific handling systems. A comparison of costs with the shipment of standard packages after segmentation should also be performed.

Moreover, the final destination of the waste shall be considered. Hence, if it is a temporary storage facility located at or close to the nuclear facility, or a disposal facility far from the nuclear facility, the chosen strategy might be different.

#### **4.3.4 Public-acceptance issues**

Public involvement is important in the transport strategy. Some provisions may actually induce a few qualms due to:

- an accident involving the transport of a large component (irrespective of the transport mode, but mainly road transport), or
- any public works required for allowing the transit of the convoys.

Hence, public acceptance is necessary and will result from the widest exchanges possible between the different operators (nuclear sites, carriers), the stakeholders and the public at large, not only living close to the facilities involved in the transport, but also close to transshipment points and transit zones, such as built-up areas.

**Figure 4.1: Advantages and disadvantages of various transportation means for large components.**

	Sea transport	Road transport	Railway transport
Advantages	<ul style="list-style-type: none"> <li>Easily used for nuclear facilities and receiving facilities located on shore or with access to a suitable harbour for very heavy components, using ships with high capacities in those cases will prove be interesting</li> <li>When a sea-transport system is used for other nuclear shipments (e.g., waste and spent fuel), it is already "within the system" and may easily be used also for transporting large components</li> <li>With a transport system already in use, transport costs for single large components will be limited</li> </ul> <p>Particular case of barge transport:</p> <ul style="list-style-type: none"> <li>more availability than ships</li> <li>better high-load capacity</li> <li>no crew on board during transportation (radiation protection)</li> </ul>	<ul style="list-style-type: none"> <li>Flexibility: availability of means, multimodal interface</li> <li>Direct transport ("door-to-door")</li> <li>Easy supervision (e.g., in accordance with special arrangement requirements)</li> <li>Costs</li> </ul>	<ul style="list-style-type: none"> <li>High level of security</li> <li>Costs</li> <li>Flexibility, if nuclear facilities are linked to the railway network</li> </ul>
Disadvantages	<ul style="list-style-type: none"> <li>Expensive costs, except if the ship is used for other freight, but in that case, non-exclusive use may prove difficult</li> <li>Flexibility: the availability of ships, particularly in case of exclusive use, is scheduled over the long term, and immobilisation costs are very high</li> </ul> <p>Particular case of barge transport:</p> <ul style="list-style-type: none"> <li>longer transport time</li> <li>ballasting of barges during load in/out operation</li> <li>need for tug boats and assistance tugs, if applicable</li> <li>no standard sea fastening available</li> </ul>	<ul style="list-style-type: none"> <li>Heavy loads/ long vehicles: their use may occur for public works and civil engineering (bridges, crossroads, etc.)</li> <li>Itineraries may be sometimes incompatible with the characteristics of the convoy (total weight, width),</li> <li>Traffic limitations (weather, regulations). In France, for example, the transportation of vessel heads is prohibited between November and March</li> <li>Less safe than other modes.</li> </ul>	<ul style="list-style-type: none"> <li>Intermittent tracking</li> <li>Network not always adapted (tunnels/large volumes)</li> <li>Availability of handling systems in case of multimodal transport</li> </ul>

#### **4.4 Waste-treatment/storage issues**

The final goal of waste treatment and storage is to prepare large components to meet clearance or reuse levels or acceptance criteria for the final disposal of radioactive waste.

##### **4.4.1 Regulatory issues**

Regulatory issues regarding clearance levels are referred to in the IAEA's *Application of the Concepts of Exclusion, Exemption and Clearance (IAEA Safety Standards Series No. RS-G-1.7, IAEA, Vienna, 2004)*. The specific quantitative clearance levels for radionuclides are based on the internationally-accepted 10 µSv concept, which means that public exposures shall not be higher than about 10 µSv/a.

Since it is difficult in practice to measure many of the radionuclides at the IAEA-specified levels for release from regulatory control, specific procedures and practices have to be developed and approved in advance by the regulatory body and its independent experts. In addition, the free release process has to be performed under a strict quality assurance programme and regularly audited by the regulatory body and its independent experts.

Issues relating to acceptance criteria for final disposal as radioactive waste are developed in Section 4.5.

Treatment, conditioning and storage have to be performed under the provisions of the licence of the site and/or of the facilities involved.

##### **4.4.2 Technical and operational issues**

Technical and operational issues concern decontamination, segmentation, waste treatment and processing. Those operations may be performed either on or off site. They have to be duly authorised by the license of the facility. The selection of the techniques and processes involved requires a complete understanding of the physical, chemical and radiological characteristics of the components to be managed.

###### *Decontamination*

Decontamination techniques/processes may be used either for reducing dose or salvaging of materials or components. In the first case, it concerns the decontamination of the primary loop of an NPP, which contains both activated and/or contaminated components. In the second case, decontamination techniques are applied on contaminated components in order to meet free release levels, as well as meeting acceptance criteria for both free release and recycling, or to lower the radioactive waste category. The main issue is the selection of a suitable decontamination technique or process which to achieve the chosen objective without creating any other issue that would prove difficult to manage, such as secondary waste (see Section 4.2).

- Advantages:
  - salvaging materials;
  - reducing doses and radiation hazards during the next steps (e.g., segmentation, transport), and
  - reducing segmentation, transport, storage and disposal costs.
- Disadvantages:
  - possible impact on the planning, when the decontamination technique is applied on site, unless the decontamination occurs in a dedicated workshop;

- producing secondary waste that may be difficult to treat and may result in additional requirements with regard to personnel and costs, thus causing additional exposures;
- generating new risks/hazards to be properly managed (e.g., radioactive dust and aerosols, chemical hazards), and
- creating additional doses during decontamination.

#### *Segmentation*

The degree of segmentation of components depends on the acceptance criteria of each task of the selected evacuation route (e.g., transport issues, facilities for treatment, storage and/or disposal).

- Advantages:
  - better characterisation in waste segregation and reduction of waste costs;
  - simplification of handling, packaging and transport issues and
  - easy disposal.
- Disadvantages:
  - time-, dose- and cost-consuming;
  - generating new risks/hazards to be properly managed (e.g., radioactive dust and aerosols, electrical hazards), and
  - producing secondary waste.

#### *Treatment*

The purpose of treatment is either to recover valuable materials or to minimise the volume of radioactive waste by:

- melting for free release (e.g., ingots meeting the acceptance criteria for recycling in a non-nuclear industry [Studsvik, Sweden; Siempelkamp, Germany]);
- melting for reuse (e.g., ingots meeting the acceptance criteria for re-use in a nuclear industry [Energy Solutions, U.S.A.; Siempelkamp, Germany] );
- melting for volume reduction (e.g., ingots meeting the acceptance criteria for direct disposal [Centraco (France)]), and
- volume reduction using compaction or supercompaction techniques.
- Advantages:
  - recovering materials, and
  - reducing transport, storage and disposal costs.
- Disadvantages:
  - producing secondary waste that need to be properly managed (e.g., filter, slags);
  - creating risks/hazards associated with the melting of metal, and
  - generating additional doses.

*Conditioning/packaging*

The purpose of conditioning/packaging is to meet the acceptance criteria for disposal. It includes the cementation of radioactive waste into a primary package and/or a final package for disposal purposes. In some countries, solid waste is directly packaged and conditioned into large containers (~20 m<sup>3</sup> volume) for direct disposal. In others, it is packaged and conditioned first into 200-L or 400-L drums that are loaded into large containers prior to disposal. The direct packaging and conditioning of solid waste into large containers may result in an important reduction of the final volume for disposal. It also minimises professional doses, shortens the segmentation time and, thus, reduces costs and risks. The general advantages/disadvantages of conditioning and packaging are:

- Advantages:
  - providing extra shielding around the radioactive waste;
  - reinforcing the integrity of the disposal package; and
  - retarding the release of radionuclides into the biosphere.
- Disadvantages:
  - time-, dose- and cost-consuming; and
  - producing secondary waste.

*Storage*

Storage may be a necessary step either to meet the acceptance criteria for free release (i.e., decay storage) or to provide a safe solution pending the availability of a disposal site. Storage may be performed on site or off site.

- Advantages:
  - further decommissioning of the facility; and
  - reducing risks by surveying a small facility with a small volume of packaged/conditioned waste compared to the volume of the decommissioned facility, where the contamination is dispersed.
- Disadvantages:
  - cost-consuming; and
  - producing secondary waste.

**4.4.3 Economic issues**

In order to assess economic issues adequately, a cost-benefit analysis should be performed. That analysis must take into account not only direct related cost, but also those relating to the protection of the workers (dose exposure), the population and the environment.

**4.4.4 Public-acceptance issues**

The main concerns of the public are related to the transport of radioactive waste (frequency, exposure, use constraints) to and from the site, and to the discharge of effluents. The public is also sensitive to the local employment. Initiatives have to be taken to inform the public adequately about the activities and the risks involved and to answer their concerns.

## 4.5 Disposal issues

### 4.5.1 Regulatory issues

In general, the development of a disposal facility and its safety case includes the establishment of waste-acceptance criteria (or waste-package specifications) that describe the conditions with which a waste package must comply in order to be accepted in the disposal facility. In most instances, that approach is based on standards packages. Variations to that packaging standard require a suitability evaluation for disposal against the facility safety case. In many countries, waste-acceptance criteria are submitted to the approval by the regulatory body and become part of the repository licence.

In most cases, waste-acceptance criteria are related to standard packages, that is to say packages that waste generators are likely to generate during the normal operation in their facilities or packages that were *a priori* specified by the organisation that is in charge of long-term waste management. In France, for instance, the design of the *Centre de l'Aube* Disposal Facility took into account metallic or concrete packages that were conditioned within nuclear facilities; in Spain the standard package is a 200-L drum with an overpack consisting of a concrete disposal package, whereas in the U.K., standard packages were specified by the Radioactive Waste Management Directorate which is part of the Nuclear Decommissioning Authority.

Since large disused components generally do not fit in with the standard-package concept, there may be no account of the disposal of such items in the licence of the disposal facility, hence the licence may not include any authorisation to accommodate them.

In the assessment of a decommissioning plan including the removal of large components, it is therefore necessary, prior to any technical investigation, to check if the disposal of large components is permitted within the applicable regulatory framework of the repository. That means that a very early co-ordination should be implemented between the decommissioning organisation and the repository operator, when non-standard conditioning modes are considered.

If both parties (decommissioning organisation and repository operator) agree to develop such a non-standard option, the repository operator should then analyse which kind of regulatory process he has to perform, for instance:

- a specific authorisation file submitted to the regulatory body, or
- a specific authorisation file submitted to the regulatory body, including the involvement of third parties (i.e., the public) that may require a public inquiry, for instance.

That information is necessary to assess the duration of the procedure and potential risks. The resulting forecast planning will then be compared with the expectations of the decommissioning organisation.

*In France, for instance, the option to dispose directly of pressure-vessel heads was considered by EDF and ANDRA, back in 1994. That option did not involve the review of the licence of Centre de l'Aube Disposal Facility, even if specific vaults have to be developed; however, a safety file was requested by the regulatory body for approval. That approval was granted in 2001 and the first vessel head was disposed of in 2004. Due to the length of the regulatory process and the construction of the vaults, EDF had to implement a storage solution.*

*In 2009, the risk involved and the length of the procedure led EDF to abandon the direct disposal of the vessel of the Chooz reactor.*

*In the U.S.A., the disposal of the Trojan reactor vessel required a review of the waste classification of the reactor vessel (e.g., LLW Class C or GTCC). It also required package certification as a Type-B Certificate of Compliance under U.S. transportation regulations in order to allow a one-time shipment of the Trojan NPP's reactor vessel with its internals for disposal at the U.S. Ecology site in Hanford, Washington.*

*In Spain, ENRESA considered, early in the José Cabrera NPP D&D project, the possibility of using non-standard oversized containers for storage at the El Cabril Repository of the NSSS Large Components with minimal segmentation. For standardisation's sake, a single enveloping container design was developed and intended for use with all components.*

*That design resembles some previous "hat-box" containers, like the one previously mentioned for the disposal of reactor-vessel heads by EDF/ANDRA. However, the foreseen duration of the licensing process and the impact on El Cabril's vault design and operations, led ENRESA to dismiss that approach for the José Cabrera Plant and to settle instead on a more conservative approach, involving the use of El Cabril standard packages, although it would be at the expense of extensive segmentation.*

#### **4.5.2 Technical feasibility**

Technical feasibility may be achieved, if sufficient technical means are implemented. It may result in significant additional costs that have to be taken into account when selecting the most relevant waste-management venues.

However, what has to be investigated for existing facilities is the feasibility to adapt to a new waste stream. Hence, the different sequences of the itinerary of the large component to its disposal cell have to be considered, such as:

- the transportation from the entrance to the disposal cell, via a treatment facility, if needed.

Depending of the transportation mode on the public domain (train, ship, and road), the unloading process, if needed, and the transportation to the disposal cell have to be assessed in order to identify which modifications the facility needs to undergo: pressure on the road, width of the road, obstacles as lamp poles, etc.:

*In Sweden, the objective of extending the existing SFR disposal facility is to accommodate waste resulting not only from decommissioning, but also from operation and maintenance. The design will take into account the possibility to dispose of large disused components. The two existing entrance tunnels are too small for very large components, such as reactor pressure vessels. Hence, it has been decided to build a third tunnel with the dual objective to dispose of large components and to facilitate the removal of excavated rock without interfering with the operation of the existing part of the repository, and*

- the disposal mode

In general, disposal structures are designed for standard packages and are not able to accept large components, without being modified. One option for the disposal of large components would be to adapt existing cells. Another option would be to design dedicated cells in order to accommodate one type or different types of large components. The latter may be useful, if additional conditioning has to be performed on site, since it will not affect standard waste deliveries. However, both options should be investigated in terms of investments and integration in the normal operation of the disposal facility.

Different handling techniques may be implemented, usually dedicated to each specific item. The development of the selected handling technique is performed

with a search for consistency with the handling technique used on the decommissioned site.

*In the Centre de l'Aube, reactor-vessels heads are disposed of in dedicated cells with their own handling tools. However, the disposal principles remain exactly the same as for standard packages. Conditioning is performed inside the disposal vault. The inner and outer spaces of the vessel head are grouted with a pump that is emplaced inside the vault.*

*For other large components, standard vaults are used. The waste could be emplaced by the standard handling crane prior to standard waste packages or put in the vault horizontally before the vault walls were built.*

### **4.5.3 Safety issues**

#### **4.5.3.1 Operational safety**

Handling techniques and conditioning techniques must be developed in accordance with the current operational safety options of the disposal facility. That is true, in particular for the containment system that may be used, if conditioning is performed on site.

Generally speaking, all hazards resulting from the management of large components on the disposal site have to be assessed and preventive measures have to be implemented. It is a good practice to review the hazards that were identified for standard waste and to adapt them to the specific case of a large component. Such a review may not be possible in a generic approach since each waste may involve specific issues.

An interesting indicator for operational safety is to check the exposure of workers in comparison with a standard waste package option, especially when remote-handling systems are impossible to use.

#### **4.5.3.2 Long-term safety**

In some countries, one main purpose of waste conditioning is to provide containment guarantees either through the waste form (e.g., embedding in a matrix) or the waste package (e.g., water tightness of a metallic package, containment properties of a concrete containers), thus addressing the consequences of a potential dispersion of radionuclides by circulating water in the repository.

The functions and performances allocated to the conditioned waste may vary with time. For instance, depending on the activity level of the waste package containment may be different. In France, containment should be demonstrated for IL waste, while for LL waste, only good conditioning practices are required. It is also currently agreed in the case of near-surface repositories that containment properties are progressively lost over the long term and that long-term safety mainly relies on the residual activity.

The description of the behaviour of the disposal facility – which might be conventional sometimes – has to be justified and is therefore taken into account in the assessment of the potential impact of the facility in the long term for water-transfer scenarios.

Consequently, in the case of a large component, a check should be made whether the conditioning mode complies with the assumptions that are made for the safety assessment for standard waste. Otherwise, a specific safety assessment must be performed.

*Standard waste is normally embedded in a matrix, with the voids being backfilled as much as feasible. That type of conditioning mode ensures containment and mechanical strength. When considering the disposal of heat exchangers as single pieces, it must be taken into account the fact that the contamination occurs mainly inside the pipes,*



where it is very difficult to backfill. Potential water pathways through the heat exchanger have to be examined in order to select the most relevant conditioning process to be used.

For near-surface repositories, the safety assessment includes the investigation of any inadvertent intrusion in the facility. Developed scenarios for standard waste packages may not be relevant and specific scenarios may have to be considered. For instance, the potential consequences of the uncovering of a large metallic piece may have to be addressed as the re-use of the activated or contaminated metal in a melting facility.

*Calculations regarding activity concentrations are a critical issue for the disposal of large components. When segmentation is selected, the size and weight of the waste are limited and, hence, contamination or activation may be considered as homogenous. With regard to the disposal of large pieces, that assumption is no more valid and it is very important to consider how the activity concentration is calculated. That is particularly true, when there is a wide range of activity in a single equipment such as a reactor vessel with its internals or a steam generator with its tube bundle.*

*The commonly-used approach to assess the hazards of an inadvertent intrusion is to consider that the radioactivity is mixed with the other materials of the waste packages. The impact is thus related to the specific activity of the waste package that is calculated through the ratio of the activity by the total mass of the package. However, when the contamination or the activation is located on some particular parts of the waste (e.g., on the inner surface of a vessel), such an approach may not be relevant and may result in an underestimation of the specific activity to be considered in some specific scenarios (e.g., the melting scenario). Consequently, it may be necessary to develop specific dedicated scenarios for the safety assessment.*

#### **4.5.4 Waste-acceptance criteria**

As stated in the case of the regulatory issues, it is a good practice to formalise into technical requirements the main assumptions that are taken into account for waste packages at the design phase of a disposal facility. Those technical requirements include in particular parameters and values that are important for the safety of the facility. They are commonly called “waste-acceptance criteria”.

Consequently, the introduction of a new waste form, like a large disused component, should result in the development of a specific technical requirement for that waste form. That is obvious for some parameters that are related to handling safety (i.e., maximum mass of the waste). It is also particularly true if conditioning has to be performed on site, since some parameters of the delivered package may affect the safety of the conditioning process.

#### **4.5.5 The use of disposal space**

When comparing different options for the management of large disused components, the use of the disposal space should be taken into consideration. Generally speaking, the disposal cost for a waste accounts for the use of space in the currently-operated facility, but does not include the cost for replacing that existing facility. However, it is clear that the implementation of any disposal facility for radioactive waste is a difficult duty. Hence, in some countries, the regulatory framework states that a disposal facility should be considered as a rare resource.

A good practice to reduce the volume of disposed waste would be to compare the disposal space needed for the disposal of a large disused component as a single piece as opposed to standard waste packages after segmentation.

#### 4.5.6 Disposal costs

Waste management is an important component in the cost of a decommissioning programme. Depending on the complexity of the programme and on national specificities, it may vary up to several tenths of the overall cost of the programme.

Consequently, when a non-standard disposal option is considered, a cost comparison with the standard disposal options is necessary, since additional costs have to be considered, such as:

- the costs of feasibility studies and of studies for the licensing process;
- the cost associated with the radiological characterisation of large components, either intact or in large pieces (e.g., dedicated equipment for large area/volume gamma survey, smear samples in difficult locations, etc.), when compared to easier characterisation of smaller and disassembled pieces;
- the costs for required additional investments (dedicated disposal vaults, handling systems, conditioning systems, etc.);
- the costs for manpower and materials during disposal, and
- the depreciation of the repository due to the use of disposal space.

When selecting a strategy for handling large components, the overall cost has to be considered, including:

- cost savings at the facility resulting from potential faster handling on site and shorter overall dismantling timeframe;
- the possibility of one single shipment, compared to multiple shipments, if segmentation is selected, and
- investments and operational costs at the storage/disposal facility.



## 5. Interdependency of activities and overall optimisation

In the previous Chapter, the advantages and disadvantages of the possible management modes of large disused components were reviewed during every phase in waste management. Those phases were considered separately and are generally beyond the responsibility of different operators and, potentially, different regulators.

This Chapter suggests a way to make an overall assessment of the most relevant management mode for a large disused component among the following:

- segmentation on the decommissioning site and storage or disposal in standard containers;
- removal from the decommissioning site as a single piece, followed by treatment or storage off site. The latter sequence may be followed by disposal as a single piece or after segmentation, and
- removal from the decommissioning site as a single piece followed by direct disposal.

The assessment may be performed on the basis of an evaluation matrix that is described in the following table.

Such an approach shall be used in a case-by-case approach. Depending not only on the large component itself and the existing situation in the decommissioned facility, but also on the storage or disposal opportunities, the assessment results may vary.

The evaluation matrix (Table 5.1) considers main issues that were identified in the previous paragraphs. Those main issues include:

- regulatory and licensing issues;
- technical and operational issues;
- safety and ALARA issues;
- economic and schedule issues, and
- public-acceptance and stakeholders issues.

Those issues shall be evaluated for each of the four stages considered (i.e., decommissioning and dismantling, waste transport, waste treatment or interim storage and final waste disposal), and taking into consideration the different possible scenarios (Table 5.2), which include decommissioning with segmentation and decommissioning with the management of large components (with or without treatment and storage before disposal).

Different aspects or parameters for each issue need to be investigated. In terms of safety issues, for instance, radiological safety or risk, potential doses to the workers and to the public, conventional safety, radiological impacts and discharges into the environment are among the topics to be addressed.

**Table 5.1: Evaluation matrix considering the main issues for different stages/processes**

ISSUE	STAGE/PROCESS				Conclusions
	Decommissioning	Transportation	Waste treatment/ Interim storage	Disposal	
	<i>Parameters</i>				
<b>Regulatory and licensing issues</b>	Prior references for similar projects	ADR waste classification (LSA, SCO or higher)	Free release limits and processes	Need to develop for special licensing process for non-standard packages, including the preparation of specific safety cases	
	“First-of-a-kind” issues (processes, containers, etc.)	Acceptability of industrial packages (IP-1/2)	Conditional clearance (recycling) limits and processes	Need to develop dedicated acceptance criteria for non-standard packages	
	Overall D&D project ALARA compliance	Licensed Type A and B packages	Treatment and conditioning process for disposal		
	Required changes in waste acceptance criteria and/or processes and facilities of disposal site	Regulatory exemptions (e.g., transport without packaging)	Interim-storage licensing		
	Applicability of free release/clearance criteria				
<b>Conclusion</b>					
<b>Technical and operational issues</b>	Availability of mature and tested technologies for the proposed concept	Number of expected expeditions	Evaluation of applicable waste-treatment techniques/processes (decontamination, segmentation, volume reduction, etc.)	Evaluation of modifications required at the disposal site for handling large non-standard packages	
	Previous references in similar projects	Packaging issues (e.g., external shielding, shock absorbers, etc.)	Need for new ancillary facilities	Need to design new dedicated storage cells for large non-standard packages	
	Feasibility/ease of deployment	Handling issues (availability and flexibility of handling means)	Minimisation of secondary waste	Need to develop a new conditioning process at the disposal site in order to accommodate large non-standard packages	
	Use of original plant systems and load-handling means	Required changes in transport infrastructure	On-site handling issues	Need to develop new characterization strategies for large non-standard packages	

	Number and extent of required plant modifications				
	Primary and secondary waste disposal policy implications (e.g., type of containers)				
<b>Conclusion</b>					
<b>Safety and ALARA issues</b>	Expected external and internal workers exposure	Compliance with transport dose limits	Expected doses to the workers due to treatment processes	Need to re-evaluate conventional and radiological risks for handling, conditioning and disposal of non-standard packages	
	Expected public exposure	Transport security and waste retrievability issues	Potential new risks/hazards (e.g., chemical, aerosols, etc.)	Expected doses to workers from the handling, conditioning and disposal of waste packages	
	On-site radiological risks (irradiation, contamination, etc.)	Optimisation of waste itinerary (road, railway and sea options)	Doses resulting from waste handling	Validity evaluation of the disposal site's performance assessment for large non-standard packages, including human-intrusion scenarios	
	Off-site radiological risks (uncontrolled activity release)				
	On-site conventional risks				
<b>Conclusion</b>					
<b>Economic and scheduling issues</b>	Total project schedule duration (forecast)	Container cost	Cost-benefit analysis (reduction of transport, storage and disposal costs <i>versus</i> treatment costs)	Overall disposal costs, including design, licensing, new process development and investment in new facilities	
	Total project cost (forecast)	FOAK containers design, testing and licensing costs	Potential risk schedule in case of treatment contingencies	Use of disposal space	
	Potential internal risks for schedule and cost	Timely procurement of containers	Costs of interim-storage facilities	Potential internal risks for schedule and cost (e.g., design and test delays, analyses uncertainties, etc.)	
	Potential external risks for schedule and cost	Impact on schedule of transport-related contingencies (e.g., road blockage, weather, etc.)		Potential external risks for schedule and cost (e.g., licensing delay, intervenor action, etc.)	

		Liabilities, cost of insurance			
<b>Conclusion</b>					
<b>Public acceptance and stakeholder issues</b>	Overall project risk perception by public	Number and visibility of off-site expeditions	Need to justify the need for interim storage to public	Public involvement in disposal site re-licensing (if required)	
	Waste minimisation via recycling/clearance	Avoidance of large population areas	Public positive perception on the reduction of waste for disposal		
		Impact of transport route restriction			
<b>Conclusion</b>					

Table 5.2: Assessment grid for possible scenarios

ISSUE	OPTION/MANAGEMENT MODE			
	No. 1 Extensive segmentation and standard containers	No. 2 Single-piece removal and off-site processing	No. 3 Single-piece removal and disposal	Conclusion
<b>Regulatory and licensing</b>	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Summarise and compare the three approaches for those issues
<b>Technical and operational</b>	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Summarise and compare the three approaches for those issues
<b>Safety and ALARA</b>	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Summarise and compare the three approaches for those issues
<b>Economic and scheduling</b>	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Summarise and compare the three approaches for those issues
<b>Public acceptance and stakeholders</b>	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Mention unacceptable issues, if any, and summarise advantages and disadvantages	Summarise and compare the three approaches for those issues
<b>Conclusion</b>	Decide on the feasibility and the advantages of that waste-management mode	Decide on the feasibility and the advantages of that waste-management mode	Decide on the feasibility and the advantages of that waste-management mode	Select the most relevant option

Comparisons may be quantitative in the case of some parameters, notably when considering doses, costs or impact on the length of the project. However, often qualitative comparisons need to be done. Qualitative measures may also provide a significant input for determining project risks. The level of difficulty to achieve the objectives should also be considered. As a first step, an investigation of potential unacceptable issues may also be conducted.

If a weighting methodology is used, results will be highly dependent on the selection of criteria that were considered as the most important. Hence, it is suggested to adopt a more neutral approach and to emphasise the selection criteria that point towards the proposed management option.

To establish that matrix in a case-by-case approach requires the involvement of the different actors of the whole waste management process: the decommissioning organisation, the transporter, the operators of the storage/treatment facilities and the disposal operators. That means that the involvement of such actors should be a prerequisite for managing large disused components very early in the design of a decommissioning plan in order to optimise it.

Indeed, that overall optimisation should not be considered as a simple coincidence of “local optimisations” in the different phases of waste management. For instance, transportation constraints or the use of a significant space in the disposal facility may be accepted, if they balance hazards in other phases, by quite lower or fewer doses to workers during dismantling works, cheaper costs, etc.

Consequently, that comparison approach should be adopted in a transparent way, first and foremost between the different actors in order to provide an objective overall optimisation; it should also be implemented with the licensing authorities in order to demonstrate that a choice that is made at one management step is influenced by the other phases. Hence, a comprehensive review is needed and may involve local stakeholders, where necessary, or form part of the local engagement plan.





## **6. Dialogue between the operator and the regulator and with society at large**

### **6.1 Introduction**

Dialogue with stakeholders is an extremely important feature of all decommissioning operations. First of all, regulators may have a statutory responsibility to engage in a dialogue with stakeholders over and above their “social and moral” responsibilities to provide information. The purpose of this section is to summarise from a regulatory perspective some of the statutory responsibilities, together with examples, and to discuss some broader issues as well as the overall context in relation to specific aspects that relate to the dismantling of large components.

### **6.2 Statutory responsible and international guidance**

IAEA document NW-T-2.5 (*An Overview of Stakeholder Involvement in Decommissioning*, IAEA, Vienna, 2009) provides a comprehensive overview of stakeholder involvement in decommissioning and a very good working basis regarding large components. That document defines a “stakeholder” as follows:

*Owing to the differing views on who has a genuine interest in a particular nuclear related activity, no authoritative definition of stakeholder has yet been offered, and no definition is likely to be accepted by all parties. However, stakeholders have typically included the following: the regulated industry or professionals; scientific bodies; governmental agencies (local, regional and national) whose responsibilities arguably cover nuclear energy; the media; the public (individuals, community groups and interest groups); and other States (especially neighbouring States that have entered into agreements providing for an exchange of information concerning possible trans-boundary impacts, or States involved in the export or import of certain technologies or material).*

The OECD/NEA Forum on Stakeholder Confidence identifies a stakeholder as ‘any actor-institution, group or individual with an interest in or a role to play in the societal decision-making process’. According to the *Good Practice Guide to Project Management*, a stakeholder is ‘a person or organization that has a vested interest in the project – either positive or negative’. There are obviously many more variations along those lines.

Those references provide very wide definitions and, hence, it is difficult to give a summary of all stakeholder and regulatory interactions. However, it does emphasise the need to interact with local communities, particularly where there are significant transport activities that may be associated with large components. That is also determined by the infrastructure in particular countries.

In Europe, public or private projects that are likely to have significant effects on the environment shall be subject to an environmental impact assessment. The legislation also requires the stakeholder’s explicit and active involvement as part of the decision-making process (as embodied in the Århus convention of the United Nations). Projects to decommission NPPs are within the scope of that legislation. This aspect should be considered as a statutory consultation where the operator has the specific duty to consult certain stakeholders. The specifics for large components will depend on whether the scope of decommissioning falls within the definition of those regulations. Nevertheless, the principles of the legislation form a good basis for the type of local consultations to be

applied and of issues to be addressed. In the United Kingdom, for instance, that is enforced through the *Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations (EIADR)*.

The EIADR process to authorise British NPPs to be decommissioned and to make changes to ongoing decommissioning projects involves extensive stakeholder consultations to be conducted as an integral part of the decision-making process. It involves a wide range of active stakeholders in order to help feed and challenge the process. All comments received are collated, reviewed and used to support the final decision. Published decision reports summarise the decision-making process with a high level of transparency.

Stakeholders are considered to be all those parties with a vested interest in the specific decommissioning project at hand. Whilst in the United Kingdom, the EIADR define some statutory consultees, those are mainly bodies with relevant statutory obligations and follow the principles of the European Directive. Hence, within the European Community, there is a statutory process that may be relevant when considering large components. The process also encompasses additional non-statutory consultees, including the general public. Other interested parties, such as the local community or pressure groups, are also consulted. That, being coupled with the IAEA guidance NW-T-2.5, mentioned previously, provides a framework of good practice that may be furthered when considering large components.

In order to involve the public, the regulator uses public notices in newspapers in the locality of the decommissioning project for information purposes about the on-going process, and requires that key documents be readily available for public consultation. The public is also invited to submit comments directly to the regulator, who also encourages licensees to liaise directly with local communities, early in the process, with a view to building constructive and beneficial relationships.

Any application for the first decommissioning licence requires an environmental impact assessment (EIA); it is stipulated by law in Germany. The EIA prescribes that the project be announced and disclosed for public inspection (public involvement). Subsequent applications require a preliminary assessment of the individual case, whether or not a further EIA is necessary. A hearing to voice and discuss objections is often held in many cases. The EIA forms an integral part of the nuclear licensing procedure. All authorities, whose jurisdiction is involved, shall take part in the licensing procedure. That statutory process is similar in the United Kingdom.

The previous paragraphs provided an overview of the responsibilities of the “nuclear regulator” for the site involved. There are, however, other regulators that have other responsibilities particularly in relation to planning, where there might be further statutory consultations. Large components in non-standard containers require specific approvals. In addition, there might be other consultation requirements with local authorities and across the transport itinerary.

### **6.3 Interaction with regulators**

Dismantling large components involves an iterative decision-making process that sometimes involves a number of regulatory organisations and, perhaps, a number of permissions or authorisations, such as:

- discharge authorisations;
- disposal authorisations either on or off site;
- safety-case approvals;
- ALARA studies;

- transportation authorisations;
- best-available-technique studies;
- best-practical environmental option studies, and
- strategic environmental assessments.

The interactions also take place over a significant timeframe depending upon the complexity of the project. The 'permissions' may also be interrelated or form significant project milestones. As part of good project management, it is essential to ensure the early involvement of the respective regulators. Similarly, most regulators have to plan their resources and, as an integral part of modern society, are expected to act as such and to promote good and safe operation. All parties, therefore, have the common goal to make the process as efficient as possible.

The approach that is favoured by a number of regulators is early involvement. In such instances, the regulator has to develop a balance between the extent of the regulator's advice and his formal approval. In some regulatory frameworks, since the regulator has the specific duty to give advice, early involvement is easier to develop. Advice, however, does not replace the requirements of individual countries to obtain a specific permission or authorisation.

An example of an approach that would facilitate such dialogue is an integrated waste strategy (IWS), which provides a key approach for the safe, environmentally sound and timely management of radioactive waste on any site. That forms an integral part of dismantling of large components. Licensees should develop and maintain a strategy that gives an overview of their approach to the current and future management of all waste that is generated or received on his site(s). The IWS should integrate and optimise all waste-related activities on a site, ranging from operational activities through to decommissioning and the waste arising from the management of contaminated land.

An IWS should demonstrate that the waste may be properly managed at the time and rate at which it will arise, taking into account the itinerary of disposal routes and the availability of facilities. The IWS should be developed as to involve regulators and other stakeholders. It should use appropriate and consistent quality-assurance arrangements that include criteria and specifications for data and information, with due account of health, safety, environmental and security management systems, as appropriate. The strategy should not be restricted to any material that the licensee currently regards as waste: it should also cover all materials that may become waste in the future. That may very well depend upon the regulatory system within the country involved. There may be a number of different regulators involved to grant a permission or authorisation, and that may raise problems in terms of timing and separation between the various stages. The possibility of differing the regulatory consultation process is also an additional complication.

It is anticipated that a study of strategic options would be conducted in order to identify a strategy for a specific waste stream (or parts thereof) that would ensure that waste-reduction opportunities are used as far as practicable throughout the life cycle from operation to decommissioning. Those are key areas for early dialogue.

In terms of large components, the IWS approach works at a number of levels. First, at the conceptual level in terms of the overall decommissioning plan, and further, as part of the project's specific activities and decision-making process regarding possible options. At some point in the planning, a form of regulatory permission is granted. Usually, a dismantling authorisation is given within the framework of the decommissioning licence and removal in a single piece is not an issue because it may prevent or reduce occupational exposures, releases and risks. However, there may be associated issues concerning the amount of generated waste and the availability of disposal facilities. In such instances, approaches, such as best practical environmental options studies,

become relevant. There are many examples of how those have been developed and used and how stakeholders have been involved; some of them are quoted in the IAEA document NW-T-2.5.

The transportation of large components, if they are not fully segmented at a site, is subject to a case-by-case review, usually under a special arrangement and becomes a key area of involvement with regulators and stakeholders along the transportation itinerary.

Availability of waste disposal facilities is also a key factor, since they may be for LLW or ILW. The facility is licensed on the basis of the safety case when the repository is opened. That is often prepared independently from dismantling projects regarding specific large components. Consequently, a specific authorisation is usually required, thus leading to the need for discussions with local stakeholders, which are normally initiated by the operator.

Since such authorisations may involve different regulatory bodies, co-ordination is needed between them, notably to decide whether a single process is warranted or not in order to cover all issues regarding various matters, such as dismantling, transportation and disposal. In some instances, the use of integrated project teams or project boards have been used to drive the regulator's involvement leading to permissions.

Communication with the wider stakeholder group becomes more complex as the number of facilities and regulators increases. The IAEA document NW-T-2.5 addresses some of the techniques in use in different countries, as well as the decisions made. A key feature is whether the involvement is part of a formal consultation with a direct impact on the decisions or option or whether it consists more of information to keep a stakeholder group informed.

## 7. Conclusion

The removal of large components in the framework of maintenance or decommissioning operations has already been performed successfully in various countries. In the United States, some RPVs have been conveyed to disposal facilities by barge and road transport. In France, a case-by-case approach has been adopted, particularly for the replacement of vessel heads and their transportation by road to the disposal facility for their disposal in dedicated cells. In Germany, old steam generators and RPVs have been conveyed to a storage facility in order to optimise further treatment and recycling operations. In Sweden, plans call for a specific part of the SFR to be developed with a view to accommodating large components to be transported from NPPs by ship.

In general, the proper management mode for large components is selected according to key drivers, which are mainly:

- the national clearance (or de-categorisation) and recycling strategy;
- the availability of treatment facilities, waste storage facilities that are able to accommodate large components;
- the capacity of the disposal facility to accommodate large components;
- the feasibility of transportation;
- economic issues, including the cost-benefit analysis, and
- the availability of adequate dismantling procedures/tools.

The ability to accommodate large components provides an opportunity for an overall optimisation of radioactive waste management resulting from maintenance or decommissioning. It should therefore be included in the design of relevant treatment, storage or disposal facilities, even if, in general, licensing issues concerning disposal in those facilities, when they are implemented, focus on waste in a standard conditioned form.

Since the selection process of a management option for large components includes considerations on the different phases of waste management, it should involve all relevant actors at an early stage (decommissioners, conveyors, and operators of treatment facilities, storage facilities and disposal facilities) in order to identify the most relevant mode overall. The optimisation process should be transparent among all interested parties. Through an early involvement, the process should be discussed with respective regulators and the acceptability of the management option to regulators is an integral part of the successful delivery of the project. In some cases, that may lead to the specific approval of all or part of the decommissioning plan. Good practice includes making the process and decisions readily available to stakeholders.

An overall optimisation addressing all key factors (risk/benefit analysis), should be developed. This report proposes a grid in order to assess all waste-management phases and to compare the different available options. The resulting grid includes the specific issues for each phase, where the different potential options (i.e., segmentation or removal in single pieces for storage or disposal) may be compared according to a grid.



## 8. Acronyms

ALARA	As Low As Reasonably Achievable
ANDRA	Agence nationale pour la gestion des déchets radioactifs (Radioactive Waste Management Agency)
ARRA	American Recovery and Reinvestment Act
ASN	Autorité de sûreté nucléaire (Nuclear Safety Authority)
ATC	Almacen Temporal Centralizado (Centralised High-level Waste Storage Facility)
AtG	Atomgesetz (Atomic Energy Act)
ATR	Advanced Test Reactor
AtVfV	Atomrechtliche Verfahrensverordnung (Ordinance Relating to the Procedure for the Licensing of Facilities)
BfS	Bundesamt für Strahlenschutz (Federal Office for Radiation Protection)
BMU	Bundesministerium für Umwelt, Naturschutz und Reactorsicherheit (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)
BWR	Boiling Water Reactor
CBA	Cost/Benefit Analysis
CERCLA	Compensation and Liability Act
CFR	Code of Federal Regulations
CLI	Commission locale d'information (Local Information Committee)
CNJC	José-Cabrera Nuclear Power Plant
CSN	Spanish Nuclear Safety Council
D&D	Decommissioning and Dismantling, Decontamination and Dismantling
DEQ	United States Department of Environmental Quality
DOD	United States Department of Defense
DOT	United States Department of Transportation
DNFSB	Defense Nuclear Facilities Safety Board
EBR-II	Experimental Breeder Reactor II
EDF	Électricité de France
EDM	Electrical Discharge Machining
EE/CA	Engineering Evaluation/Cost Analysis
EIA	Environmental Impact Assessment
EIADR	Environmental Impact Assessment for Decommissioning Regulations
ENRESA	Empresa Nacional de Residuos Radioactivos
EPA	U.S. Environmental Protection Agency
ESK	Entsorgungskommission (Nuclear Waste Management Commission)
ETR	Engineering Test Reactor
HEPA	High-Efficiency Particulate-Air (filter)
HIC	High-Integrity Containers
HL	High Level
HLW	High Level waste
HWCTR	Heavy Water Component Test Reactor
FSD	Full System Decontamination
GOCO	Government Owned Contractor Operated
GRS	Gesellschaft für Anlagen- und Reactorsicherheit (Society for Facility and Reactor Safety)
GRWP	General Radioactive Waste Plan



GTCC	Greater-Than-Class-C
IAEA	International Atomic Energy Agency
ICDF	Idaho CERCLA Disposal Facility
ILW	Intermediate Level Waste
INL	Idaho National Laboratory
ISFSI	Independent Spent Fuel Storage Installation
IWS	Integrated Waste Strategy
KTA	Kerntechnischer Ausschuss (Nuclear Technical Committee)
LILW	Low and Intermediate Level Waste
LL	Low Level
LLW	Low Level Waste
LLWR	Low Level Waste Repository
MEDOC®	Metal Decontamination by Oxidation with Cerium
MTR	Materials Test Reactor
NDA	Nuclear Decommissioning Authority
NPP	Nuclear Power Plant
NTCRA	Non-Time Critical Removal Action
OSHA	Occupations Safety and Health Administration
PBF	Power Burst Facility
PNGMDR	Plan national de gestion des matières et des déchets radioactifs (National Management Plan for Radioactive Materials and Waste)
PPV	Peak Particle Velocity
PWR	Pressurised-Water Reactor
RCRA	Resource Conservation and Recovery Act
RH	Remote Handled
RPV	Reactor Pressure Vessel
RSK	Reaktor-Sicherheitskommission (Reactor Safety Commission)
RVI	Reactor Vessel Internals
S&M	Surveillance & Maintenance
SFL	Final Repository for Long-Lived Reactor Waste
SFR	Final Repository for Short-Lived Reactor Waste
SG	Steam Generators
SKB	Svensk Kärnbränslehantering (Swedish Nuclear Fuel and Waste Management Company)
SLCs	Site Licence Companies
SRS	Savannah River Site
SSK	Strahlenschutzkommission (Commission on Radiological Protection)
StrlSchV	Strahlenschutzverordnung (Radiation Protection Ordinance)
TLD	Thermoluminescent Dosimetry
TRU	Transuranic Waste
UK	United Kingdom
UKNWM	UK Nuclear Waste Management Ltd.
USA	United States of America
USDOE	United States Department of Energy
USNRC	United States Nuclear Regulatory Commission
UVPG	Gesetz über die Umweltverträglichkeitsprüfung (Environmental Impact Assessment Act)
VAC	Variance at Completion
VLLV	Very Low Level Waste
ZPPR	Zero Power Physics Reactor
WAC	Waste-Acceptance Criteria

## 9. References

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*Annex 1a***Dismantling large components at the Chooz A NPP in France**

by Jean-Jacques Grenouillet, EDF-Centre d'ingénierie de déconstruction et environnement (CIDEN)

**Background**

Located in northern France, close to the Belgian border, Chooz-A is the first pressurised-water reactor (PWR) to be dismantled in France. The unit was designed by Westinghouse as an upscale of Yankee Rowe (U.S.A.) with a capacity of 300 megawatts (MW).

The plant was shut down in 1991 and placed in safe-storage conditions for about 40 to 50 years pending deferred dismantling.

The large components to be dismantled include:

- the RPV and the internals;
- the vessel head;
- four steam generators, and
- the pressuriser.

The objective of the project is not only to dismantle of the above-mentioned components with a high level of performance regarding safety, radiation protection and cost, but also to prepare or anticipate the dismantling of the large components of the next PWRs that will be dismantled in France.

**EDF waste management policy**

*Électricité de France* (EDF) has defined a waste-management policy for decommissioning activities. Its purpose is:

- **optimising waste-management**

Optimisation is not limited to dismantling works, but has to be achieved throughout the entire decommissioning process (i.e., dismantling, transportation and disposal) with a view not only to reducing costs and duration, but also to minimising doses and releases.

- **making the best use of the repository capacity**

The best use of the repository is achieved through waste sorting and decontamination in order to adopt the best dedicated route available. High density is also sought for waste packages.

- **limiting on-site interim storage**

Buffer storage facilities on site are designed with limited capacities, thus forbidding any waste to be generated as long as a disposal route is not available and, once it is, imposing that it be transported to the repository as soon as possible.

- **developing recycling**

Although free release is not authorised in France, waste material may be recycled within the nuclear industry in order to manufacture waste containers, for example,

- **trying innovative solutions**

To prepare dismantling for the next generation of nuclear power plants

### **Dismantling of large components at the Chooz A NPP**

Of course, the dismantling for large components, such as steam generators (SG) or the reactor pressure vessel (RPV), was the key activity where EDF Waste Management Policy had to be applied.

Consequently, the optimisation of the entire decommissioning process and the use of innovative solutions were the key drivers for the selection of dismantling scenarios for large components.

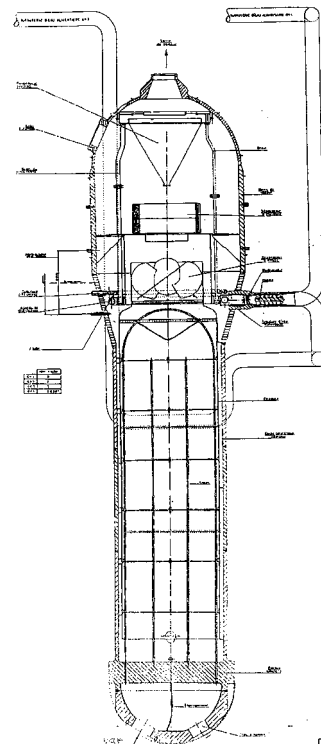
### **SG Dismantling**

#### **Characteristics of the Chooz-A NPP steam generators (SG):**

Parameter	Value
External diameter (top)	3.17 m
External diameter (bottom)	2.37 m
Height	13.81 m
Weight	113 t
Activity (1 Dec. 2012)	680 GBq

Two scenarios were assessed:

- removal in single pieces, and
- segmentation.



Due to the deferred strategy having been selected, the primary loop was not decontaminated after shutdown. Hence, the activity of the SG is quite high and decontamination will be performed in both scenarios, although the decontamination objectives are different:

- for the single-piece scenario, the aim is to decategorise the SGs from LLW to VLLW, and

- for segmentation, the goal is to minimise doses to workers and the public.

A multi-criteria comparison of both scenarios was performed (see tables below) and resulted in the selection of the single-piece disposal for SGs.

Scenario	Dose	Gas release	Schedule	Weight	Waste volume	Transport
Single piece	0.7 man·mSv	No	–	532 t	300 m <sup>3</sup> 4 waste packages	4 1,200 km
Segmentation	9 man·mSv	<sup>3</sup> H <sup>14</sup> C	22 months	525 t	600 m <sup>3</sup> 245 waste packages	72 21,000 km

Because SGs are non-standard waste for the VLLW repository, ANDRA prepared a specific study to assess the feasibility of their final disposal. Feasibility was demonstrated, but specific handling tool will be necessary in order to deposit SGs in the vault due to their heavy weight and to save space.

### RPV and reactor vessel internals (RVI)

For dismantling RPVs and RVIs, two scenarios were assessed:

1. their full segmentation and disposal in standards packages, and
2. a segmentation limited to the most activated parts and a conditioning of the least activated part of the internals in the RPV itself, the whole package being disposed at the LLW repository.

In both cases, the most activated parts of the internals, which are classified as long-lived ILW, have to be stored at some interim storage facility designed and operated by EDF for that waste category.

A multi-criteria comparison of both scenarios (see table below) established that the most interesting scenario was the disposal of the RPV as a single piece.

Criterion		Full segmentation	Disposal as a single piece
Dismantling techniques		–	++
Induced tasks	Civil works reinforcement	0	–
	Reactor pool tightness	–	++
Doses		-	++
Packages	Design and fabrication	0	-
	Licensing	0	--
Secondary waste		–	+
Waste volume generated		–	++
Transportation		0	--
Duration		–	++



Feasibility studies were undertaken regarding packaging, on-site handling, transportation and disposal. They all concluded to the technical feasibility of that scenario. A cost estimate for every project phase was performed on the basis of those feasibility studies. Regarding transportation, several routes were assessed: road, rail and river. The most flexible option was transportation by boat because the size of the package was close to the limits for transportation by rail, while transport by road was found too costly due to the number of arrangements to be made along the itinerary. The authorisation process for transportation by road was found also to be very problematic, because all municipalities involved had to approve it.

The most critical issue was disposal at the LLW repository. Because that option is not described in the safety case of the repository, ANDRA had to prepare specific studies in order to demonstrate that disposing of the RPV as a single piece was meeting the specific safety requirements of the repository regarding long-term safety. In particular, some intrusion scenarios were assessed and it was found that, due to the significant alpha contamination of the internals declared by EDF, any RPV segmentation in the repository, once the facility is closed after more than 300 years, was not acceptable from a radiation-protection point of view. A more accurate estimate of the alpha contamination may have changed that conclusion, but that would have required a new characterisation of the internals, which was not compatible with the deadlines of the decommissioning project. Thus, EDF decided to discard that scenario and to proceed with the full segmentation of the RPV and RVIs.

## Annex 1b

## The disposal of reactor pressure vessels heads at the Soulaines LLW disposal site (France)

by Pascal Lecoq and Michel Dutzer, ANDRA, France

### 1. Introduction

In 1994, EDF, the national utility, requested ANDRA (*Agence nationale pour la gestion des déchets radioactifs*), the French national agency for the management of radioactive waste, to take over 55 reactor pressure vessel (RPV) heads from all PWRs (900 and 1,300 MW).

By 1994, 24 of the 55 vessel heads had already been removed and stored in an EDF facility located in southern France.

Since the disposal of such large components was not described and licensed in the safety report of the *Centre de l'Aube* and in the regulatory body's technical prescriptions, it was necessary to request a special authorisation from the Nuclear Safety Authority (*Autorité de sûreté nucléaire –ASN*), which is the French regulatory body.

### 2. Relationship with regulatory body

The study relating to the disposal of large components (long-term safety and operation aspects) began in 1995, and the first authorisation request was sent to ASN in December 1997.

The main provisions being foreseen included:

- the disposal of the RPV head with the use of a biological shielding plate under the head and of a protection plate for adapters. No containment performance was specified (the picture below shows the component for disposal, without its shielding plate). That point was a major deviation from the fundamental safety rule, which prescribes a multi-barrier disposal system involving the geological environment, a disposal vault and a package (conditioned waste);
- the disposal in dedicated vaults (with sizes less important than for standard vaults), equipped with a movable roof and a gantry crane 160-t capacity): 12 components per vault equipped with separate internal walls. RPV heads may be embedded directly inside the vaults, thanks to a specific equipment (grouting platform interfaced with the guide tubes used for injection and air extraction/filtration), and
- the establishment, based on both the radiological characterisation of the first 24 RPV heads within a mean spectrum (averaged activity level for every radionuclide) and a maximum spectrum (highest activity level of every radionuclide), and the decision to limit acceptance for the disposal of RPV head whose activity would be less than that maximum spectrum and less than the embedding threshold, which, in the French concept, is the threshold between ILW waste, for which containment

performances are requested and have to be demonstrated, and low-level waste, for which good conditioning practices are requested, without demonstrating their containment properties (e.g.,  $^{60}\text{Co}$ :  $3.7 \cdot 10^3 \text{ Bq} \cdot \text{g}^{-1}$ ).

**Figure 1: Vessel head removal**



Investigations by the regulatory body lasted 18 months, and the decision was unfavourable, due to:

- the lack of an envelope (packaging) all around the waste, and
- the observation, with regard to the embedding conditions, of a continuity between the package and the filling material (inside the vault), without that continuous envelope.

Consequently, the file was revised: the package concept was changed, and the confining envelope, which was initially used for transportation only, was maintained for disposal purposes in order to form, together with the shielding plate, the first barrier around the waste. Hence, the mass of the large components increased from 60 and 80 t to 100 and 120 t, respectively.

Filling operation inside the protective shield (900-MW model)

External filling (900-MW model)

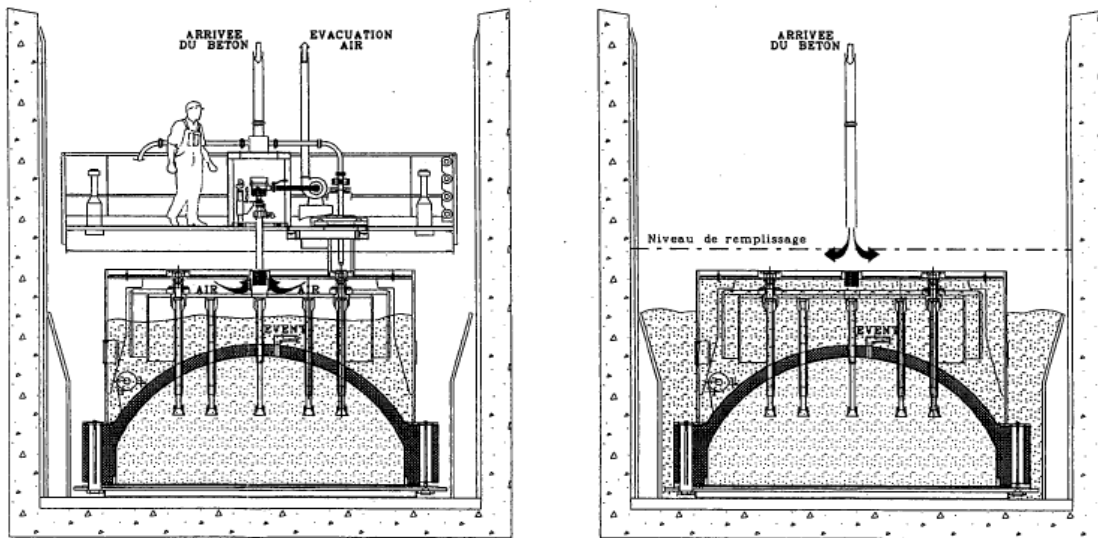


Figure 2: Arrival of the PRV head convoy at the Soulaines disposal site for LILW



Figure 3: Handling from the storage area to the dedicated vault

(On the left, in front of the vault, the floor used for grouting.)



**Figure 4: PRV head at its disposal location, after grouting**



### **3. Relationship with the stakeholders**

The delivery of vessel heads at the Soulaines disposal site was discussed during a meeting of the Local Information Committee (*Commission locale d'information* – CLI). That institutional committee is prescribed for any basic nuclear facility; its members are representatives of elected officials, civil-life citizens and associations. The commission ensures the link between the operator and the population.

The questions raised by the members of the CLI related to external exposures by PRV heads, the responsibility for transportation and the different tests performed at ANDRA's disposal site before the disposal of the first RPV head.

At the same time, a media file was prepared and distributed to local newspapers.

Later, a meeting was organised just before the delivery of the first RPV head, on the initiative of the President of the CLI, in a municipality located close to the disposal site, in order to provide information on transportation conditions. In that respect, it is important to note that little roadwork was required, but the most important part of it (i.e., the building of a new bridge) took place 10 km from the disposal site, thus causing traffic to be partly diverted during that time.

With regard to the interest warranted by that new activity, the population watched the heavy convoys pass through their villages, but that subject has long ceased to be a current event.

## Annex 2

## **Requirements for decommissioning and dismantling, treatment and storage in Germany, especially with regard to the management of large components**

by Bernd Rehs, Federal Office for Radiation Protection (BfS), Germany

### **1. Legal and regulatory framework for decommissioning and dismantling, treatment and storage**

In Germany, the legal bases for the licensing procedures involving the decommissioning of nuclear facilities are the Atomic Energy Act (Atomgesetz – AtG), the statutory ordinances on the basis of the AtG, as well as general administrative provisions. Section 7, para. 3 of the AtG contains the basic requirement for licensing decommissioning. It prescribes that, for any installation that has been licensed according to Section 7, para. 1 of the AtG, the decommissioning, safe enclosure or dismantling of that installation or of parts thereof suspended shall require a licence once operation has been permanently suspended.

The licensing procedure for decommissioning nuclear facilities is governed by the Ordinance Relating to the Procedure for the Licensing of Facilities (Atomrechtliche Verfahrensverordnung – AtVfV) in accordance with Section 7 of the AtG. It contains regulations pertaining to decommissioning, particularly with regard to third-party involvement and environmental impact assessment (EIA).

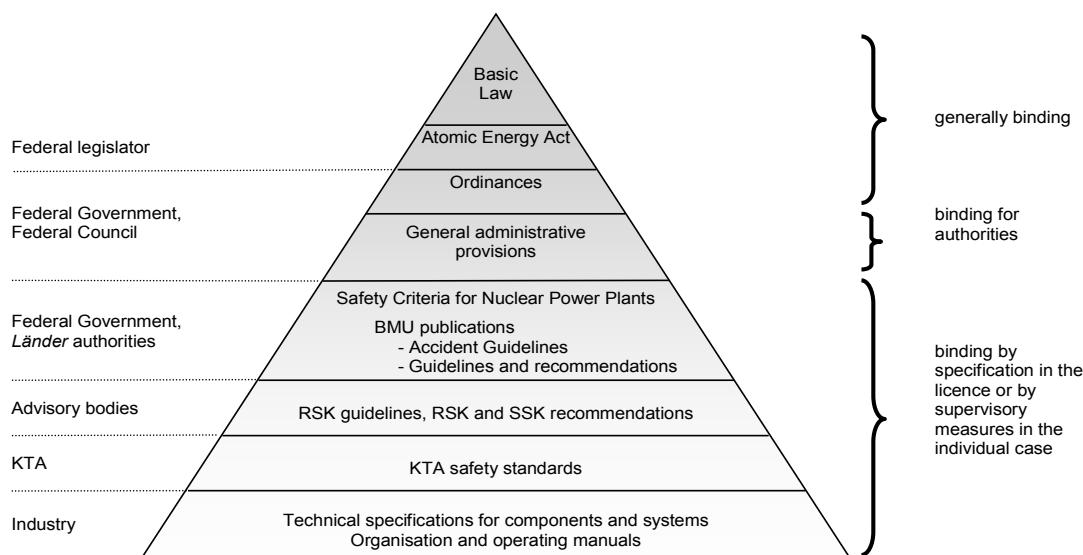
The Radiation Protection Ordinance (*Strahlenschutzverordnung* – StrlSchV) is also relevant for decommissioning nuclear facilities, as it specifies technical and operational measures, procedures and precautions in order to prevent damage due to ionising radiation. It includes the definition of the principles of radiation protection, the regulations concerning the transportation and transboundary shipment of radioactive materials with regard to clearance, to knowledge in radiation protection, to the in-plant organisation of radiation protection, to the protection of individuals in radiation-protection areas, including the physical supervision of radiation protection, to the protection of the public and the environment, to the protection against significant safety-related events, as well as to radioactive waste. Section 7 par. 1 of the StrlSchV (materials handling requiring a licence) may be used as the legal basis for the licensing of storage facilities for waste or large components.

The requirement for an environmental impact assessment (EIA) for decommissioning and dismantling nuclear facilities is prescribed in the *German Environmental Impact Assessment Act (Gesetz über die Umweltverträglichkeitsprüfung – UVPG)*. In addition, the AtG and the AtVfV provide relevant regulations for the performance of the EIA. Typically, the EIA is part of the licensing process for the first decommissioning licence and reviews the whole range of impacts of a given project on the environment. That EIA includes an announcement and disclosure of the project for public inspection. As a rule, all federal, Land, local and other regional authorities, whose jurisdiction is involved, shall take part in the licensing procedure. In the case of further applications on individual measures for

decommissioning, a preliminary assessment of the individual case is required in order to identify the need for an EIA.

A whole range of codes and guidelines of a predominantly technical nature exists below the level of laws and ordinances on the so-called sublegal level. Those are, in particular, the publications of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (*Bundesministerium für Umwelt, Naturschutz und Reactorsicherheit – BMU*), administrative instructions and recommendations by the Commission on Radiological Protection (*Strahlenschutzkommission – SSK*), the Reactor Safety Commission (*Reaktor-Sicherheitskommission – RSK*), the Nuclear Waste Management Commission (*Entsorgungskommission – ESK*), founded in 2008, as well as regulations of the Nuclear Technical Committee (*Kerntechnischer Ausschuss – KTA*). The RSK recommendation in 2002, entitled “Safety requirements on the storage of low and intermediate level waste in the longer term”, is of particular importance for managing low-level waste and ILW and is also relevant for storing large components.

**Figure 1: Legal and regulatory framework for nuclear activities including D&D in Germany**



During decommissioning, it may be necessary to transport large components through public territory to a storage/treatment facility. For that kind of transport, the requirements of the nuclear law as well as of the dangerous goods legislation must be met. In the case of transportation by road and inland waterways, the regulatory body of the respective Federal State (*Land*) is in charge of a transport licence under the legislation on radiation protection (§ 16, StrlSchV), while the Federal Railway Authority is in charge for railway transport. In parallel, according to the legislation on dangerous goods for those modes of transportation, a special agreement under the legislation on dangerous goods is generally required, for which the Federal Office for Radiation Protection (*Bundesamt für Strahlenschutz – BfS*) is responsible for all modes of transport. In the context of the special agreement, the radioactive inventory of the large component must be analysed, while discrepancies must be compared to the required package category with regard to its radioactive inventory and packaging must be determined (if it is impossible to allocate a described package category to the large component). Furthermore, measures have to be identified in order to compensate discrepancies and to assure the same level of safety. Although an EIA is not required as part of the transport application, it is a prerequisite that no predominantly public interests be in conflict with the selection of the transport route, the time of transport and the type of transport. A direct involvement of

the public is not prescribed, but all institutions concerned shall be informed early enough before transport.

## 2. Participants in nuclear licensing and supervisory procedure

Any nuclear facility needing to be decommissioned requires the licensee or plant owner to apply for a decommissioning licence. In the case of larger facilities, the licensing procedure is often divided into several steps. Partial authorisations are issued for every step.

The licence application, supported by the specified documents, shall be submitted to the regulatory body of the respective Land. Those documents describe, among other things, the decommissioning process, the planned dismantling measures, the associated techniques to be used, the environmental impact, the safety assessment and the provisions for radiological protection. The full particulars are given in the AtVfV.

**Figure 2: Decommissioning procedure for nuclear facilities**

Final shut down →	As a rule: Removal of fuel elements	Immediate dismantling or dismantling after safe enclosure	Subsequent use / green field
Operation			
	Post-operational phase		
	Planning and licensing according to Sect. 7 par. 3 of the AtG	Decommissioning	
			Final state
Operational licence		Decommissioning licence(s)	Release from AtG

The timely planning for licences is an important task for the applicant. In the case of the first application for a decommissioning licence, the applicant is required to describe the overall decommissioning and dismantling concept and to ensure that it is meaningful. The EIA is part of the licensing process and reviews the whole range of impacts of a given project on the environment. In general, the operational licence is suspended by the decommissioning licence.

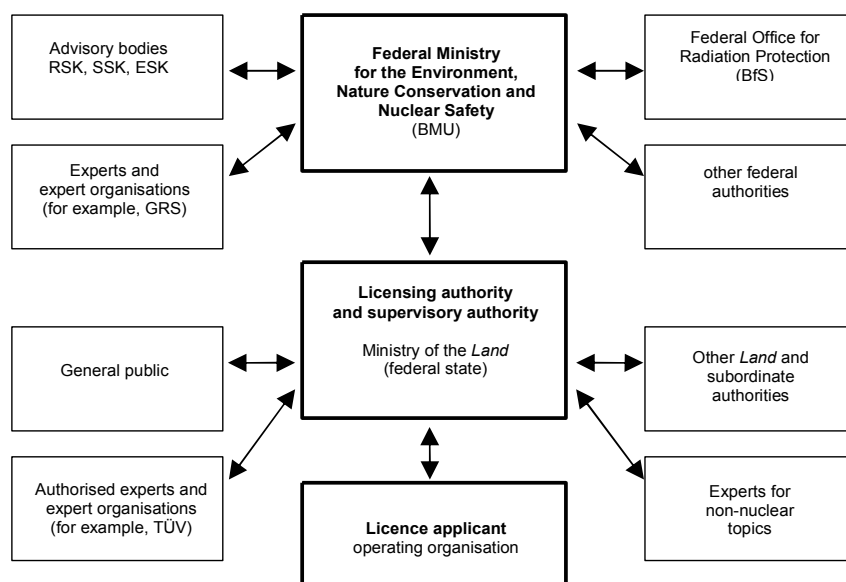
The Federal Länder apply the AtG under the supervision of the Federal Government (federal executive administration). The competence for granting, cancelling or withdrawing a licence lies with the regulatory body which is the respective Federal Land ministry responsible for nuclear regulations. The work authorised by the decommissioning licence is supervised by the relevant regulatory body of the Federal Land concerned in order to ensure compliance with specified conditions and restraints. Independent experts are usually involved in order to carry out additional controls and assessments by order of the regulatory body. The supervisory authority pays particular attention to compliance with the legal framework and the licensing requirements. It monitors, with the help of authorised experts, in particular:

- compliance with operating procedures;
- discharge limits;
- release criteria for materials, buildings and sites from nuclear regulatory control, and
- occupational and public radiation protection.



The BMU supervises the licensing and supervising activities of the Federal Länder and is entitled to give directives to them. In that context, the BMU may request technical and scientific advice from the RSK, the SSK, the ESK, other expert organisations, such as the Society for Facility and Reactor Safety (*Gesellschaft für Anlagen- und Reaktorsicherheit* – GRS) and the BfS.

**Figure 3: Relationship between the parties involved in licensing and supervising decommissioning and dismantling activities in Germany**



### 3. Decommissioning guideline

The Guide to the Decommissioning, the Safe Enclosure and the Dismantling of Facilities or Parts Thereof as Defined in Section 7 of the AtG (Decommissioning Guideline) has been adopted in 1996 as a consensus between the Federal Government and the authorities of the Federal Länder in order to foster an effective and harmonised approach in licensing procedures for decommissioning. Its purposes are:

- to compile the relevant licensing and supervision aspects in decommissioning procedures;
- to develop a common understanding between the Federal Government and the Federal Länder on the method to carry out decommissioning procedures, and
- to harmonise opinions and approaches as far as possible.
- In particular, the Decommissioning Guideline contains proposals for a practical approach concerning the decommissioning, safe enclosure and dismantling of nuclear facilities pursuant to Section 7 of the AtG, together with decommissioning measures, licensing and supervision. It was updated following the revised requirements in the legal and sublegal regulatory framework and was republished in the Federal Gazette on 28 October 2009.

### 4. Treatment and storage of radioactive substances

The methods for treatment of radioactive substances and waste arising from the decommissioning of nuclear facilities are essentially comparable with the methods for treatment of radioactive substances and waste from the operation of nuclear facilities. The same boundary conditions apply for the collection, sorting, conditioning and

documentation of radioactive decommissioning waste as for operational waste. In order to reduce the volume of waste, the residues should be separated into utilisable substances and radioactive waste already when they arise.

In order to avoid unnecessary radiation exposure of the personnel, the treatment of radioactive residues only has to take place to such a degree that long term storage is possible and the radioactive waste can later be conditioned without considerable efforts to a form then required for disposal in a repository. If, in particular, contaminated and activated metal parts, for which the nuclide vector indicates a decay of the activity within a foreseeable period of time so that the material can be cleared by measurements or reused in nuclear technology, later utilisation is given preferential consideration instead of disposal. A reduction in the volume of the radioactive waste may be reached or unnecessary radiation exposure avoided by decay storage of radioactive non-segmented large components.

With regard to later segmentation of large components after storage for an appropriate period, it is to be ensured that radioactive waste that may arise from utilisation can be brought into a repository. In this context adequate documentation of the radioactive inventory, dose rates, material composition, origin and demonstration of long term stability must be created and preserved at least until the end of storage.

The storage of unconditioned waste (untreated waste) in the facility must be described and, where necessary, regulated in the licensing notice, as must the preparation for transport or storage of conditioned waste packages on the site of the facility. For the storage of radioactive waste from operation and decommissioning and radioactive residues for decay storage, construction and operation of an on-site storage facility can be applied for which can be integrated into residual operation during decommissioning and dismantling but after dismantling of the facility it has to be further operated autarkic with a separate licence. The radioactive waste from previous operation and decommissioning of the facility are to be kept at a storage facility until they can be delivered to a repository and will be called off by the operator of the repository. For optimisation of the decommissioning process, it is also possible to create places for large components in the storage facility. In the case of long term storage of large components the long term stability of the large components must be demonstrated. For this purpose appropriate protection against corrosion of the large components is an important requirement, which might need air conditioning. A concept for surveillance must be in place for the storage facility and the waste, for this purpose a good accessibility of the waste packages and large components is advantageous. The operator of the storage facility must prepare regular reports on the situation of the storage facility and the inventory including a prediction of the further storability of the waste and large components.

With regard to the storage facility, the control over the following hazards must be demonstrated:

- mechanical impact, like drop of a waste package or large component;
- fire;
- failure of safety-related components, such as electrical power supply, control technology, hoisting and transport devices, and
- external impacts depending on the local conditions, such as floodwater, lightning, earthquakes, and storms.

It may also be specified in the licensing notice under which preconditions external conditioning facilities can be made use of. For external transports that might be necessary in this connection and might require a separate licence, the regulations of the Radiation Protection Ordinance are relevant.

An comparison of decommissioning strategies with and without long term storage shows, that the basic aspects are the questions of necessity of an storage facility (already available or to be constructed especially for this task), handling techniques (high capacity necessary in the case of large components), techniques for dismantling (necessity of remote controlled techniques in case of in situ dismantling), transport (one large load or many small loads), radiation protection (shielding for transport of large component, reusable where applicable or necessity of remote controlled dismantling), and packaging for disposal (expensive packaging with higher waste volume in case of immediate in situ dismantling).

**Figure 4: North Interim Storage Facility**



## **5. Conditioning of waste for Konrad repository**

The former Konrad iron ore mine located near the city Salzgitter in Lower Saxony / Germany will be converted into a repository for radioactive waste with negligible heat generation (most of the decommissioning waste). The Federal Office for Radiation Protection (BfS) is the competent authority to conduct this work. The Konrad repository is not designated for a disposal of large components. Radioactive waste must be specially treated and subsequently packaged (conditioned) before disposal in the Konrad repository.

Liquid waste is either reduced or cemented. Solid waste is shredded, desiccated, incinerated, pressed or cemented. As soon as the waste has been processed into waste products (for example, solids, pellets or concentrates) they are packaged in approved, standardised containers.

Cylindrical concrete drums made of normal or heavy-duty concrete are generally used for fixed waste. These are filled with drums containing the radioactive waste with capacities in the region of 200 or 400 litres. Any remaining cavities are subsequently filled with poured concrete before the lids are attached to the bodies of the drums.

Cast cylindrical drums vary in size and wall-thickness, depending on requirements. They are most often used for the packaging of unfixed waste. In this case, too, the lids are permanently attached to the bodies of the drums.

Containers are large-volume, rectangular receptacles made of steel plate, reinforced concrete or cast materials and are available in various versions with regard to size and wall-thickness. The largest container, with a volume of approximately eleven cubic metres, has room for 28 x 200-litre drums before it is permanently sealed.

Conditioning is the sole responsibility of the waste producers – i.e. the nuclear power plants, research establishments or industrial nuclear facilities. Which form of approved packaging is used is their decision.

In the context of quality assurance it is reviewed, that the waste acceptance requirements are fulfilled. This is accomplished by the BfS together with instructed technical experts.

According to the final storage conditions, different types of radioactive waste may be packaged together, however, as far as possible, any potential or actual reactions between the waste, the fixing media (usually concrete) and the packaging materials must be ruled out.

The expected availability of a repository in the near future might have consequences on planning of decommissioning, regarding the selection of a decommissioning strategy, the waste management and the necessity of interim storage of decommissioning waste in the future.

## **6. Clearance procedure in Germany**

Only a small fraction of the materials of a nuclear facility came into contact with radioactive substances or was activated by neutrons. Most of the contamination can be removed by appropriate decontamination techniques. Inactive materials or materials with trivial levels of radionuclides can be released from nuclear regulatory control for unrestricted use or for removal (conventional disposal) or for recycling (melting) of scrap metal.

In Germany quantitative requirements for the release of materials, buildings, and sites from nuclear regulatory control were introduced into the Radiation Protection Ordinance (StrlSchV, § 29) in the year 2001.

The quantitative, radionuclide specific clearance levels are based on the internationally accepted 10  $\mu$ Sv concept, which means that public exposures shall not be higher than about 10  $\mu$ Sv/a.

In practice it is difficult to measure many of the radionuclides at levels specified in the StrlSchV for release from regulatory control. Therefore it is an important task to provide proof for the compliance with the requirements of the StrlSchV with reasonable means.

In order to ensure compliance any material to be released from a nuclear facility has to pass an officially regulated process with many stages of quality assurance. This process is supervised by the regulatory body and its independent experts.

The practical experience in Germany shows, that the release of materials from nuclear regulatory control has practical implications, for example, on the amounts of radioactive waste. Due to the release of materials from nuclear regulatory control the projected amounts of conditioned radioactive waste from the decommissioning of a large NPP are rather low (a few percent of the total mass of a plant).

A further reduction in the volume of radioactive waste can be reached (or unnecessary radiation exposure avoided) by decay storage of radioactive non-segmented large components with subsequent segmentation and/or clearance measurements.



## Annex 3

## **Dismantling large components at the José-Cabrera NPP (CNJC) in Spain**

by Juan Luis Santiago, ENRESA, Spain

### **1. Background**

Located in central Spain, near Madrid, the José-Cabrera NPP (also known as Zorita) is the first PWR to be dismantled in Spain. The unit is a one-loop Westinghouse PWR, with a capacity of 150 MW.

The plant was shut down in 1996 and ENRESA (*Empresa Nacional de Residuos Radioactivos*) has decided its prompt decommissioning, starting in 2010.

In preparation for decommissioning, a full system decontamination (FSD) of the whole reactor cooling system (including the reactor vessel in the flow path) was carried out in 2006-7.

The large components to be dismantled include:

- the reactor pressure vessel (RPV) and the internals;
- the vessel head;
- the SG;
- the pressuriser and the surge line;
- the reactor coolant pump, and
- the primary loop piping

The objective of the project is not only to ensure the safe and efficient dismantling of those large components, but also to gain experience and to learn lessons to be applied during the future decommissioning and dismantling of the remaining six operating PWRs in Spain, whose operational lives are currently planned to end between 2021 and 2028.

### **2. ENRESA's waste management policy**

ENRESA has defined a waste-management policy for decommissioning activities, which includes the following elements and basic principles:

#### **Waste-management routes**

**Spent fuel and greater-than-Class-C (GTCC) metal waste** (HLW and LILW) resulting from the segmentation of RVIs will be placed in interim storage at the site of the Independent Spent Fuel Storage Installation (ISFSI). They will be transferred, in due time, to the yet-to-

be-built Centralised High-level Waste Storage Facility (*Almacen Temporal Centralizado – ATC*).

**LILW**, including low activated and contaminated metal parts, will be disposed of at ENRESA's current LILW waste-disposal cells at El Cabril. Currently, all waste to be disposed of at El Cabril must be conditioned inside the only two types of approved packages (CE-2a and CE-2b concrete boxes).

**VLLW**, similar in concept to an engineered conventional landfill, where waste may be disposed directly or inside conventional packages ("Big Bags", IP 20 containers, etc)

**Materials approved for clearance**, either unconditional or conditional (e.g., for recycling) are no longer considered as waste and are disposed of conventionally or through specialised contractors.

### **Waste-management optimisation**

Optimisation applies not only to dismantling operations, but also to on-site and off-site waste management. Elements to be taken into consideration during dismantling include:

- the physical and radiological characteristics of materials;
- the feasibility of *in-situ* decontamination;
- removal and mechanical handling capabilities, and
- the segmentation approach and its techniques.

Elements to be considered for waste management include:

- waste types;
- waste containers;
- transport limitations and public acceptance;
- waste-acceptance criteria;
- waste packaging/conditioning;
- handling capabilities at the site and at disposal facilities, and
- the design of interim-storage and disposal facilities.

The optimisation on the use of the available disposal site volume is achieved through the following:

- waste segregation at origin;
- waste decontamination;
- increasing the packing density, and
- designing new containers for optimum filling.

### **3. Dismantling of large components at CNJC**

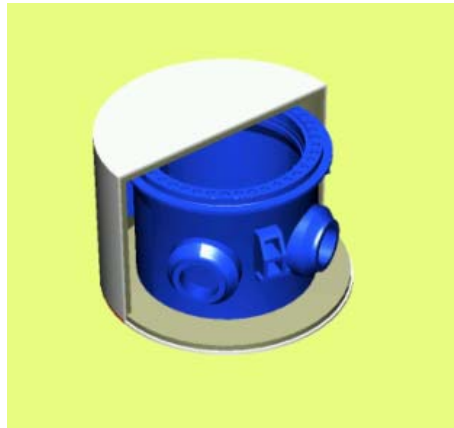
The following case study describes the results obtained by ENRESA using the above-mentioned criteria, in the specific case of CNJC large components (including the RPV) dismantling project.

➤ **Removal and conditioning of large components as a single piece is not considered a viable option due to:**

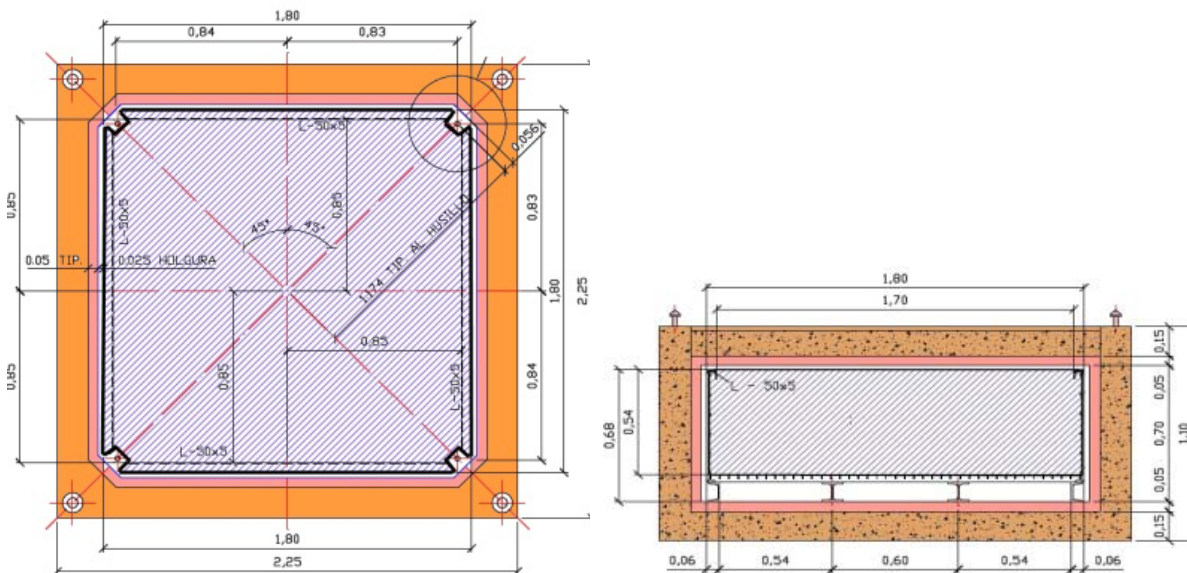
- waste segregation at origin;
- the need for a specific disposal licence at El Gabril, and
- transportation and public-acceptance issues.

➤ **Segmentation therefore is required. Two options have been analysed:**

- **option a:** Segmentation into large pieces for disposal in a large container measuring 4.52 m in diameter by 2.82 m in height), or



- **option b:** Segmentation into small pieces for disposal in approved concrete packages:
  - **CE-2a size** (external dimensions: 2.25 m square by 2.2 m high), or
  - **CE-2b size** (external dimensions: 2.25 m square by 1.1 m high).





The following table summarises the main criteria and attributes that ENRESA used to assess options and to delineate strategies for removing and disposing of large components at the José-Cabrera NPP.

Criteria	Attributes
<b>Safety</b>	<ul style="list-style-type: none"> <li>• Public/operators dose</li> <li>• Radiological safety/risk</li> <li>• Conventional safety</li> </ul>
<b>Technical</b>	<ul style="list-style-type: none"> <li>• Feasibility</li> <li>• Use of existing plant systems</li> <li>• Ease of deployment</li> </ul>
<b>Waste Management</b>	<ul style="list-style-type: none"> <li>• Waste minimization</li> <li>• Radiological discharges</li> <li>• Environmental impacts</li> </ul>
<b>Socio-Political</b>	<ul style="list-style-type: none"> <li>• Public acceptability</li> </ul>
<b>Regulatory</b>	<ul style="list-style-type: none"> <li>• Licensing</li> </ul>
<b>Economic</b>	<ul style="list-style-type: none"> <li>• Costs</li> </ul>

The following table summarises the general advantages and disadvantages of the minimum segmentation (large packages) approach, for a generic project, as perceived by ENRESA.

Advantages	Disadvantages
Reduced extent of component segmentation, implying lesser risks and uncertainties	May require design and licensing of new waste container or qualification of component as such
Reduced production of secondary waste	May require external heavy lifting devices on-site and/or create a new waste route
Reduced number of heavy lifts and off-site transportations	New containers may require special transport arrangements (Weight, height, public areas, etc.)
Reduced radiological dose uptake to workers and off-site radiological impact	Usually requires re-licensing of the disposal site to accept to new containers/waste types
To reduce overall schedule duration	May require significant modifications to the design and operation of the disposal site
To reduce overall dismantling costs	May result in an increase in volume finally occupied at disposal site, due to poor packing factor derived from large packages geometry and size

### Comparison between options

The following table shows the square results between the segmentation extent options, performed by ENRESA as part of the CNJC optioneering study for the dismantling of large components:

Parameter	Large container	CE-2A	CE-2B
<b>Vol. of final waste (m<sup>3</sup>)</b>			
LILW	662	765	531
VLLW	103	105	106
<b>On-site handling</b>	Require new equipment and waste routes	Use existing equipment and waste routes	Use existing equipment and waste routes
<b>Transportation</b>	Need special transport arrangements	Normal	Normal
<b>Changes to disposal site (handling at repository)</b>	Yes	No	No
<b>Dose uptake (man·mSv)</b>	880	1.385	1.465
<b>Change to acceptance criteria</b>	Require new license for waste disposal	No	Small change to the existing license
<b>Licensing process</b>	Require changes in operating specifications for waste disposal	No	Simple license process
<b>Economic costs (€)</b>	- 2.015.000	Base	- 1.588.750

### Summary and conclusions

The use of the CE-2b package is a feasible option and is easy to implement as a logical extension from the CE-2a.

The use of the CE-2b package results in an important reduction in the total volume of final waste packages and does not require, in itself, any changes in the current waste handling and kinematics.

The large size container could optimise worker doses and decommissioning program, therefore reducing costs and risks. As this would require a specific design and licensing process, so this option may only be taken into consideration for future decommissioning projects.



## Annex 4

## **Possible means to manage and store the BKAB RPV and other Swedish large radioactive components**

by Leif Johansson, Barsebäck Decommissioning (in cooperation with SKB)

### **1. Swedish decommissioning projects**

Beside a pressurised heavy water reactor in Ågesta that was permanently shut down in 1974, and two test reactors in Studsvik, that were permanently shut down in 2005, two BWR units in Barsebäck were permanently closed in 1999 and 2005, respectively. Both of the latter reactors, with 615 MWe each, have been prepared for a care and maintenance period awaiting dismantling, which has been planned as a joint five-year project starting in 2020 to be carried out according to the Swedish system, thus requiring the repository for dismantling waste to be operational before the demolition begins. The goal is for the Barsebäck site, together with its remaining buildings and equipment to be released for free use, after which the site owner shall be responsible to decide which will be the future fate of the buildings and land area as a whole.

All decommissioning projects have to be co-ordinated by the Swedish Nuclear Fuel and Waste Management Company (*Svensk Kärnbränslehantering – SKB*) in conjunction with NPP owners, who are responsible for establishing the decommissioning strategy and taking care of the dismantling itself. On the other hand, the transportation, interim storage and disposal of spent fuel and radioactive waste from Swedish NPPs are the responsibility of SKB.

### **2. Barsebäck NPP studies covering the examination and planning for the removal of RPVS as single pieces**

One major part of the overall dismantling project involves the deconstruction of the reactor pressure vessel (RPV) and of its internals (RVI). In the case of Swedish NPPs, there are two major optional strategies for dismantling RPVs and RVIs: the first one is to segment the RPV and its RVIs, while the second is to remove the whole RPV without its internals. Barsebäck has chosen to even study a third option that covers removal of single pieces, including RVIs.

The management of those components is crucial for planning future dismantling. The main objective of the studies is to form a basis to compare the time and cost required for various options, not only for Barsebäck itself, but also to provide input for SKB's ongoing planning project to extend tunnels and caverns in the final repository for short-lived radioactive waste (SFR) and design of the final repository for long-lived radioactive waste (SFL), for future decommissioning waste.

Feasibility studies on the third option include advantages and disadvantages by taking into consideration geometry, stress strength and lifting aspects, including different removal options and time schedules. Barsebäck has also added the required radiation shielding, appropriate means to secure and anchor RVIs and, finally,

transportation to the harbour. Six different alternatives for single-piece removal were studied, with the pros and cons listed for each of them. The outcome identified three methods (Figure 1), with the most promising ones being to lift the whole RPV with a crane and to remove it horizontally with a tower gantry, while the third was to lower inside the reactor containment. Based on the outcome of those studies, the preferred single-piece removal technique will then be identified.

## 2.1 Techniques and methods

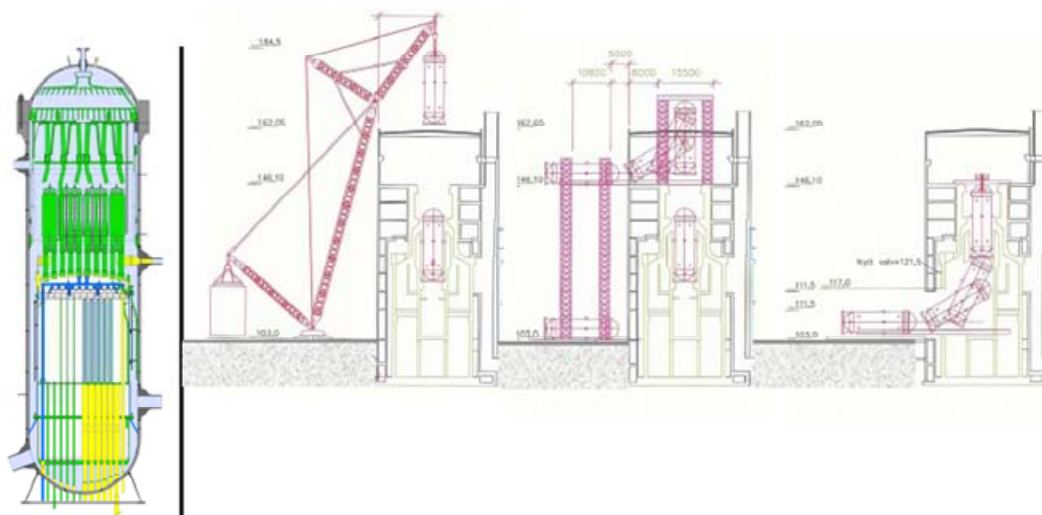
Both Barsebäck RPVs are 20.7 m long and 5.5 m in diameter. The total weight to be transported, without RVIs, equals 540 t, but jumps to 715 t, if internals and the required radiation shielding are added.

Conditions for the studies aimed at creating opportunities to compare different variables such as the schedule, logistics, costs, removal techniques and temporary structures associated with more or less radiological and “conventional” risks. Aspects, such as the possibilities to obtain acceptance from the relevant authorities, were also considered.

All three methods are fully achievable using the known technology, but the outcomes have shown the benefits of lifting RPVs by crane and also lowering them inside the containment. Especially in the case of the third option as reactor hall and crane are more or less intact, the benefits are low radiological impact and opportunities to make use of transportation openings in the containment- and in the reactor building walls for other dismantling activities e.g. less radioactive large and heavy components.

In order to transfer the RPV into a horizontal position using a tower gantry requires temporary large and complex devices. That procedure has too many uncertainties to provide a good comparison with the other two alternatives to be made. Consequently, that option will not be recommended for the Barsebäck NPPs.

**Figure 1. Three removal options at the Barsebäck NPP 1 and 2 RPVs as single pieces.**



## 2.2 Radiological aspects

Different radiological analyses and calculations show that it is fully acceptable for managing RPVs as single pieces, including RVIs, from Barsebäck to the final disposal at the SFR or SFL facilities.

With the Monte Carlo model for the neutron, photon, and electron transport of the RPVs, with and without the biological shield and different radiation shielding geometries, an estimation of dose rates around the RPV was performed.

As an example; the radiological status of Barsebäck RPVs in 2021, thanks to radioactive decay since 2005 and taking advantage of the radiation shielding offered by the component itself, included radiation shielding applied inside the vessel (7.5 cm SS), provides estimates of exposure-dose rates around the RPV (core level) of about 2 mSv/h.

### **2.3 Authorities/the Swedish regulators requirements regarding nuclear waste**

Regarding nuclear waste, an inventory must be drawn of all nuclear waste within the site of a facility. All nuclear waste that is handled, processed, stored or disposed of at the facility must be confined safely. In addition, all necessary preparatory measures must be taken at the facility for the safe confinement of nuclear waste to be transported and stored or disposed of at another facility.

The Swedish regulators require that 'waste treatment plans' be established for all waste categories arising from the exchange of components or for other waste arising from the operation of nuclear installations. Any arising nuclear waste which, in terms of quantity and type, deviates from the specifications referred to in the safety report, all necessary measures for the safe confinement of non-conforming waste shall be documented in a 'waste treatment plan' characterising the waste and explaining how the waste will be treated for final disposal.

### **2.4 SKB management and transportation of large components**

SKB and the nuclear industry have intensified their efforts to review various options for handling and disposal of large components in order to bring substantial savings not only in dismantling time, but also in dose uptakes for the decommissioning staff.

A pre-project to extend tunnels and caverns at the SFR facility for future decommissioning waste started in 2007. Current plans call for the application to extend the final repository for short-lived reactor waste (SFR) to be submitted in 2013. Approval will take at least two years to obtain; the expansion of the SFR is expected to begin in 2016, and the commissioning is scheduled for 2020.

Since the SFR is not adjusted for the disposal of RPVs and other radioactive large components as single pieces, then they have to be stored temporarily above ground, or left on individual NPP sites until all NPPs have been closed. At a later stage, once all decommissioning waste has been disposed of, except RPVs, entrance tunnels may be widened in order to allow the RPV to be transported to the disposal caverns. Another alternative is to segment the RPV and use the existing waste packages.

In Sweden, ships are used for transporting nuclear waste, since all NPPs and nuclear-waste facilities located on the seashore. The SKB transport system consists of the especially-built ship M/S Sigyn, and a number of shipping containers and special vehicles for loading and unloading.

Transporting large radioactive components in Sweden is not a big issue, but is impossible for RPVs, including their activated RVIs, under current transport regulations. A Type-B (U) transport container is required for RVIs. Transport under special arrangements is possible, but is currently very unlikely.

### **2.5 Current situation concerning planning for RPV disposal**

As Barsebäck NPP, the Swedish nuclear industry and SKB have agreed to present a proposal to the SKB Management Board in early 2010 with a view to extending tunnels

and caverns in the SFR facility and preparing for ability to manage whole RPVs. The proposal is to accept BKAB's second alternative, which is the removal of the whole RPV as a single piece, but without RVIs. The Oskarshamn-3 and Forsmark-3 NPPs, with a power of 1,200 MWe for each NPP, both NPPs set the geometric boundaries of the SFR tunnels and caverns. Those RPVs are the largest waste pieces considered for transport and disposal as single pieces.

### 3. Management and transport experiences for large components

#### 3.1 Ringhals NPPs Steam Generators

The Ringhals NPPs are owned by Vattenfall AB, with 3 PWRs and 1 BWR. SGs were replaced in two of the PWRs (three from each unit), in 1989 and 1995. Retired SGs are considered as waste, which normally is stored temporarily on site pending transport for final disposal or off-site treatment.

A joint agreement was signed between Ringhals NPPs and Studsvik Nuclear to treat and recycle those SGs with a view to developing a method and techniques for minimising waste volumes for final storage. Another benefit of the treatment is that for Ringhals NPP there will be no need for a new interim storage at Ringhals for future planned exchanges for other big components. For many years, Studsvik Nuclear has developed methods to treat large contaminated components as well as treatment and recycling of metallic scrap both from operation and decommissioning. That experience has now been applied for the treatment of a retired SG.

Each SG weighs about 310 t and measures 21 m in length by 5.5 m in diameter; it requires a storage volume of 400 m<sup>3</sup>. With a volume reduction over 90 per cent, less than 40 m<sup>3</sup> will be stored at the SFR or SFL Facility for short-lived or long-lived waste, respectively.

Three SGs have been treated in Studsvik facilities from 2006 to 2009. Three other SGs have been delivered to Studsvik with a roll-on/roll-off ship M/S Electron with the capability to take all three SGs on board. Those three SGs have been treated since 2010.

Other large components have been sent to Studsvik as whole pieces for scrap melting, including two reheaters from the Barsebäck NPP, weighing 148 t each on them and measuring 22 m long by 4 m in diameter.

**Figure 2: Steam Generator at Ringhals NPP**



## Annex 5

**LARGE ITEM DISPOSAL AT THE DRIGG LOW LEVEL WASTE REPOSITORY, UNITED KINGDOM**

by Steve Griffiths, UK Health & Safety Executive, United Kingdom

Currently the UK operates only one repository for low level radioactive waste, the LLWR near Drigg in Cumbria. It is located on the West Cumbrian coast near the village of Drigg. LLWR is designed for the management of solid LLW and has operated as the principal national disposal facility for LLW since 1959. LLWR is managed and operated on behalf of the Nuclear Decommissioning Authority (NDA) by UK Nuclear Waste Management Ltd. (UKNWM), parent body of LLW Repository Ltd. UKNWM is a consortium led by URS, Studsvik and AREVA. Waste is accepted at LLWR based on conditions for acceptance (1).

Although there is some history of disposal of non-containerised “large items” at the Drigg site these are anecdotally described as “not quite fitting into an ISO container (2)” and enquiries indicate that their disposal was restricted to the legacy times when items were tumble-tipped into open trenches at the site, a practise now long ceased.

The feasibility of true single large item disposal at the LLWR presents complex problems arising from the poor suitability of both rail and road infrastructure in UK.

LLWR is serviced both by road and rail links. The static weight of large items being taken nominally as up to ~300 metric tons would not necessarily preclude transportation by rail but the practicalities of this route are limited. The ageing rail infrastructure includes numerous tunnels, bridges and sections of line with overhead electrification. All these would require either careful justification or significant work to ensure the safe transit of large loads. Nuclear facilities in UK are by design in remote locations, not all of which are serviced by rail connections and the rail network itself has evolved to service intercity transportation rather than heavy freight and as such tends to route through town centres, exacerbating the tunnel, bridge and pantograph concerns already identified. Within only a few miles of the LLWR itself there are requirements to pass both over and under a series of bridges that may preclude the passage of items significantly outside the footprint and mass of a rail car.

Current road transport regulations in the UK limit routine weights to 44 tons and although systems are in place to transport items of up to ~120 tons (a 150-ton limit with allowance for a 30-ton vehicle) the limitations imposed on such moves should not be underestimated. Permissions can be granted for loads exceeding 150 tons all-up but the number of roads available for the movement of such loads is very limited. Heights above 4.9 metres inclusive of trailer are difficult to transport by road and in addition to special permissions would require the route to be surveyed in detail. Width restrictions come into place at overall widths of 2.9, 5 and 6.1 metres, the latter requiring special permissions and routing. If a route could be identified whereby large items could be transported by road, extensive liaison with the relevant police authorities would be required. It would also be necessary to meet current UK legislative limits for maximum speed, axle and wheel loading and provide indemnity to highways and bridge authorities.



On arrival at LLWR the unloading and handling of such loads would present problems given the equipment available which is used to handle typical maximum loads of 35 tons. Should equipment be brought in to enable the unloading and handling of the items, the local ground loading limit for the repository of 30kN/m<sup>2</sup> per metre item height [2] and stacking requirements developed to ensure best use of the limited space available would need to be met.

In light of the above limitations, although not impossible the transport and disposal of large items would present very significant difficulties. Segmentation and packaging of items, while undoubtedly consuming more space and accruing higher dose to staff, is currently the only practical route for large item disposal.

Where the materials used in construction of large items are suitable and the activity either sufficiently low or sufficiently short-lived, a recycling route has potential and also fits in with policy concerning opening up of alternative routes for very low level radioactive waste. Delay and decay to achieve this and or free-release criteria are met would potentially generate revenue that could partly offset the cost of the process itself and where the specific activity precludes this route the material could feasibly be recycled into packaging for other LLW (or even ILW) items destined for repository disposal, such that the additional activity burden of the recycled material would be negligible.

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*Annex 6a***US DOE Idaho national laboratory reactor decommissioning**

by Andrew Szilagyi, US Department of Energy

**Abstract**

The United States Department of Energy (DOE) primary contractor, CH2M-WG Idaho was awarded the cleanup and deactivation and decommissioning contract in May 2005 for the Idaho National Lab (INL). The scope of this work included dispositioning over 200 Facilities and 3 Reactors Complexes (Engineering Test Reactor (ETR), Materials Test Reactor (MTR) and Power Burst Facility (PBF) Reactor). Two additional reactors were added to the scope of the contract during the period of performance. The Zero Power Physics Reactor (ZPPR) disposition was added under a separate subcontractor with the INL lab contractor and the Experimental Breeder Reactor II (EBR-II) disposition was added through American Recovery and Reinvestment Act (ARRA) Funding. All of the reactors have been removed and disposed of with the exception of EBR-II which is scheduled for disposition approximately March of 2012. A brief synopsis of the 5 reactors is provided below.

**Engineering Test Reactor (ETR):** ETR was the largest and most advanced materials test reactor in the world at startup in September 1957. The 175 megawatt thermal test reactor evaluated fuel, coolant and moderator materials. In 1972 the ETR was modified by the addition of a Sodium Loop Safety Facility into the reactor core which supported the DOE breeder reactor safety program. The ETR was deactivated almost immediately after its shutdown in December 1981. The reactor was removed and disposed of in September 2007.

**Materials Test Reactor (MTR):** The MTR was the second reactor operated at the INL (National Reactor Testing Station in 1952). The reactor operated at 40 megawatts. MTR contributed to the design of pressurized water, organic moderated, liquid metal cooled and other reactors. The material test reactor was shut down in April 1970. The reactor was removed and disposed of in November 2010.

**Power Burst Facility Reactor (PBF):** Reactor start-up in September 1972 was part of the reactor safety testing program. It was designed to simulate various kinds of imagined accident scenarios caused by rapid power changes within milliseconds. It simulated severe fuel rod burst tests and loss-of-coolant accidents. Data from its tests were used to develop and validate fuel behavior codes for the Nuclear Regulator Commission. The reactor was shut down in 1985 and removed and disposed of in 2008.

**Zero Power Physics Reactor (ZPPR):** Reactor start-up in April 1969. The ZPPR is a low power physics reactor that provided reactor physics data for any type of fast neutron spectrum reactor. The reactor consisted of two separate honeycomb lattice core assemblies. Fuel was loaded into the two lattice work halves and moved together to achieve a low power critical condition. Data was then easily extrapolated into full power

conditions. The reactor was placed into standby in April 1992. The reactor was removed and disposed of in 2009.

**Experimental Breeder Reactor No. II (EBR-II):** The EBR-II reactor was built and started operations in September 1961 to demonstrate the feasibility of on-site fuel reprocessing as an adjunct to a liquid metal cooled fast-breeder -reactor power plant. These objectives were met within the first few years of operation. The reactor operated at 62.5 megawatts and supplied electricity to the power grid at the site until its shutdown in 1994. The reactor is currently undergoing D&D with the first phases of the sodium treatment being completed. Expected completion of reactor disposition is March 2012.

For the purpose of this paper the ZPPR reactor due to its unique design as compared to the other four reactors, and the fact that it was relatively lightly contaminated and irradiated will not be discussed with the other four reactors. The ZPPR reactor was readily accessible and was a relatively non-complex removal as compared to the other reactors. Additionally the EBR-II reactor is currently undergoing D&D and will have limited mention in this paper.

Prior to decommissioning the reactors, a risk based closure model was applied. This model exercised through the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Non-Time Critical Removal Action (NTCRA) Process which evaluated several options. The options included; No further action - maintain as is, long term stewardship and monitoring (mothball), entombment in place and reactor removal.

Prior to commencing full scale D&D, hazardous constituents were removed including cadmium, beryllium, sodium (passivated and elemental), PCB oils and electrical components, lead, asbestos and mercury among others.

Each reactor required isolation in order to be removed. Due to activated metal within the reactor vessels, dose rates above the cores ranged from 50 R/hr to 1200R/hr. Subsequent dose rates outside the vessels varied from 60mR/hr to greater than 50R/hr. Due to the elevated dose rates, the project team decided to fill the ETR and MTR reactor vessels with grout to a level above the core region to reduce dose.

To remove the ETR reactor, access to the support shoes was required. These shoes were encased in the high density concrete biological shield approximately 8' below grade. The project team used explosives to remove the biological shield. The demolition had to be controlled to prevent damaging the reactor vessel and to limit the seismic impact on a nearby operating reactor. Upon completion of the blast, the concrete was removed exposing the support shoes for the vessel.

Two reactor buildings (ETR and PBF) had to be removed to accommodate lifting systems for the reactor vessels. Two reactors (PBF and MTR) were removed via mobile cranes, two reactors were sized and removed in pieces (ZPPR and MTR), and ETR reactor, due to its weight, was removed via a twin gantry lifting system.

## **1. Introduction**

### **1.1 Contaminants**

Although all the reactors had been defueled, they contained significant amounts of highly radioactive cobalt, strontium, caesium, tritium and transuranic contamination as well as irradiated beryllium in the case of ETR. Each facility contained several hundred thousand of pounds of lead with a high of approximately 1.5 million pounds in the case of ETR. They also contained vast amounts of asbestos-lined piping with a high of over 1.5 linear miles in the case of EBR-II.

## **2. Demolition approach**

### **2.1 Environmental characterisation and documentation**

The final disposition of the reactors was of primary concern for two agencies, the Idaho Department of Environmental Quality (DEQ) and the U.S. Environmental Protection Agency (EPA). The final end state of each facility/reactor was determined through the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Non Time Critical Removal Action (NTCRA) process. This process uses the Engineering Evaluation/Cost Analysis (EE/CA) to present alternatives and evaluate these alternatives and features input and oversight by the agencies and the public. The alternatives that are presented in the EE/CA are evaluated for protectiveness (risk) for the public, the worker, and the environment; technical feasibility; and cost. While cost and technical feasibility were important for selecting the alternatives for the final disposition of the reactors, in the end, it was risk to the worker and protectiveness of public health that most influenced the selection of the final disposition of each reactor vessel.

During the EE/CA process, interfacing early and often with the agencies was key to determining the disposition of each vessel. Biweekly status meetings and tours kept the agencies informed and allowed an atmosphere of trust to develop between the agencies and the project team. An excellent working rapport was established that allowed both sides to communicate concerns and issues in a timely manner and to resolve the issues without impacting project schedule and milestones.

One of the most important and time and cost intensive issues involved is determining the radiological and chemical source term of each vessel. This information was key for identifying the disposal path for the vessels. Each vessel was a research vessel that experimented with effects of neutron fluxes on materials. The information that was gained from these experiments was used to develop models of the influences of neutron fluxes on materials. The models were further refined as more experimental data became available. As a result, modelling of the processes in a nuclear reactor has become an accepted method of characterizing radiological inventories in reactor vessels. As an example the characterization of the ETR vessel employed the use of two models, the Origin II Code and the MCNP4C Codes. Using these modelling codes, an expert nuclear physicist on the project team determined isotopic concentrations of activated metals within the reactive core region of the vessel.

The radiological inventory in the vessels was used to determine the suitability for disposal at various waste disposal sites. Through the alternative analysis, all but two disposal sites were eliminated for each vessel. Only the disposal area at the Nevada Test Site and the Idaho CERCLA Disposal Facility (ICDF) were considered viable alternatives because the vessels did not exceed inventory or concentration limits specified in the Waste Acceptance Criteria (WAC) of these two facilities. Determining the concentrations of isotopes in the vessels components became crucial in determining whether the vessel met these WACs. To determine the concentrations, it was important to understand requirements and limitations to concentration averaging. The project team proposed and received concurrence from the agencies on the ETR, MTR and PBF reactor vessels that the proper "waste package" for the purpose of concentration averaging was the entire reactor vessel. The walls of the vessel were both part of the waste and functioned as the package. Therefore, the concentrations of ETR, MTR and PBF vessels (waste package) was determined by averaging the isotopic inventory in the vessel over the entire mass of the vessel internals and walls. The weight of the grout that was introduced into the MTR and ETR vessels was not used as part of the mass of the waste package for the purpose of concentration averaging.

The agencies and the public were extremely interested in the ETR vessel in particular from the transuranic waste classification aspect. Transuranic waste is defined as waste that contains more than 100 nanocuries per gram of transuranic isotopes. In addition, the

waste acceptance criteria for the ICDF limited transuranic concentrations to less than 10 nanocuries per gram.

Generally, the characterization of the ETR vessel was determined by developing the inventories and determining concentrations of constituents by the project team, independent of any past characterization activities. In other words, to ensure accuracy, the project team developed its own source terms based on sampling and analysis data it generated. In the case of the transuranic inventory in the vessel, it was necessary to obtain a sample of the beryllium reflector that surrounded the active core. Beryllium ore when mined contains naturally occurring uranium (U 238) as an impurity. The neutron flux present during reactor operations activates (adds neutrons) to the U 238 nucleuses and converts these to transuranic isotopes. Transuranic isotopes are of a concern for disposal due to their extremely long half-lives.

Sampling the beryllium reflector in the vessel required intense preparation. The ETR vessel was drained of coolant and sealed in 1982. With no coolant water in the vessel, radiation dose uptake by the sampling team was the primary concern. The beryllium reflector was 25 feet below the top opening of the ETR vessel. Many obstacles such as experiment tubes between the vessel opening and the beryllium sample location prevented direct access for the sampling effort. The project team developed remote sampling techniques and tools. Cameras and monitors were used so samplers would not be directly exposed to radiation emanating from the reactor core. A mockup of the sampling activity, set up on the main floor of the ETR building and extended through a hole in the floor to the basement below, was used to simulate working in the vessel. The sampling crew spent many hours practicing obtaining a sample. D&D management required a readiness review to be conducted to ensure that activities could be performed safely. Even with all the planning and practice, it was the sample team's ability and ingenuity that overcame unforeseen obstacles and successfully obtained a sample with far less than expected exposure to the workers.

Analysis of the beryllium sample provided the modeller with the data necessary to model the total inventory of transuranic isotopes in the reflector. From the modelling, it was determined the transuranic concentration in the ETR vessel to be less than 2 nanocuries per gram well below the ICDF WAC.

The transuranic data as well as the total radionuclide and non-radionuclide inventories were presented in the EE/CA. Besides using the inventories for waste determination of the vessel it was also used in the human health and environmental risk assessments. Because the ETR vessel met the WAC, had the least risk for the public and the workers, and cost the least, the alternative for disposal of the ETR vessel at the ICDF was the selected alternative by the agencies and generally supported by the public. The final end state of the ETR facility and disposition of the ETR vessel was documented in the CERCLA NTCRA Action Memorandum for Decommission the Engineering Test Reactor Complex under the Idaho Cleanup Project, January 2007 (DOE/ID-11303).

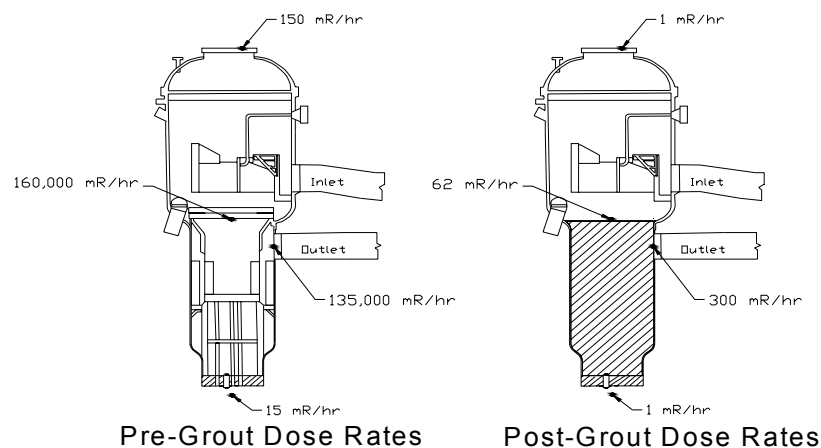
## **2.2 Radiological characterization and mitigation**

From the start of each reactor D&D, the project team desired to know the dose rates associated with each reactor vessel to help determine source term. Direct radiation measurements of the external surfaces at that time were not possible since in each case the reactors were enclosed within high density concrete biological shields where such a small gap between vessel and shield prevented the insertion of a detector probe. To perform the initial dose rate characterization, sets of thermoluminescent dosimetry (TLD) chips, and remote detectors such as AMP-100's were utilized through available experiment and access ports to the reactors. Information was processed and modelled to determine dose rates in the reactor interiors. As D&D progressed on each reactor and previously inaccessible areas opened, additional dose rate characterization information was obtained as necessary.

Due to relatively high dose rates in both MTR and ETR reactor vessels a method to shield the dose was necessary to remove the reactors. The most practical way to reduce the dose rate was to shield the radiation at its source. An analysis was performed which analyzed various grout densities for their shielding effectiveness, flow ability (i.e. ability to fill the void spaces around the core), and the grout contribution to the total weight of the lifted load when the reactor was removed. A final grout density of 1.5 g/cc was chosen for both vessels. Calculations and modelling using this grout density determined a maximum contact dose rate with the reactor vessels of less than 500 mrem/hr.

The grout was more effective than anticipated in the case of the ETR vessel. The dose rate at the primary outlet piping was reduced from 135 R/hr to 300 mrem/hr and the 300 mrem/hr was the highest measured dose rate on any of the vessel external surfaces. Inside the reactor at the grout fill line, the dose rate was reduced from 160 R/hr to 62 mrem/hr. Dose rates in the nozzle trench were reduced from the 150 mrem/hr contact dose rate to 1 mrem/hr. See Figure 1 for the pre- and post- grout dose rates.

**Figure 1: ETR Vessel Dose Rates**



The dose savings from grouting the ETR reactor were substantial. For example, preliminary dose estimates for the cutting of the primary piping from the vessel were as high as 15.62 R. The actual dose received by the workers who cut these pipes following grouting of the reactor was less than 400 mrem.

Grouting in the MTR vessel was less effective. Due to the design of the reactor with the base plate of the core on the bottom of the reactor grout did not reduce the dose rate as expected. Doses in excess of 50 R/hr still existed on the MTR vessel base area. Additional shielding was utilized to shield the workers during removal.

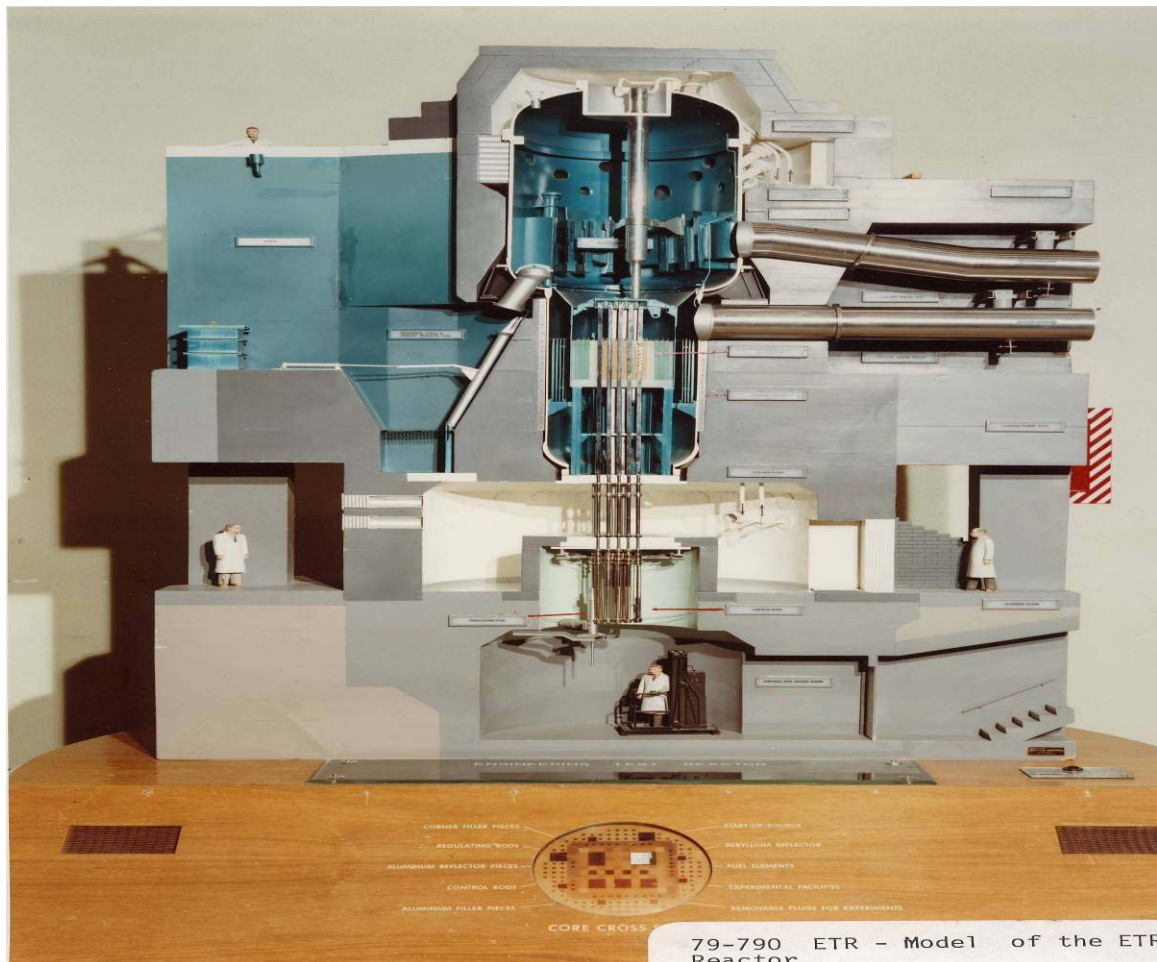
The PBF reactor vessel did not require grouting due to relatively lower dose rates as compared to the other reactors. The PBF reactor was grouted when it was placed into the disposal cell.

### **2.3 Reactor vessel removal preparations**

In order to remove each reactor access to the mounting plates/shoes was required. These plates/shoes were encased in the reactor biological shields. For the PBF reactor these mounting plates were readily accessible. For MTR the reactor was located primarily above grade and the biological shield was readily accessible and was removed with heavy equipment, which provided a level of shielding for the workers. In the case of ETR which was primarily below grade and closely encased in a high density concrete biological shield some innovation was required. In this case several of the above grade biological shielding pieces could be removed to support reactor refuelling and maintenance. These

pieces averaging 50,000 pounds were removed and disposed of. The remainder of the biological shielding primarily below grade was constructed of approximately 6 feet of poured high density, reinforced magnetite concrete with  $\frac{3}{4}$ " carbon steel forms. Figure 2 is a cross section of the ETR reactor vessel model. Initially the method for removal involved using a large excavator with shear and hammer attachments and plasma cutting for the forms. This method due to concrete density (225 lbs/ft<sup>3</sup>) proved to be both highly hazardous and time consuming. The project decided to use explosives to remove the biological shield. A subcontractor was selected to drill into the primary shield and subsequently perform a controlled demolition of the shield to just above the shoes. The demolition had to be controlled to prevent damaging the reactor vessel and to limit the seismic impact on the Advanced Test Reactor (ATR) and support facilities. Seismic impact had to be less than 0.25 in/sec peak particle velocity (PPV) as measured at three separate facilities. Two separate blasts were performed successfully with PPV readings all less than 0.114 in/sec. Upon completion of the blast the concrete was removed exposing the support shoes for the vessel.

**Figure 2. ETR model cross section**



#### **2.4 Reactor containment facility removal**

In order to facilitate the lifting equipment to remove the ETR and PBF reactor vessels the reactor containment facility had to be removed. The larges of these two reactor containment facilities (TRA-642) measured 90' wide by 136' long and 56' high. The PBF containment facility was smaller in comparison, but a similar path forward was used.

The first step was to isolate all utilities supporting the facility. Exterior siding was then removed to expose the structural support members. The structural steel was then weakened to facilitate a controlled demolition of the building. The ETR facility was located adjacent to operating facilities supporting the operating Advanced Test Reactor (ATR), which required pulling the facility over in a specific direction. When weakening of the facility was completed, each facility was pulled over using Heavy Equipment (See Figure. 3). Upon completion of the demolition of the facility, the debris was sized and hauled to on-site disposal. The MTR vessel did not require its containment facility to be removed due to adequate access and the size of the reactor.

**Figure 3: Building TRA-642 pullover**



## 2.5 Reactor removal

The ETR reactor vessel estimated weight with the grout was approximately 135 tons. Additionally the vessel dimensions were 36' tall by 13' in diameter. Due to size and weight constraints of the reactor, a twin gantry system was chosen as the method to lift the vessel from its location and place it on a transport vehicle for disposal. This is a similar approach used to install the vessel in 1956 (see Figure 4). The reactor support shoes were attached to the lower biological shield with studs and nuts. The studs, which were anchored into the lower biological shield, were cut and removed thus freeing up the reactor vessel from its supports. The shoes then rested on the lower biological shield. The reactor was lifted with jacks from the shoe area approximately 20" to verify no interferences and then lowered and placed on its support shoes.

The twin gantry system was placed on the reactor floor and a haul road for the reactor was built/improved between ETR and the disposal facility. Due to the weight of the vessel and transport vehicle, 95 percent compaction was required on the haul road.

The project team commissioned and completed an independent self-assessment prior to lifting the vessel to evaluate readiness for this evolution.

Due to the age of the vessel and the uncertainty of the installed lifting fixtures, specialty lifting lugs were designed, fabricated and load tested for the reactor. Lifting lugs were installed on the top and bottom of the vessel. The top of the vessel was rigged to the gantry and lifted upwards. The second gantry tower was attached to the rigging on the bottom of the vessel and the vessel was rotated from a vertical position to a horizontal



position. A special purpose Goldhoffer multi-axle trailer with cradles was driven under the vessel. The vessel was lowered onto the trailer and then secured with tie-downs. The vessel was transported to the disposal facility approximately 2-3 miles. The gantry was re-assembled at the disposal facility and the vessel was placed in its burial location.

**Figure 4: Installation and removal of the ETR vessel**



The PBF reactor was removed using two hydraulic all terrain cranes. The primary hydraulic crane was a 550 ton mobile crane which lifted the vessel vertically and a second 120 ton hydraulic crane was utilized to down end the reactor for transport (see Figure 5).

**Figure 5: Removal of the PBF vessel.**



The MTR vessel due to its segmented design was sized and removed inside the MTR containment facility and transported to the on site disposal facility.

### 3. Conclusion

Removal of the ETR, PBF and MTR reactors were a significant success from many aspects. The Idaho Cleanup Project calls for the disposal of the three reactors between May 2005 and September 2012; ETR was the first reactor completed under the CH2M-WG Idaho contract and was removed 2 years ahead of the baseline schedule. PBF the second reactor removed was removed 4 years ahead of the baseline schedule and the MTR Reactor was removed 18 months ahead of the baseline schedule.

CH2M-WG Idaho used a combination of innovative demolition techniques to protect workers and nearby operating facilities. Finally, the approval for onsite disposal set a precedent for the remaining reactors to be disposed of onsite, saving millions of dollars in disposal costs.

The following critical metrics were used to demonstrate the success of this demolition project:

- Outstanding safety record for the entire duration of the project. TRC rate of 4.55 in 2005 to a current rate of 0.29.
- Removed all reactors significantly ahead of schedule and at a significant cost saving.
- Cost performance index for the project is 2.38, which equates to a \$308M positive cost Variance at Completion (VAC) on a \$512M project.
- Schedule performance index for the project was 1.51, which equates to 51 percent ahead of schedule.



*Annex 6b***Decommissioning and dismantling considerations for sizing of large components in the United States**

by Andrew Szilagyi, US Department of Energy

Evaluates leading to decisions regarding size reduction versus one piece removal of large components contained within a facility is a multi-factor/criteria process with the following factors being considered:

1. Are the D&D workers placed at risk of injury if the component is sized in place? Some factors to be considered are:
  - a. Dose rates from activated materials and contamination
  - b. Internal and external contamination levels
  - c. Amount of hoisting and rigging required
  - d. Working at extreme heights
  - e. Confined spaces
  - f. Chemical and electrical hazards
2. Size restraints for packaging and transportation
3. Waste compatibility; does the component contain hazardous materials, i.e., asbestos, lead, beryllium, etc. Frequently the component itself will serve as a robust waste container for purposes of transportation so the internal material does not have to be disturbed and the component can be removed intact and transported as a unit.
4. Regulatory drivers:
  - a. There are numerous regulatory drivers that affect the decision on size reduction of large equipment. The radioactive materials packaging requirements for transport are found in 49 CFR. Based on the testing to meet these requirements, packaging manufacturers provide containers that have weight limitations. Also, the largest Industrial Packaging (IP) and Type A containers available are the size of cargo containers (8' x 8' x 20'). Wastes that must be transported in a Type B container (i.e. TRU waste to WIPP) must fit in the TRUPACT-II (contact-handled) or RH cask (remote handled).
  - b. If the equipment is larger than the available packaging, the equipment must be size-reduced or the equipment qualified as a radioactive materials packaging (if possible).
  - c. In order to minimize the volume of RCRA mixed waste, select portions of equipment will be removed to segregate the mixed portion from the non-mixed waste.

- d. Individual disposal sites Waste Acceptance Criteria (WAC) can influence packaging selection and size reduction. Criteria such as void volume, required compressive strength, and specific activity are examples of considerations for required size reduction.

In general, attempts are made to remove large components using heavy equipment to avoid hands-on disassembly and sizing. If sizing is necessary, the component may be sized as it's removed, using heavy equipment, or after removal depending on the particular configuration. The safety of the D&D workers and protection of the environment are the primary considerations when planning and executing D&D work.

When disassembly and sizing is required, several methods are employed to eliminate, to the extent possible, exposures to the workers and releases to the environment. These methods may include:

1. Building containments with HEPA filtered ventilation.
2. Point source HEPA filtered ventilation.
3. Applying fixative or lock-down material to "fix" the contamination to the component.
4. The use of remote tools to maintain safe distances and minimize exposure.
5. Combinations of the methods identified above.

In summary, many factors influence the decision process for large component handling and sizing during demolition. It is always preferable to use machines as opposed to people, provided exposures (radiological, chemical, industrial hazards, etc.) to personnel and releases to the environment can be mitigated.

## Annex 6c

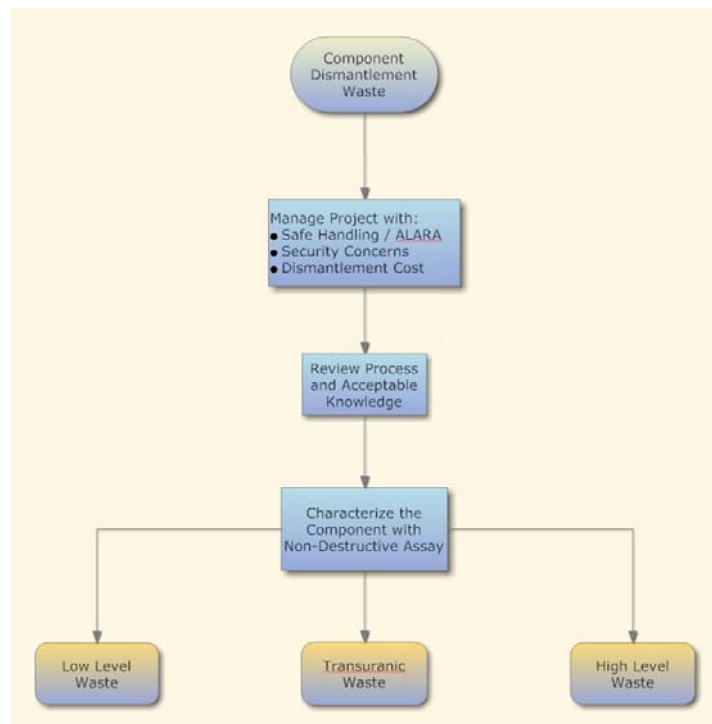
## Large components dismantlement flow chart in the United States

by Andrew Szilagyi, US Department of Energy

The beginning steps are identical for large or regular components (Figure 1). The starting point of this flowchart assumes that it has already been determined the component has been categorized as waste. The first step is to make sure that all components are handled safely, that ALARA is followed, that any security concerns are managed, and that the dismantlement cost or any other cost is constantly reviewed. After this, the process knowledge and acceptable knowledge should be reviewed; this will help in the following step which is characterization with non-destructive assay. At this point, the project manager is presented with the first three alternatives which will determine the path to follow. If the waste is characterize as:

- Low level waste (LLW) proceed to Section 1 and follow Figure 2
- Transuranic waste (TRU) proceed to Section 2 and follow Figure 5
- High level waste (HLW) proceed to Section 3 and follow Figure 7

**Figure 1: Characterization of disposal process**



**Section 1: Low Level Waste**

**Follow Figure 2**

**STEP L1: Is the component Low Level Waste (LLW) Class A?**

- **YES** → Proceed to **STEP L2**
- **NO** → Note DOE only works with Class A. Class B, C & higher are used only in the commercial field.

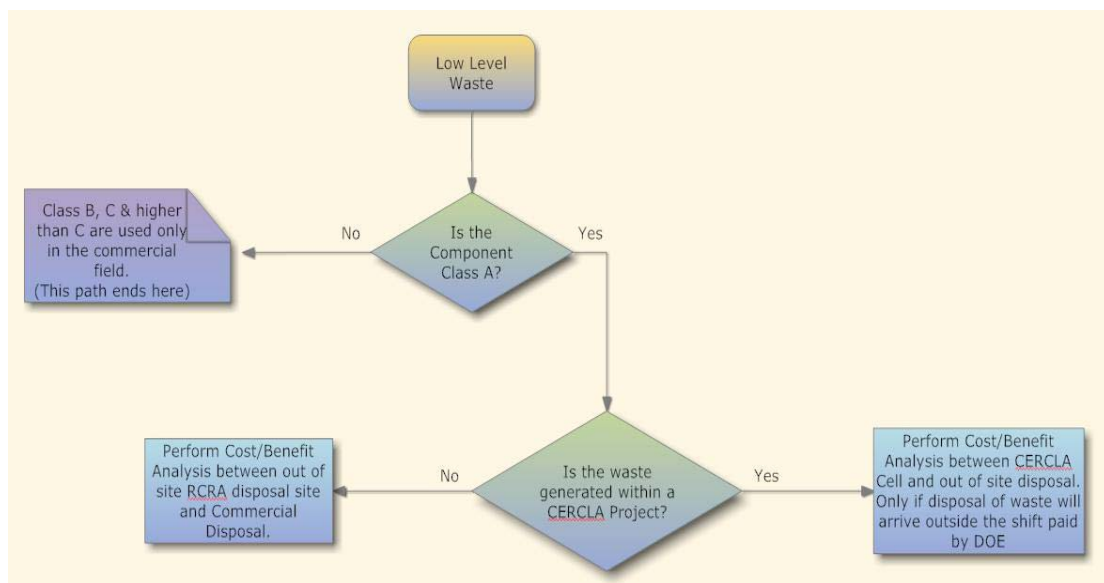
**STEP L2: Is the waste generated within a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Project?**

- **YES** → Perform a cost/benefit analysis (CBA) to determine if it is best to use an onsite CERCLA cell for disposal or on offsite disposal facility. **PROCEED TO STEP L2.1 USING FIGURE 3**

\* The CBA will only be performed if the waste will arrive at the CERCLA cell outside of the 40 hour work shift paid by DOE. For example, if the waste needs to arrive on a Saturday, the project manager will have to cover the costs.

- **NO** → Perform a cost/benefit analysis (CBA) to determine the best disposal site between a RCRA site or a commercial disposal site. **PROCEED TO STEP L2.2 USING FIGURE 4**

**Figure 2: Low level waste disposal flowchart, part 1**



**Follow Figure 3****STEP L2.1: Is there a CERCLA Cell onsite?**

- **YES** → Proceed to **STEP L2.1.1**
- **NO** → Perform a CBA to determine the best disposal site between a RCRA site and a commercial disposal site. *PROCEED TO STEP L2.2 USING FIGURE 4*

**STEP L2.1.1: Does the waste meet the CERCLA Cell's Waste Acceptance criteria (WAC)?**

- **YES** → Proceed to **STEP L2.1.2**
- **NO** → Decontaminate to reduce radiation levels. Proceed to **STEP L2.1.3**

**STEP L2.1.2: Does the component meet the Site Transportation Requirements?**

- **YES** → Ship to designated site for disposal
- **NO** → Size reduce to decrease payload. Then proceed to **STEP L2.1.1**

**STEP L2.1.3: Does the new pieces meet with CERCLA Cell's Waste Acceptance Criteria?**

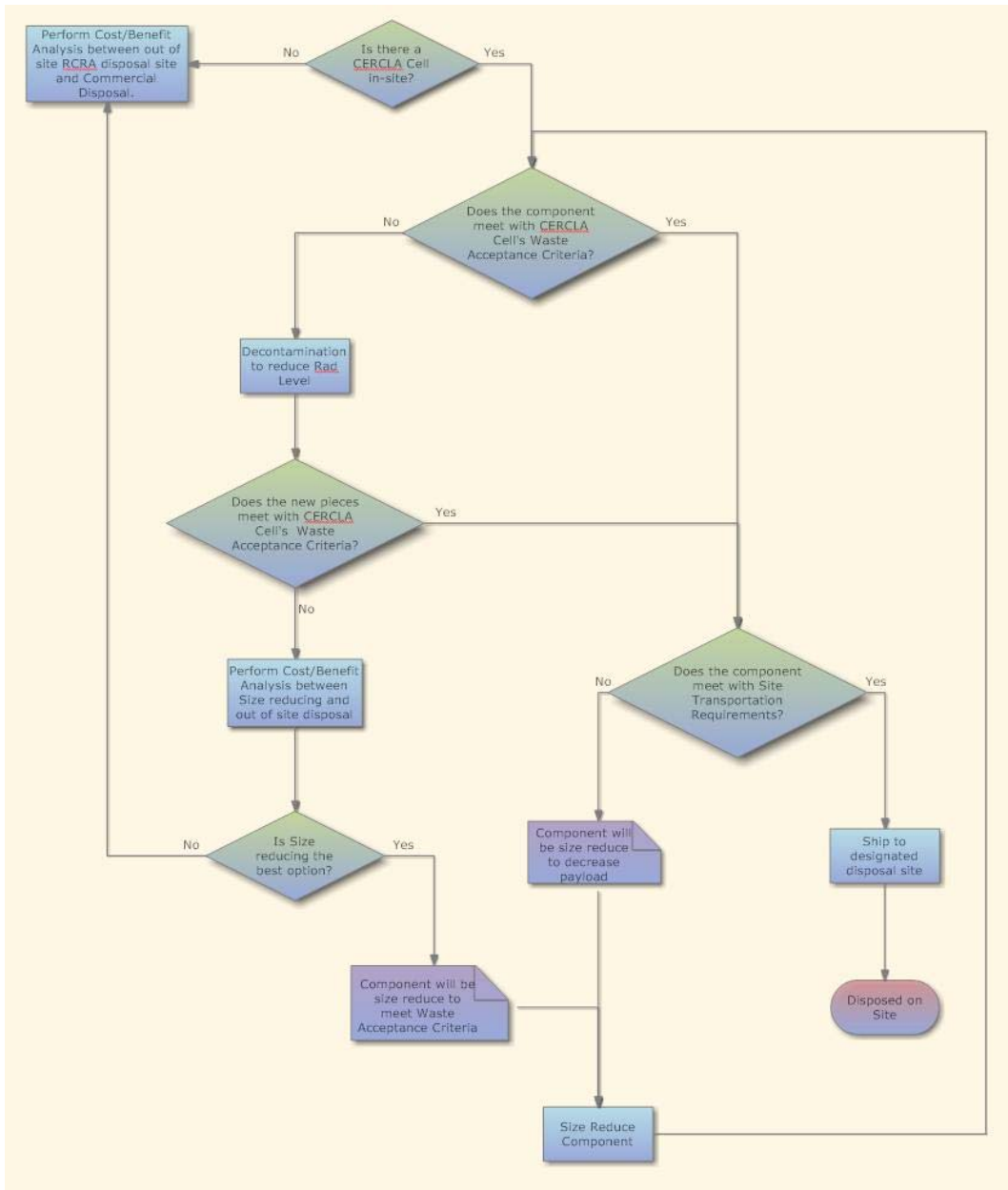
- **YES** → Proceed to **STEP L2.1.2**
- **NO** → Perform a CBA between size reducing the component or offsite disposal. Proceed to **STEP L2.1.4**

**STEP L2.1.4: Is size reduction the best option?**

- **YES** → Size reduce and proceed to **STEP L2.1.1**
- **NO** → Perform a CBA to determine the best disposal site between a RCRA site and a commercial disposal site. *PROCEED TO STEP L2.2 USING FIGURE 4*



Figure 3: Low level waste disposal flowchart, part 2



**Following Figure 4****STEP L2.2: Does the waste meet the Waste Acceptance Criteria (WAC)?**

- **YES** → Proceed to **STEP L2.2.1**
- **NO** → Decontaminate and proceed to **STEP L2.2.3**

**STEP L2.2.1: Does the waste fit in a DOT regulated package?**

- **YES** → Choose mode of transportation by performing a CBA on the transportation alternatives between truck, barge, or rail. The number of alternatives will depend on the disposal site chosen. Proceed to **STEP L2.2.2**
- **NO** → Size reduce to reduce dimensions. Repeat **STEP L2.2.1**

**STEP L2.2.2: Can the method of transportation hold the payload?**

- **YES** → Ship the waste to the designated disposal site for disposal.
- **NO** → Perform a CBA between the second alternative and size reducing.  
Proceed to **STEP L2.2.4**

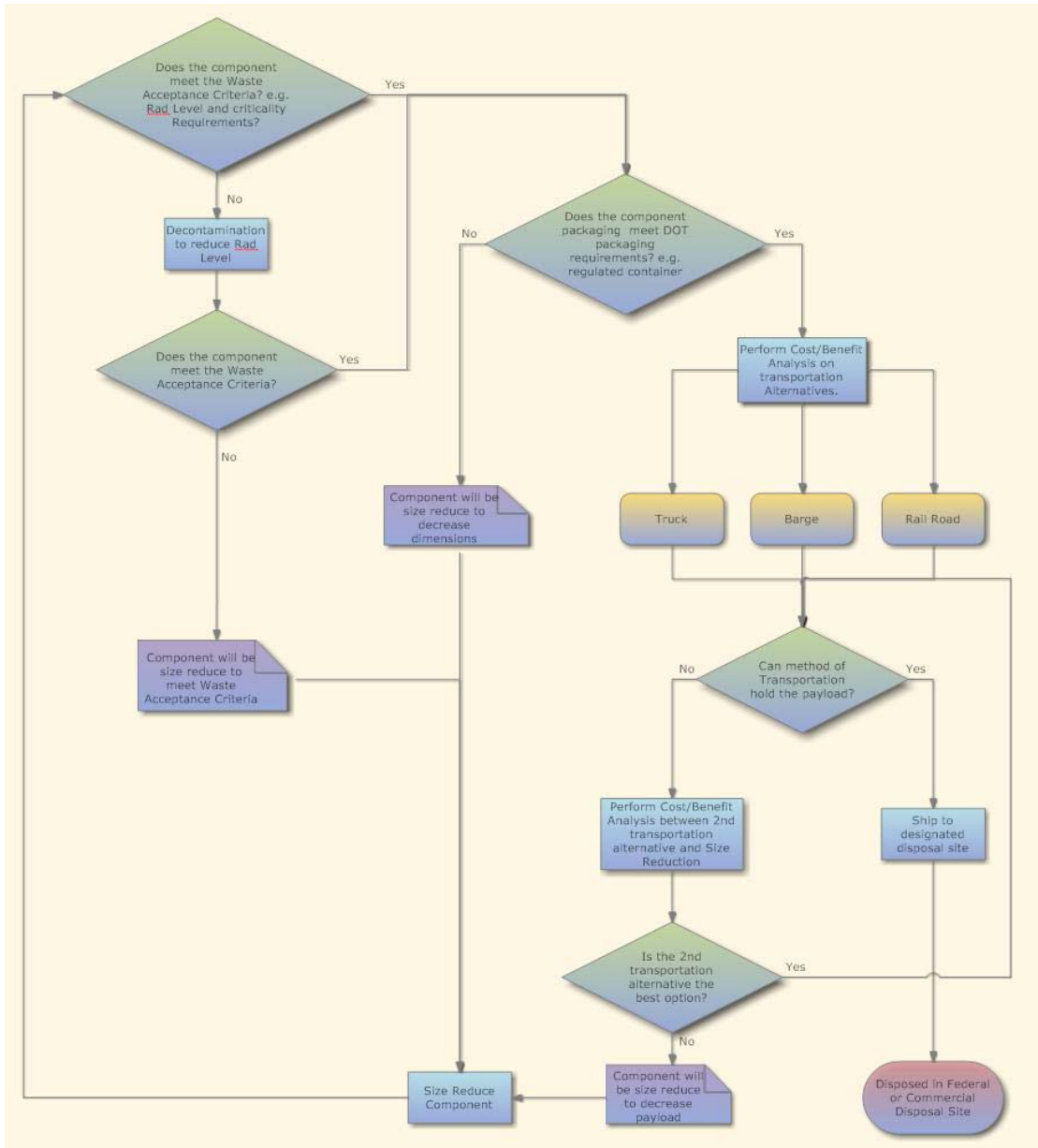
**STEP L2.2.3: Does the component meet the WAC after decontamination?**

- **YES** → Proceed to **STEP L2.2.1**
- **NO** → Size reduce and return to **STEP L2.2**

**STEP L2.2.4: Is the second transportation alternative the better option?**

- **YES** → Ship to the designated site for disposal.
- **NO** → Size reduce and return to **STEP L2.2**

Figure 4: Low level waste disposal flowchart, part 3



## Section 2: Transuranic Waste

### Follow Figure 5

#### **STEP T1: Confirm that the waste matches the transuranic (TRU) waste definition.**

- To be considered TRU waste, it needs to have an atomic number greater than 92, be an alpha emitter with half-lives greater than 20 years and TRU radionuclide concentrations greater than 100 nCi/g of waste. Proceed to **STEP T2**

#### **STEP T2: Does the component meet the Transuranic Disposal Site's Waste Acceptance Criteria (WAC)?**

- **YES** → Proceed to **STEP T3**
- **NO** → Treat the waste to meet the WAC. Proceed to **STEP T6**

#### **STEP T3: Is the component of Defense Waste?**

- **YES** → Proceed to **STEP T4**
- **NO** → There is no disposal site and the waste will have to be managed by the operating site. In such cases, perform a CBA to determine which D&D action is the best and execute it.

#### **STEP T4: Is the component classified Transuranic Waste?**

- **YES** → Perform a CBA to determine the best option between sanitation and disposal of the waste as a classified waste. Then proceed to **STEP T5**
- **NO** → Proceed to **STEP T5**

#### **STEP T5: Is the surface dose of the package less than 200mREM/hr?**

- **YES** → This package will be considered *contact handled waste*. Proceed to **STEP T7**
- **NO** → This package will be considered *remote handled waste*. Proceed to **STEP T8**

#### **STEP T6: After treatment does the component meet with the Transuranic Waste Acceptance Criteria?**

- **YES** → Proceed to **STEP T3**
- **NO** → There is no disposal site and the waste will have to be managed by the operating site. In such cases, perform a CBA to determine which D&D action is the best and execute it.

**Follow Figure 6**

**STEP T7: Does the package fit in the TRUpact III? (64.5" x 102" x 63")**

- **YES** → Proceed to **STEP T9**
- **NO** → Size reduce and return to **STEP T5**

**STEP T8: Does the waste fit in a 55 gallon drum?**

- **YES** → Proceed to **STEP T9**
- **NO** → Size reduce and return to **STEP T5**

**STEP T9: Can the truck hold the payload of the components?**

- **YES** → Ship to designated disposal site and dispose.
- **NO** → Size reduce and return to **STEP T5**

Figure 5: Transuranic waste disposal flowchart, part 1

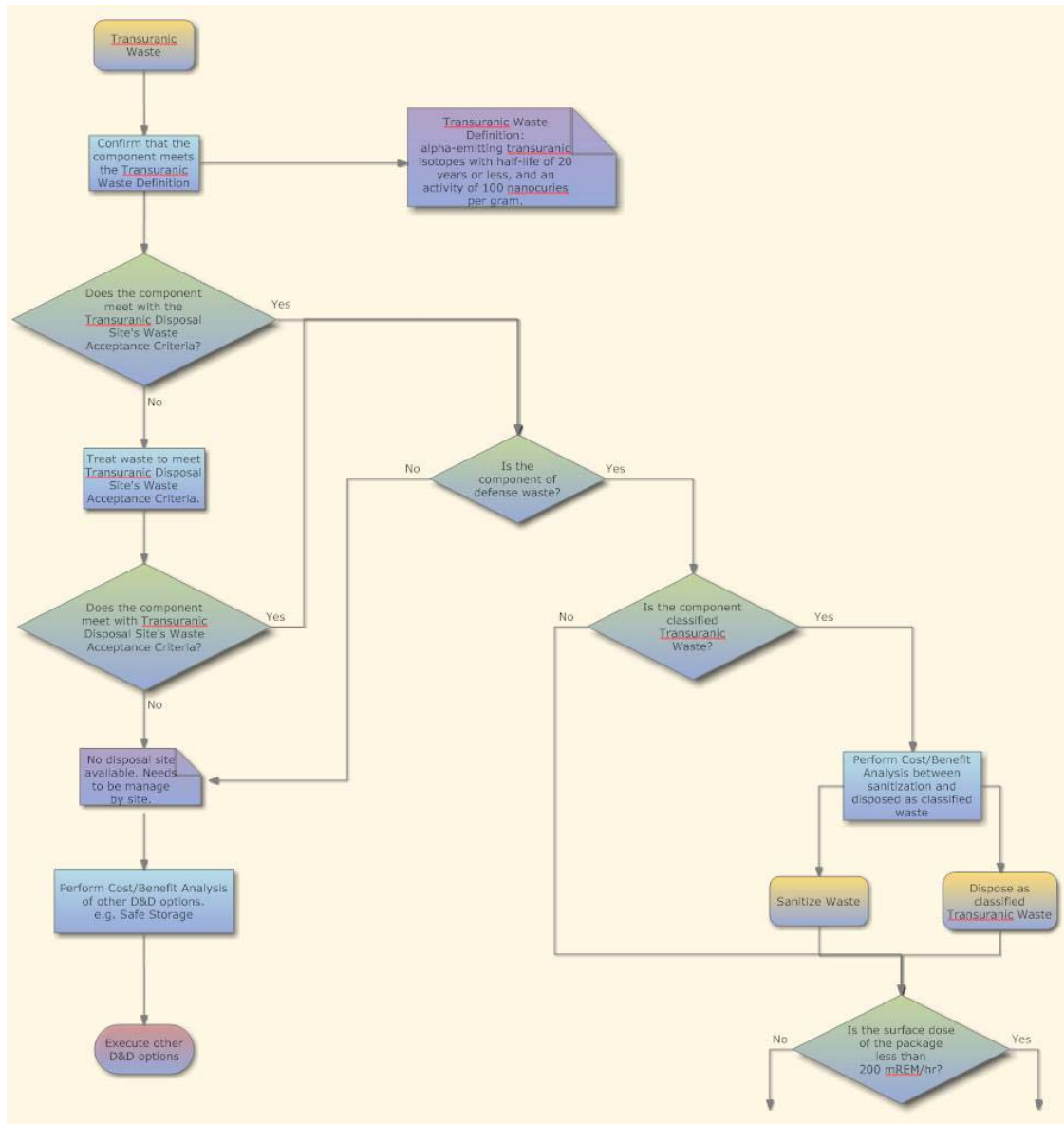
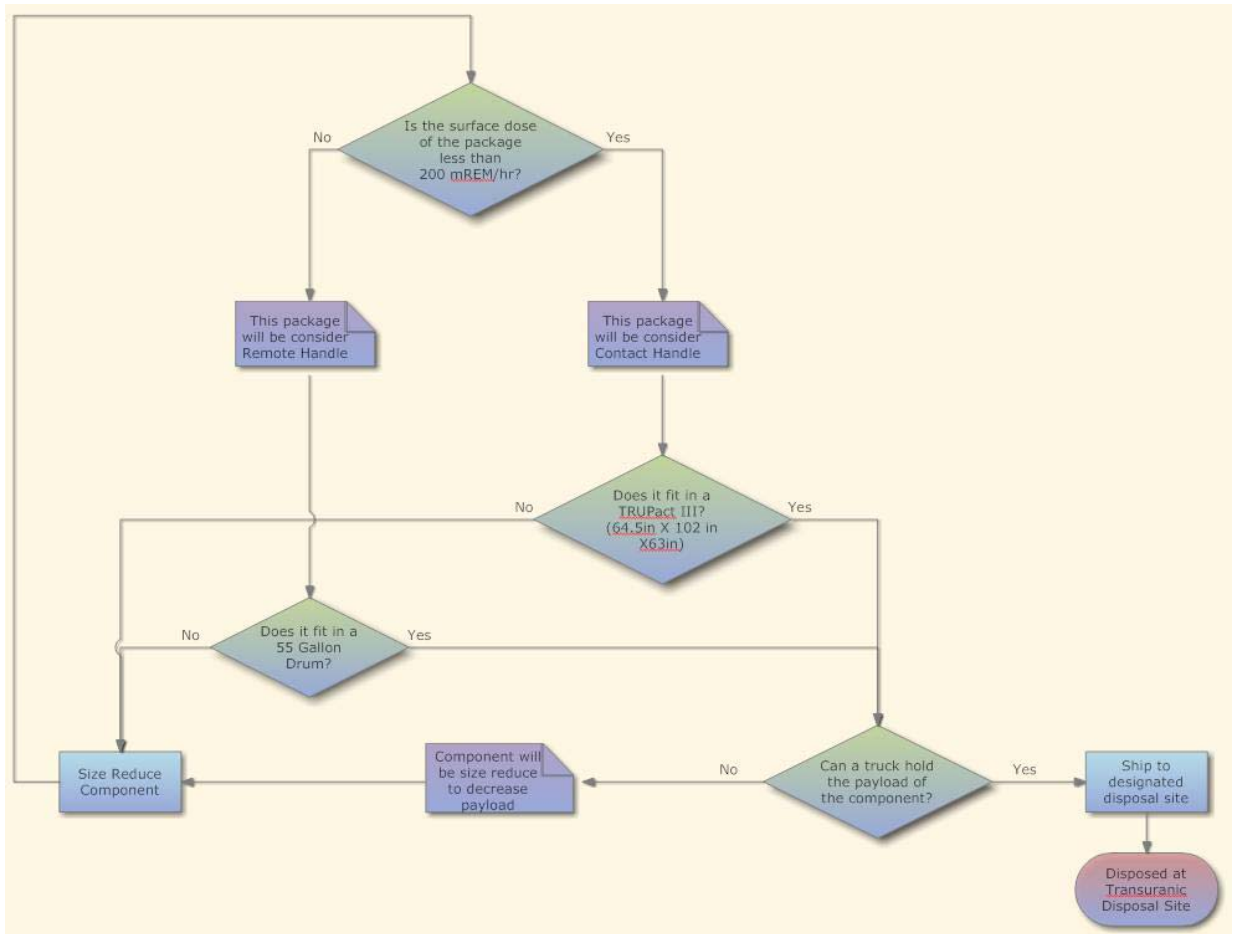


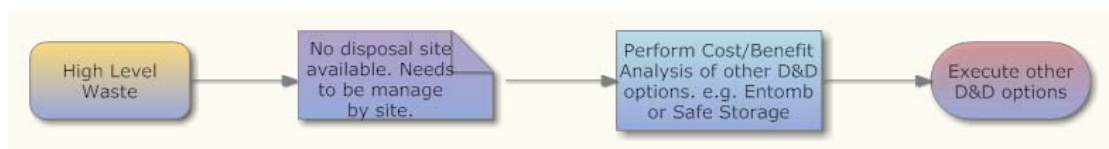
Figure 6: Transuranic waste disposal flowchart, part 2



### Section 3: High Level Waste

In the United States, Congress has to approve the opening of a high level waste disposal site. Since such approval has not been made, there is no disposal site available and the site has to manage their HLW. The project manager will have to perform a CBA to determine the best D&D action and execute it (Figure 7).

Figure 7: High level waste disposal flowchart.



## Annex 7

## Questionnaire: involved actors in large disused components management

### SUMMARY OF RESPONSES TO THE QUESTIONNAIRE

<p><b>What is the country (institutional) structure for decommissioning? Include the responsibilities for the whole process (management of liabilities, decommissioning, transport, waste treatment/storage and waste disposal). Please indicate whether organisations are public or private and whether there are important providers of services (e.g. commercial smelting).</b></p> <p><b>Please describe briefly who does what and where the responsibilities lie.</b></p>	<p>Belgium</p> <p>Electrabel establishing the decommissioning provisions for its NPP's</p> <p>Synatom, responsible for nuclear fuel management and will take over responsibility for decommissioning</p> <p>ONDRAF/NIRAS entrusted with provisions for decommissioning of other facilities. It also has transport responsibilities</p> <p>France</p> <p>No specific institutional structure, the responsibility is with the operator. Transport is often subcontracted and ANDRA is responsible for nuclear waste disposal.</p> <p>Germany</p> <p>The licensee or plant owner has to apply for a separate decommissioning license. Services including interim storage and treatment of residual material can be undertaken by key service providers (contractors).</p> <p>Sweden</p> <p>Facilities are jointly owned by the state and private companies. There are also companies that provide services.</p> <p>UK</p> <p>The UK does not have a single institutional structure for decommissioning, though the general principle is that the site operator (licensee) has the responsibility for performing the work on its site and arranging for radioactive waste disposal.</p> <p>Spain</p> <p>Spanish Law establishes that the State Owned Entity ENRESA is the responsible for the whole decommissioning process for nuclear facilities in Spain. It does sub contract some of the process. ENRESA is also responsible for radioactive waste</p> <p>USA</p> <p>For commercial sites the responsibility for decommissioning rests with the operator. The US government has responsibility for decommissioning all government owned facilities.</p>
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<p><b>Which bodies have responsibility for onsite safety regulation, discharges and disposal?</b></p>	<p>Belgium Regulation is undertaken by federal agencies.</p> <p>France Regulation is established by the French Government.</p> <p>Germany Regulatory framework is established by government, it is also responsible for construction and operation of repositories for radioactive waste. Regulatory body is licensing and supervising decommissioning. Operator remains responsible until release of facility out of regulatory control.</p> <p>Sweden Decommissioning is included in the license which is granted by the Government and regulated through a regulatory body.</p> <p>UK The UK government establishes regulation, through a number of safety transport and environment regulators. There is no specific license granted for decommissioning</p> <p>Spain The Spanish Nuclear Safety Council (CSN) is an independent administrative authority set up by law 15/1980</p> <p>USA There are several federal agencies responsible for regulation. Decommissioning activities within the United States (U.S.) are governed by the federal government's codified rules, called the <i>Code of Federal Regulations (CFR)</i>. Generally regulatory oversight of commercial nuclear facilities rests with NRC. Government owned facilities are regulated by DOE under CERCLA when decommissioning.</p>
<p><b>Which body(s) owns the facilities?</b></p>	<p>Belgium Facilities are owned by the operators.</p> <p>France Facilities are owned by the operators.</p> <p>Germany Privately owned electric power companies (NPPs) and publicly owned facilities (Research- and Prototypereactors, Greifswald and Rheinsberg NPPs).</p> <p>Sweden Ownership is a complicated co-ownership.</p> <p>UK Ownership is complicated with a mixture of private sector companies but a single organisation responsible for decommissioning.</p> <p>Spain The facility operators are the owners.</p>

	<p>USA</p> <p>In general it is the facility owners or government. However there are facilities that are under a Government owned contractor operated arrangement.</p>
<p><b>Describe the responsibilities for funding of the decommissioning plan and disposal plan (including for oversight of funding arrangements and whether or not the funds are managed by the licensee organisation). Are they one and the same body?</b></p>	<p>Belgium</p> <p>Financial provision for decommissioning is by endowments from the operators.</p> <p>France</p> <p>The operators have to ensure that adequate and secured funding provisions are supplied.</p> <p>Germany</p> <p>A mixture of funding from central government and the respective Land (publicly owned facilities). Financial reserves have to be accumulated by owners of the facilities in the case of privately owned facilities.</p> <p>Sweden</p> <p>The licensee of a nuclear facility which generate or has generated residual products must pay a nuclear waste fee. The fees are collected in a fund, the Nuclear Waste Fund. This Fund is an external and fully ringed-fenced governmentally controlled and administered fund. There is also external oversight of this arrangement.</p> <p>UK</p> <p>Funding is currently provided by the state though for new build this will be by the operators via a segregated fund.</p> <p>Spain</p> <p>Regulations on fuel cycle activities requires the conclusion of contracts between ENRESA and the companies owning nuclear power plants and other fuel cycle facilities. The objective of these contracts is to regulate the collection of the financial resources for decommissioning during the operating life time of the installations.</p> <p>USA</p> <p>Funding for DOE and DOD facilities is provided by the United States government on an annual basis, provided through the government budget process. Normally, if a decommissioning project is a specific line item in the budget, funding is ensured for completion of the plan. Funding for DOE projects is dependent on congressional imposed budgetary conditions. Conversely, private companies that have commercial nuclear facilities licensed under the NRC are responsible for funding their decommissioning project.</p>

Whilst there are differences between countries there are some common threads. Regulation is through the state though the number of regulators involved may vary. In summary, the IAEA principles concerning independence of the regulatory body are followed. Funding arrangements vary but there are plans. Similarly, ownership of facilities is a mix of state and private. Some systems require a separate decommissioning license with Spain having the clearest demarcation of responsibilities for the decommissioning phase and waste management responsibilities.

### **Answers to Supplementary Questions**

Only received response from Sweden – key features are

- The systems are the same
- Multiple regulators are involved and they are more wide ranging.
- Tendency to focus on transport and waste treatment plans, optioneering and early engagement.
- Transport contractor responsibility
- Use made of sea which reduces impact on general public.
- Regional focus on stakeholder engagement.

In UK a key feature is the importance of transport in view of the country infrastructure which means generally use of road or rail with some sea transport possible. This results in increase of communities and need for local engagement.

### **FORMAT OF QUESTIONNAIRE TO BE COMPLETED FOR EACH COUNTRY**

*The aim of the following is to establish an overview of the various bodies [Actors] that have responsibilities or input to the issue of large component decommissioning. In answering the intent is to cover the overall organisation and those bits that have most relevance to large components. The answers should reflect the areas from site operations to decommissioning as well as the wider issue of disposal at another location.*

- *What is the country (institutional) structure for decommissioning? Include the responsibilities for the whole process (management of liabilities, decommissioning, transport, waste treatment/storage and waste disposal). Please indicate whether organisations are public or private and whether there are important providers of services (e.g. commercial smelting).*
- *Please describe briefly who does what and where the responsibilities lie. Mention any special control mechanisms that exist inside/between the institutions involved (e.g. technical expert organisations)? For example, are there institutions that control the decisions and the planned procedures of other institutions? Which institution is responsible for the choice of the decommissioning strategy?*
- *Which bodies have responsibility for onsite safety regulation, discharges and disposal?*
- *Which body(s) owns the facilities?*
- *Describe the responsibilities for funding of the decommissioning plan and disposal plan (including for oversight of funding arrangements and whether or not the funds are managed by the licensee organisation). Are they one and the same body?*

## QUESTIONNAIRE RESPONSE – BELGIUM

**What is the country (institutional) structure for decommissioning? Include the responsibilities for the whole process (management of liabilities, decommissioning, transport, waste treatment/storage and waste disposal). Please indicate whether organisations are public or private and whether there are important providers of services (e.g. commercial smelting).**

**Please describe briefly who does what and where the responsibilities lie.**

### Management of decommissioning and liabilities

In Belgium, a distinction is made between Nuclear Power Plants and other nuclear facilities.

### NPPs

Seven commercial nuclear reactors of the PWR type are operated in Belgium by ELECTRABEL, a subsidiary of GDF-SUEZ, leading to a total installed capacity of 5.7 GWe.

By convention with the Belgian State, since 1985 ELECTRABEL was setting up provisions for the decommissioning of its NPPs. Midyear in 2003, a new law was published concerning the establishment and management of financial provisions for ultimate decommissioning of the seven nuclear power plants including the management of the spent fuel from these power plants. The provisions will both be centralised at SYNATOM<sup>2</sup>, which has meanwhile been transformed into a 100% subsidiary of ELECTRABEL. The Belgian State owns a golden share in SYNATOM which gives it some specific rights such as to veto some decisions.

A Surveillance Committee has been created as a legal entity which is entrusted with the control of the establishment and the management of the financial provisions of SYNATOM: methodology of the settlement of the provisions, the investment policy, the refunding (loans) of the invested funds.

The advice formulated by the Surveillance Committee is binding for SYNATOM. With regard to its advice on the existence and sufficiency of the financial provisions for decommissioning and management of the spent fuel, the Surveillance Committee has to follow the unanimous opinion that ONDRAF/NIRAS has formulated on this matter.

SYNATOM will take over the legal responsibility for decommissioning. The management of nuclear fuel was already its responsibility.

### Other nuclear facilities

The National Agency for Radioactive Waste Management and fissile material (ONDRAF/NIRAS) is entrusted by laws with the survey of the financial provisions for decommissioning of other nuclear facilities than commercial power plants. The cost evaluations and the mechanism for provisioning are analysed by the operator and presented to the Agency within the decommissioning plans and summarised within the questionnaire for the national inventory. Decommissioning and remediation costs as well as the annual necessary financial provisions are re-evaluated every five years. Nevertheless, the legal responsibility for building up sufficient provisions, for the management of the funds and for performing the decommissioning programmes remains with the operator or the owner.

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2. SYNATOM, a private company is the owner of the fuel loaded and unloaded in the Belgian nuclear power plants (NPPs). The Belgian State has recognised the exclusivity of this company with regard to the management of the nuclear fuel cycle including the management of the spent fuel.

The financing of the ongoing decommissioning programmes for which no provisions were made in the past, is provided by means of annual endowments from the Federal government and with contributions from the electricity producers.

Until now, 4 Nuclear Liability Funds have been raised by the Federal Government. These funds concern the decommissioning and remediation programmes of the former EUROCHEMIC reprocessing plant (site 1 of Belgoprocess), the former waste processing site of the Nuclear Research Centre (site 2 of Belgoprocess), the Nuclear Research Centre SCK•CEN site limited to the facilities already in operation before 31<sup>st</sup> December 1989, and the Institute for Radio-Elements.

For the facilities of SCK•CEN built after the 31<sup>st</sup> December 1989, SCK•CEN is securing by its own means a decommissioning fund.

#### Transport, Waste Treatment/Storage and Waste Disposal

Transport, treatment, storage and disposal of radioactive waste are belonging to the missions of ONDRAF/NIRAS. The transport of radioactive waste on Belgium territory is managed by ONDRAF/NIRAS which is subcontracting it to external companies. The treatment, conditioning and storage of radioactive waste are subcontracted to Belgoprocess a subsidiary of ONDRAF/NIRAS. The operator may also treat and condition its waste. Treatment and conditioning processes need to be approved by ONDRAF/NIRAS.

Radioactive waste disposal is performed by ONDRAF/NIRAS. Conventional waste is disposed in private landfills.

#### **Which bodies have responsibility for onsite safety regulation, discharges and disposal?**

Regulation is established by the Belgian Government and/or by the Belgian Parliament. The Federal Agency for Nuclear Control (FANC/AFCN) is an independent administrative authority set up by law of 15 April 1994 and entrusted with a general mission concerning the protection against ionising radiation. FANC/AFCN is in charge of delivery licenses i.e.

- transport of radioactive material;
- nuclear installation (from commissioning up to decommissioning);
- releases of air and evacuation of effluents;
- free release of material coming from nuclear sites;
- control of non-nuclear installation (handling of Natural Occurring Radioactive Material).

Together with its subsidiary Bel V, he is performing safety audit in the nuclear facilities.

#### **Which body(s) owns the facilities?**

The operators of the facilities (Belgonucleaire, Belgoprocess, Electrabel, SPE, FBFC, IRE, JRC-IRMM, SCK•CEN) own the facilities.

**Describe the responsibilities for funding of the decommissioning plan and disposal plan (including for oversight of funding arrangements and whether or not the funds are managed by the licensee organisation). Are they one and the same body?**

See Management of decommissioning and liabilities.

## QUESTIONNAIRE RESPONSE – FRANCE

**What is the country (institutional) structure for decommissioning? Include the responsibilities for the whole process (management of liabilities, decommissioning, transport, waste treatment/storage and waste disposal). Please indicate whether organisations are public or private and whether there are important providers of services (e.g. commercial smelting).**

**Please describe briefly who does what and where the responsibilities lie.**

In France there is no institutional structure for decommissioning. The operator of a facility is responsible for decommissioning and must make provision for the funding of decommissioning.

The companies that presently operate nuclear facilities in France must be considered as private companies even if in every board the French Government has generally the major share and can make decision<sup>3</sup>.

Decommissioning is therefore performed under the responsibility of the operator. Waste conditioning can be performed on site but can also be subcontracted to external companies (for instance to SOCODEI for incineration and melting services or to ANDRA for compaction services).

Transportation is subcontracted by decommissioners to private companies.

Nuclear waste<sup>4</sup> disposal is performed by ANDRA that is a State owned company in a contractual framework with the companies that used ANDRA's services. Conventional wastes are disposed in private landfills.

**Which bodies have responsibility for onsite safety regulation, discharges and disposal?**

Regulation is established by the French Government.

The Nuclear Safety Authority (ASN) is an independent administrative authority set up by law 2006-686 of 13 June 2006 concerning nuclear transparency and safety (known as the "TSN law"). ASN is tasked, on behalf of the State, with regulating nuclear safety and radiation protection in order to protect workers, patients, the public and the environment from the risks involved in nuclear activities. It also contributes to informing the citizens.

TSN law improves and clarifies the status of ASN with regard to nuclear safety and radiation protection. ASN thus increases its independence and its legitimacy with respect to those in charge of promoting, developing and carrying out nuclear activities. It enjoys a new legal foundation and a status comparable to that of its counterparts in other industrialised nations. It also has enhanced powers enabling it to penalise violations and take all necessary urgent measures.

The core duty of ASN is:

- Regulations

ASN contributes to drafting of regulations, by giving the Government its opinion on draft decrees and ministerial orders, or by issuing technical regulatory decisions. ASN is consulted on the draft decree and ministerial order of a regulatory nature related to nuclear safety.

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3. In AREVA that operates conversion plants for uranium, enrichment plants, fuel fabrication plants (for UOX and MOX fuels), reprocessing plants; public shares are 87% of capital. In EDF shares that are owned by the State are 84%. CEA for nuclear research and ANDRA for waste management are State owned companies but the general rule is valid for them.

4. A nuclear waste is waste that is generated in a nuclear facility in an area where it is, may be or may have been contaminated or active. It has to be managed in a route with reinforced traceability.

ASN also makes the individual decisions stipulated in the Public Health Code.

It can take decisions in technical regulations to complete the procedure for implementing decrees and orders related to nuclear safety and radiation protection, except those related to occupational medicine. These decisions are approved by the ministers in charge of nuclear safety, for those of them who are related to nuclear safety, or ministers responsible for radiation protection, for those of them who are related to radiation protection.

ASN can also order individual decisions and impose requirements as specified by law TSN.

ASN instructs authorization to commission or decommission nuclear facilities and makes proposals to the Government on the decrees. It issues the requirements for such facilities.

#### Inspection

ASN checks compliance with the rules and specifications applicable to the nuclear facilities. ASN also has appropriate powers of enforcement and punishment.

- Information

ASN informs the public and other stakeholders (local information committees, environmental protection associations, etc), about its activities and the state of nuclear safety and radiation protection in France.

In the event of an emergency, ASN assists the Government.

It in particular sends the competent authorities its recommendations regarding the civil protection measures to be taken.

Regarding safety generally ASN provides to operators safety objectives to be achieved for the design, for operation or for dismantling of facilities. These objectives, as well as good practices, are described in safety rules. ASN performs an expertise of the technical means that are proposed by the nuclear operator. The way the operator has to demonstrate the compliance with the safety objectives is not prescribed by ASN.

It should also be underlined that, according to the decree of the 2nd of November 2007, when an operator wants to make minor modifications in the design or in the operational mode of a facility he has to submit a file to ASN. Another option is the implementation in the operator's organization of an independent assessment commission to assess the proposed modifications. This organization, its area of work have to be approved by ASN and can be audited. Its program of work has to be provided to ASN.

These processes are valid for construction of nuclear facilities, including waste treatment facilities and disposal facilities<sup>5</sup>, operation and dismantling.

#### **Which body(s) owns the facilities?**

The operators of the facilities (CEA, EDF, AREVA, ANDRA) own the facilities.

#### **Describe the responsibilities for funding of the decommissioning plan and disposal plan (including for oversight of funding arrangements and whether or not the funds are managed by the licensee organisation). Are they one and the same body?**

According to the waste act 2006-739 of the 28th of June 2006, the operators have to estimate cautiously decommissioning costs and waste management costs. It includes the costs all phases of decommissioning: decommissioning, conditioning, treatment, storage, transportation, disposal.

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5. However this regulation is not valid for very low level waste disposal facilities, because of the activity to be managed. However ASN supervises radiation protection in these disposal facilities.

They have to establish provisions relating to these charges and assign exclusively to assets necessary to cover these provisions. They have to submit every three years a report to the administrative authority (evaluation of conditions, calculation methods, choices about assets and their management) and annually update the report and immediately notify of any important event in this area.

Furthermore a National Commission is created to check the adequacy of provisions for future expenses and asset management; it submits a report to Parliament and the High Committee for Transparency and information on nuclear safety; this report is public.



## **QUESTIONNAIRE RESPONSE - GERMANY**

***What is the country (institutional) structure for decommissioning. Include the responsibilities for the whole process. Indicate whether organisations are public or private and whether there are important providers of services?***

***What are the responsibilities and what are the control mechanisms between the institutions involved. Which institution is responsible for the choice of the decommissioning strategy?***

When a nuclear facility is to be decommissioned, the licensee or plant owner has to apply for a decommissioning licence on the basis of the Atomic Energy Act (AtG). He chooses the decommissioning strategy and he remains responsible for safety and accomplishment of decommissioning until the site is released from nuclear regulatory control. The application documents include a safety assessment of the planned measures and have to be submitted to the regulatory body of the respective Federal State (Land), who involves authorised expert organisations for assessment.

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supervises the licensing activities of the Federal States and harmonises the appliance of the legal framework. In this context, the BMU may request technical and scientific advice from the Reactor Safety Commission (RSK), the Commission on Radiological Protection (SSK), the Nuclear Waste Management Commission (ESK), expert organisations (for example, Society for Facility and Reactor Safety (GRS)), and the Federal Office for Radiation Protection (BfS). If necessary, BMU may give directives to the regulatory body of the respective Federal State (see also Annex 2).

Within the framework of supervision (accompanying control), the regulatory body of the respective Federal State must ensure that, in particular, the provisions of the decommissioning license are considered. It has also to decide on the termination of a licence and the respective release of an operator from its obligations. Independent authorised experts are typically involved to carry out supplementary controls and assessments by order of the regulatory body.

For the practical work during decommissioning of nuclear facilities, adequate permit procedures are required that enable supervision and can be applied for planning and performance of specific dismantling measures.

An important provider of services is the Energiewerke Nord GmbH (EWN), who is decommissioning and dismantling the Greifswald Nuclear Power Plant (KGR) and the Rheinsberg NPP (KKR). The EWN took over the Arbeitsgemeinschaft Versuchsreaktor GmbH (prototype reactor) and the WAK Wiederaufbereitungsanlage Karlsruhe Rückbau- und Entsorgungsgesellschaft mbH (prototype reprocessing plant) as subsidiary companies. Besides the dismantling activities, the interim storage of the spent fuel elements and the treatment and interim storage of residual material (including large components) and radioactive waste are main tasks of EWN. The only shareholder of the EWN is the Federal Ministry of Finance.

Another provider of services is the Gesellschaft für Nuklearservice mbH (GNS), which is the lead company of nuclear economy companies in the field of waste management and decommissioning.

The company Siempelkamp Nukleartechnik (NIS Ingenieurgesellschaft is a subsidiary company hereof) provides comprehensive services in planning of decommissioning as well as melting of radioactive contaminated scrap metal.

In Germany the Federal Government is responsible for construction and operation of repositories for radioactive waste. Concretely the Federal Office for Radiation Protection (BfS) is consigned to do this task (operator). A double security and surveillance system has been established for radioactive waste repositories in Germany. The repositories are subject to control through the BfS Repository Surveillance unit, furthermore they are supervised by the Federal Ministry for the Environment, Nature Conservation and

Nuclear Safety (BMU). The BfS Repository Surveillance unit works on a professionally independent basis and holds a special organisational position, which is allocated to the vice-president of BfS. It has special authorities and instruments in order to be able to issue necessary decrees at any time that have to be observed by the other BfS organisational units. For the licensing (planning approval) of repositories for radioactive waste the respective Federal State (Land) is responsible. According to the polluter pays principle the producers or rather the deliverers of radioactive waste have to pay all costs related to disposal of radioactive waste.

#### **Which body(s) owns the facilities?**

The operators and owners of nuclear power plants (NPP) in Germany are privately owned electric power companies, which are responsible for operation as well as for decommissioning of the facilities. Also commercial nuclear fuel cycle facilities are privately owned facilities. Prototype reactors and the Greifswald and Rheinsberg NPP are publicly owned or inherited facilities. The Energiewerke Nord GmbH (EWN) is decommissioning and dismantling the Greifswald NPP (KGR) and the Rheinsberg NPP (KKR). The only shareholder of the EWN is the Federal Ministry of Finance. The EWN took over the Arbeitsgemeinschaft Versuchsreaktor GmbH (prototype reactor) and the WAK Wiederaufbereitungsanlage Karlsruhe Rückbau- und Entsorgungsgesellschaft mbH (prototype reprocessing plant) as subsidiary companies.

The operators of research reactors are universities and research centres which are financed by the Federal Government, thus being the owner of the research reactors. In so far, costs of operation and decommissioning of research reactors fall within the government's responsibility.

#### **What are the responsibilities for funding decommissioning and disposal?**

In the case of publicly owned or inherited facilities (research reactors; facilities within research centres or at universities; prototype reactors and the Greifswald and Rheinsberg nuclear power plants), decommissioning funds are being provided within the annual Federal budget. In the case of research and prototype facilities the Federal Government typically covers 90 % of the costs, while the rest is borne by the respective Land. The decommissioning of the nuclear power plants in Greifswald and Rheinsberg, inherited from the former German Democratic Republic, is completely financed by the Federal Government. Financing includes all expenses incurred for the post-operational and transition phase, disposal of the fuel assemblies, execution of the licensing procedure, dismantling of the radioactive part of the facility, and disposal of the radioactive wastes, including all preparatory steps.

In the case of privately owned facilities (for example, NPPs and fuel cycle facilities) financial reserves have to be accumulated during the operational phase by the owner of the respective facility. The legal basis for accumulating and managing of financial reserves is provided by an interaction of several laws:

- the Atomic Energy Act (AtG) requires the removal of waste
- the Commercial Code (HGB) requires to accumulate financial reserves for future liabilities
- the Income Tax Law (EStG) regulates the taxation of reserves.

These reserves include the costs of the post-operational phase in which the facility is prepared for dismantling after its final shut-down (including removal of fuel elements and operational waste), the costs for the licensing procedure and supervision, the costs of dismantling (dismantling and interim storage of all components and all buildings of the controlled area), and the cost of the interim and final storage of all radioactive waste from decommissioning. The reserves are held in the portfolio of and managed by the owners of facilities. Reserves reduce the income of the operators subject to taxation.

Annual cost calculations have to be prepared in order to justify the amount of the respective reserves which are reviewed by tax authorities.

## QUESTIONNAIRE RESPONSE - SWEDEN

**•What is the country (institutional) structure for decommissioning? Include the responsibilities for the whole process (management of liabilities, decommissioning, transport, waste treatment/storage and waste disposal). Please indicate whether organisations are public or private and whether there are important providers of services (e.g. commercial smelting)**

**Please describe briefly who does what and where the responsibilities lie.**

The Swedish NPPs are, in different constellations, jointly owned and controlled by the state and the private industry. Under Swedish law, the holder of a license to operate a nuclear facility is primarily responsible for the safe handling of spent nuclear fuel and radioactive waste, as well as decommissioning and dismantling of the facility. With help from SKB (Swedish Nuclear Fuel and Waste Management Company), jointly owned by all NPP utilities, to assist them in executing their responsibility for all handling, transportation and storage of spent fuel and radioactive waste outside the nuclear power plants, as well as for disposal of spent nuclear fuel and low and intermediate level nuclear waste.

Studsvik Nuclear AB supply services to the nuclear industry e.g. management to practical dismantling work and the subsequent waste treatment process of dry and metallic waste by burning and melting. They are also responsible for management of legacy waste but the waste is disposed off in SKBs facilities.

**Please describe briefly who does what and where the responsibilities lie. Mention any special control mechanisms that exist inside/between the institutions involved (e.g. technical expert organisations)? For example, are there institutions that control the decisions and the planned procedures of other institutions? Which institution is responsible for the choice of the decommissioning strategy?**

Decommissioning is included in the License for nuclear activities, which were obtained from the Swedish Government in connection with the construction, and operation of the plant. It covers the activities undertaken at the facility from construction to the final dismantled unit. Related to the construction of a nuclear power plant also requires a preliminary planning for the future decommissioning.

The licensees must comply with applicable regulatory requirements and establish plans for future decommissioning and dismantling. Planning for decommissioning and execution of dismantling work shall be carried out in cooperation between the licensees of nuclear reactors and SKB but the main responsibility lies on the licensee for the nuclear reactor, which is responsible for planning, licensing issues and the implementation of the physical demolition, and for treatment of waste. This also includes determination of what strategy to apply to each power plant and planning for the entire plant decommissioning.

From a national point of view, it is necessary to coordinate between the nuclear facilities. SKB has been delegated this task from the Swedish nuclear power companies and is responsible for study and report on appropriate technology and making estimates of the cost, waste quantities and waste types for decommissioning and dismantling of Swedish NPPs.

Sweden has a forum in which the utilities work to get coherence in both technical and strategic issues called the 'Decommissioning Group' (Rivningsgruppen). In this group all license holders for NPPs participates together with SKB. The group is organized by SKB and advises SKB on matters concerning technology and logistics issues related to decommissioning such as choice of technologies and processing and handling of waste. This group also gives recommendations and support to funding arrangements for the decommissioning of the nuclear facilities.

**Which bodies have responsibility for on site safety regulation, discharges and disposal?**

The Swedish Radiation Safety Authority (SSM) is a regulatory authority under the Swedish Government, Ministry of Environment with a gathered national responsibility within the areas of nuclear safety and radiation protection. SSM reports to the Ministry of the Environment.

Work involving radiation is regulated in a series of regulations, based on The Radiation Protection Act, the Radiation Protection Ordinance, the Act on Nuclear Activities and the Swedish Environmental Code. The requirements are also based on the international recommendations for ionizing radiation, based on the International Radiation Protection Commission's (ICRP) internationally recognized principles, i.e. justification, optimization and dose limitations.

Responsibility for radiation safety lies entirely on the licensees that operate with radiation. SSM, as a regulator, inspects and monitors that the nuclear installation operates in a safe manner, follows rules and requirements and take their responsibilities. SSM regulates management of spent fuel, radioactive waste (discharges of radioactive substances) and decommissioning, physical protection of nuclear materials and the transport of radioactive material.

**Which body(s) owns the facilities?**

Swedish nuclear power station consists of a complicated co-ownership. Largest owners are - Vattenfall AB, which is wholly owned by the Swedish state, Finnish Fortum and German Eon.

**Describe the responsibilities for funding of the decommissioning plan and disposal plan (including for oversight of funding arrangements and whether or not the funds are managed by the licensee organisation). Are they one and the same body?**

The licensee of a nuclear facility which generate or has generated residual products must pay a nuclear waste fee. The fees are collected in a fund, the Nuclear Waste Fund. This Fund is an external and fully ringed-fenced governmentally controlled and administered fund.

The fee shall cover the licensees' share of the total costs for management and disposal of all spent fuel and nuclear waste generated from all nuclear facilities also for decommissioning and dismantling. The most important actions are to plan, build and operate the facilities and systems needed, also to conduct research and development related to this.

SSM is responsible for the review of the cost estimates and to suggest the level of fees to be paid by licensees to the Nuclear Waste Fund. Furthermore, SSM is responsible to control that the nuclear utilities has made the payments to the Fund and also to audit the disbursements.

SKB is responsible to establish an overall cost estimate for all licensees and for SKB's own costs. The estimates are based on SKBs current planning for management (transport and disposal) of spent fuel and radioactive waste. A significant cost item is the decommissioning of the nuclear installations. These costs are estimated in collaboration between SKB and the utilities. Necessary future work is presented in SKBs RD & D programs and shall be submitted to the government every three years.

Estimates of decommissioning costs for nuclear power plants have been based on estimates for a reference plant and transferred to other plants by scaling. Today, unit and site specific decommissioning are successively performed for all NPPs. These studies focus on estimates of waste volumes and the radionuclide inventory as an input to the design and safety assessment of the repository for decommissioning waste but they also includes updates of the estimates of decommissioning costs.

## QUESTIONNAIRE RESPONSE – UK

**•What is the country (institutional) structure for decommissioning? Include the responsibilities for the whole process (management of liabilities, decommissioning, transport, waste treatment/storage and waste disposal). Please indicate whether organisations are public or private and whether there are important providers of services (e.g. commercial smelting)**

**Please describe briefly who does what and where the responsibilities lie.**

The UK does not have a single institutional structure for decommissioning, though the general principle is that the site operator (licensee) has the responsibility for performing the work on its site and arranging for radioactive waste disposal. The organisation ultimately makes the decision on the work to be undertaken. The Nuclear Decommissioning Authority (NDA), a non-departmental public body, owns a number of sites and has responsibilities through the Energy Act 2004, for the decommissioning and clean-up of the UK's civil public sector nuclear sites. This includes:

- developing UK-wide nuclear Low Level Waste (LLW) strategy and plans;
- the long-term management arrangements for the UK's higher radioactive wastes; and
- 19 former UKAEA and BNFL sites.

NDA does not directly manage the facilities that it owns. It contracts out the delivery of site programmes through management and operation contracts with licensed operators, Site Licence Companies (SLCs), at each site. The SLCs manage sites, including preparing site plans, performing and sub-contracting work.

The remainder of the nuclear industry in UK is operated by commercial companies that have responsibility for all operational activities. In the case of the British Energy, fleet of reactors the liabilities will at the end of life pass to the NDA and the decommissioning activities managed as described above.

In the case of new build a decommissioning fund is being set up which the operators will fund with the expectation that at the end of operational life they will be responsible for decommissioning.

Again, the primary responsibility for carrying out the decommissioning activities rests with the operator. The operator may however contract out work, such as waste conditioning either on site to other companies but the responsibility for delivery still rests with the site operator.

Transportation is a mixture, with the use of private companies as well as facilities owned by the NDA or the site operator.

### **Which bodies have responsibility for onsite safety regulation, discharges and disposal?**

The UK Government establishes regulation.

The Health and Safety Executive was set up by statute in 1974 and has responsibility for regulation of Health and safety across all work activities in the UK. The Nuclear Directorate, which is part of HSE, has responsibility under the Nuclear Installations Act for the regulation of nuclear licensed sites. ND is tasked with regulating nuclear safety, accumulation of radioactive waste and radiation protection at the sites in order to protect the public from the hazards arising from ionising radiations.

HSE regulates the nuclear industry through its Nuclear Directorate (ND). The Directorate's primary goal is to ensure that those it regulates have no major nuclear accidents. It is responsible for the UK safety regulation of nuclear power stations, nuclear chemical plants, decommissioning, defence nuclear facilities, nuclear safety research and strategy and for civil nuclear operational security and safeguards matters.

Through its own regulation and in partnership with other regulators and agencies, ND works to deliver its mission « *To protect people and society from the hazards of the nuclear industry* ». ND also takes responsibility for approving security arrangements within the industry, and for securing compliance with those arrangements. It also oversees safeguard measures to verify that States comply with their international obligations not to use nuclear materials for nuclear explosives purposes.

The Environment Agency (England and Wales) and the Scottish Environment Protection Agency (Scotland) (referred to as the environment agencies) were established by the Environment Act 1995 and have responsibilities for the protection of the environment and members of the public. The environment agencies have responsibilities under the Environmental Permitting Regulation (England and Wales) 2010 and the Radioactive Substances Act 1993 (for Scotland) for the regulation of radioactive discharges from nuclear licensed sites; subject to conditions that ensure minimisation of discharges in line with the UK Discharge Strategy and protection of the environment. Additionally the environment agencies are the responsible bodies for authorising radioactive waste disposal facilities in the UK.

The environment agencies regulate under some fundamental principles;

- optimisation of protection on the basis that radiological doses and risks to workers and members of the public from a source of exposure should be kept as low as reasonably achievable (the ALARA principle);
- application of limits and conditions to control discharges from justified activities;
- sustainable development;
- the precautionary principle;
- the polluter pays principle;

Transport of radioactive material is currently regulated separately by the department of transport.

**Which body(s) owns the facilities?**

The position is complex. NDA own the sites as described in the response to question one but for the non-NDA, “estate” ownership rests with the operator of the facility or in the case of defence facilities, they are owned by the crown.

**Describe the responsibilities for funding of the decommissioning plan and disposal plan (including for oversight of funding arrangements and whether or not the funds are managed by the licensee organisation). Are they one and the same body?**

The current regulatory framework in UK makes no distinction between the various phases from operations through to defueling and decommissioning. It is the operators who are responsible. All operators have a responsibility to prepare decommissioning plans as part of regulation plus where applicable NDA require a near term work plan and expect a life cycle plan. Funding for decommissioning is provided currently by the state for the NDA estate and for British Energy reactors. However, recent legislation, the Energy Bill 2008, ensures that operators of new nuclear power stations accumulate funds to meet the full costs of decommissioning and their full share of the waste management costs. A funded decommissioning plan is also required.

## QUESTIONNAIRE RESPONSE – SPAIN

**•What is the country (institutional) structure for decommissioning? Include the responsibilities for the whole process (management of liabilities, decommissioning, transport, waste treatment/storage and waste disposal). Please indicate whether organisations are public or private and whether there are important providers of services (e.g. commercial smelting)**

**Please describe briefly who does what and where the responsibilities lie.**

Spanish Law establishes that the State Owned Entity ENRESA is the responsible for the whole decommissioning process for nuclear facilities in Spain.

As such, ENRESA responsibilities cover aspects such as:

- Managing the national Decommissioning Fund, fed from fees to the Spanish nuclear utilities, all of them 100% private entities
- Taking over the License of the nuclear sites to be decommissioned until the end of the D&D process and finalization of the corresponding Licensing Termination process
- D&D planning, including cost estimation and required funds appraisal
- Overall managing of the D&D project, including contractors selection and supervision
- Handling, transport and disposal of all radioactive wastes generated during the decommissioning project

Although the final responsibility of managing D&D projects belongs to ENRESA, it usually subcontracts large packages of work, under both fixed price and T&M terms, to engineering or service companies.

Radioactive waste disposal is also under exclusive responsibility of ENRESA, which is the owner and operator of the “El Cabril” LILW and VLLW Disposal facilities. Cleared materials are sent to dedicated recyclers/handlers, while conventional wastes are disposed in public or private landfills.

### **Which bodies have responsibility for site safety regulation, discharges and disposal?**

The Spanish Nuclear Safety Council (CSN) is an independent administrative authority set up by law 15/1980.

In accordance with the provisions of that Law, the top management bodies of the Nuclear Safety Council are the plenary and the Presidency, which will act in exercising their respective roles in compliance with the principles established in article 4.3 of the aforementioned Law 15/1980, of April 22nd.

The Plenary of the Council is the visible head of the CSN (collegiate organisation) and is made up of the president and four counsellors, the election of which follows a rigorous democratic process in the Spanish Parliament.

During their term, which lasts six years, the members of the Plenary oversee the correct compliance of the functions and obligations of the organisation with respect to Spanish society, which focus basically on the surveillance and control of nuclear facilities and those using ionising radiations.

The CSN supervises safety in the use of radioactive materials in medicine, industry and research, the control of wastes, the transport of materials, the protection of professionally exposed personnel and the impact that radiations and releases might have on the public and the environment.



Within these realms of competence the authority of the CSN is absolute. Its reports are binding when the objective is to impose conditions of safety and protection or to refuse a permit or authorisation. Likewise, the organisation has the power to interrupt the operation of a facility if it determines that it is unsafe.

The core functions of CSN are:

- proposals to Government for regulations and standards
- dictate obligatory standards on its own initiative
- control of facilities operation
- action in the event of emergencies
- reporting on facility projects
- radiation dose control.
- environmental surveillance.
- granting of personnel licences.
- performance and promotion of research plans
- information to the public opinion and the Parliament
- relations with the State Administrations.
- relations with other similar foreign and international organisations.

**Which body(s) owns the facilities?**

The operators of the facilities (Gas Natural, ENDESA, IBERDROLA, NUCLENOR, ENUSA, etc) are their owners and are granted the corresponding operating licenses.

However, when a facility is going to be dismantled or decommissioned, the site license is temporarily transferred to ENRESA, although the prior operator maintains the bare site ownership.

Once ENRESA has finalized the D&D project and achieved the Termination of the License (LTP), the right of use of the cleared site is returned to the owner, be it as Brown Site (In case of conditional clearance for Industrial scenario) or as Green Field (Unconditional clearance for unrestricted use).

**Describe the responsibilities for funding of the decommissioning plan and disposal plan (including for oversight of funding arrangements and whether or not the funds are managed by the licensee organisation). Are they one and the same body?**

Regulations on fuel cycle activities requires the conclusion of contracts between ENRESA and the companies owning nuclear power plants and other fuel cycle facilities. The objective of these contracts is to regulate the collection of the financial resources for decommissioning during the operating life time of the installations.

These regulations were revised in 2003 to apply the polluter pays principle in a more direct manner. Whereas prior to 2003 a general fee was applied to all electricity producers, since 2004 a more complex system is applied where nuclear utilities bear the bulk of the expenses.

These amounts are allocated to the build-up of a interest-bearing fund, managed by ENRESA. According to the corresponding royal decrees, the revenues transferred to the fund arise from:

- Supply and access tariffs proportional to electricity sales. The applied percentages are set by the royal decree establishing the electricity tariff for each year.

- Direct billing to operating NPP licensees of specific amounts resulting from multiplying the gross kilowatt-hours generated by each plant in each calendar month by a plant-specific unit value, to be revised annually and established by a royal decree.
- Fees collected for the management of radioactive wastes arising from the manufacturing of fuel assemblies and for the dismantling of the facilities at which such fuel assemblies are manufactured.
- Billing to the operators of radioactive facilities generating radioactive wastes and involved in medicine, industry, agriculture and research, via tariffs approved by the Ministry of Industry, Tourism and Trade.
- Any other revenue collection method not contemplated in the previous paragraphs.

The financial management of the fund by ENRESA is governed by the principles of security, profitability and liquidity. The total amount shall cover the costs related to the activities contemplated in the General Radioactive Waste Plan (GRWP). For nuclear power plants, a 40 years service lifetime is assumed in the calculation.

Every six months ENRESA has to produce a report on the state of the fund.

The GRWP includes activities regarding the management of radioactive waste, spent fuel as well as dismantling and decommissioning of both nuclear facilities and as a result of the uranium mining and milling activities performed prior to 1984.

The GRWP is revised every four years or upon request of the Ministry of Industry, Tourism and Trade. Besides, during the first six months of every year, ENRESA draws up an updated economic-financial study of the costs of the activities contemplated in the GRWP. Furthermore each year a technical-economic assessment is submitted to justify the suitability of the annual budget for the next financial year and to provide forecasts for the next three years.

## QUESTIONNAIRE RESPONSE – USA

**What is the country (institutional) structure for decommissioning? Include the responsibilities for the whole process (management of liabilities, decommissioning, transport, waste treatment/storage and waste disposal). Please indicate whether organisations are public or private and whether there are important providers of services (e.g. commercial smelting).**

Decommissioning activities within the United States (U.S.) are governed by the federal government's codified rules, called the *Code of Federal Regulations (CFR)*. Within the overall governing structure, primary responsibility for decommissioning nuclear facilities is shared by two separate agencies; one for the decommissioning of commercial nuclear facilities; and one for non-commercial, mostly defense-related (but also other) nuclear facilities. More specifically, the Nuclear Regulatory Commission (NRC) oversees the decommissioning of commercial nuclear reactors and facilities (and a few DOD and DOE facilities), while the U.S. Government is responsible for the decommissioning of all Government owned nuclear facilities. For the Government owned facilities, the U.S. Department of Energy (DOE) and the U.S. Department of Defense (DOD) are responsible for implementing the entire decommissioning process, which was established by the Atomic Energy Act of 1954. For the DOE, the decommissioning process is defined and directed by DOE Order 430.1B and its associated guides, which identify specific requirements to be followed for decommissioning activities, as well as DOE Order 435.1 Radioactive Waste Management and 10 CFR 835 which covers health and safety regulations.

In addition, when defense-related facilities are undergoing decommissioning, other U.S. agencies can regulate activities associated with decommissioning. For example, during decommissioning projects, the U.S. Environmental Protection Agency (EPA) can implement regulations under the Comprehensive, Environmental Response, Compensation and Liability Act of 1980 (CERCLA) and the Resource Conservation and Recovery Act of 1976 (RCRA) to ensure that contaminated debris and/or radioactive waste is cleaned up to proper levels and safely shipped, treated and disposed of at properly permitted facilities. The U.S. Department of Transportation (DOT) also regulates activities related to the transport of materials and wastes generated during decommissioning of both commercial and non-commercial nuclear facilities.

### **Life Cycle of a DOE Facility**

In order to fully comprehend the overall structure for decommissioning nuclear facilities within the federal government, it is essential to understand the total "life cycle" of a DOE defense-related facility, and how that facility moves from its operational stage to shutdown, and to eventual decommissioning.

When a DOE facility reaches the end of its life cycle, it then progresses through three primary phases: **(1) transition; (2) disposition; and (3) post-decommissioning.**

Transition begins when a facility is determined to be surplus and is no longer required for any agency mission. An engineering-planning evaluation is performed to define the set of conditions that will determine: (1) the final disposition of the surplus facility; (2) its wastes; and (3) the planned future land use (referred to as the "end-state"). This evaluation is essential in order to identify the resources needed for decommissioning activities. Identification of the end-state is normally conducted in collaboration with federal and state regulators, local community planners, tribal governments and various other stakeholders.

Disposition usually includes deactivation, decommissioning, and any surveillance & maintenance (S&M) activities. After a facility's operations are shut down, deactivation is typically performed. Deactivation removes the facility from "active service" and places it in a safe and stable condition that can be economically monitored and maintained, until

decommissioning can occur. The deactivation process ensures adequate protection of the worker, public health and safety, and the environment. Deactivation tasks typically include removal of hazardous and radioactive materials and fuel, and the draining and/or de-energizing of non-essential systems.

During decommissioning, the facility may be decontaminated and/or dismantled, and then released, demolished, or entombed. Radiological decontamination ensures that all radioactive components are removed, all surfaces are cleaned, and radioactive waste is properly packaged and sent to an appropriate disposal facility. Dismantlement is the removal of equipment, fixtures, fittings, etc. from a structure, followed by the controlled breaking of the structure into pieces and removal of them from the facility. Demolition is the controlled tearing-down of a structure, usually without the sequential breaking involved with dismantlement.

S&M activities continue throughout the decommissioning process until the facility can be released for unrestricted use. Surveillance encompasses any activity at a facility that involves periodic inspection of a facility, equipment, or structure. Surveillance is performed to demonstrate compliance, identify problem areas requiring corrective action, and determine the facility's present environmental, radiological, and physical condition. Maintenance includes any activity performed at a facility, on a day-to-day basis, required to sustain the property in a condition suitable for its designated purpose. Maintenance includes preventative, predictive and corrective maintenance.

The Post-Decommissioning Phase includes long-term monitoring and/or remedial action to comply with overall site plans and regulatory requirements. S&M activities conducted throughout the life of the decommissioning project are converted to long-term S&M after decommissioning. Sites may be transferred to remedial action projects so that final cleanup of adjacent soil or groundwater can be performed, in accordance with environmental regulatory requirements and future land and facility uses.

**Please describe briefly who does what and where the responsibilities lie. Mention any special control mechanisms that exist inside/between the institutions involved (e.g. technical expert organisations)? For example, are there institutions that control the decisions and the planned procedures of other institutions? Which institution is responsible for the choice of the decommissioning strategy?**

As mentioned in question number one above, decommissioning of nuclear facilities involves different government agencies, depending on whether the facility is commercial or Government owned, such as those owned by DOE. For commercial nuclear reactors, the actual owners of the plant, such as a power company, are responsible for choosing the decommissioning strategy and conducting the work. Commercial firms frequently perform their own D&D work, but can, and often do, hire contractors that specialize in such work. Both NRC and DOE have prepared guidance and directives for licensees and contractors to follow. The DOE performs its own decommissioning activities on defense-related facilities, using various prime and subcontractors to complete the work. As previously noted, the DOE adheres to guidelines established under the Atomic Energy Act of 1954, and follows the specific requirements identified in DOE Order 430.1B, 435.1 and 10 CFR 835.

When undergoing decommissioning, DOE facilities and sites are regulated under CERCLA, as a result of a joint policy agreement between EPA and DOE that specifically addresses DOE decommissioning projects and designates a preference for CERCLA to oversee the work, and to ensure that cleanup is performed to established safe levels. Under the joint policy, decommissioning activities are normally conducted as non-time critical removal actions under CERCLA response authority (unless the circumstances at the facility make it inappropriate). However, non-time-critical removal actions are also flexible enough to be implemented at facilities not governed under CERCLA. Lastly, decommissioning activities adhere to the community relations and public participation requirements established by CERCLA, the National Contingency Plan (NCP), and DOE policies.

**Which bodies have responsibility for on-site safety regulation, discharges and disposal?****Safety Regulation**

As identified earlier in this document, several federal agencies are responsible for aspects of the decommissioning process. The agencies involved in regulating or providing oversight to the decommissioning process include the DOE, NRC, EPA, DOT, the Occupational Safety and Health Administration (OSHA), and the Defense Nuclear Facilities Safety Board (DNFSB). Individual states also may have some regulatory authority to oversee decommissioning projects.

The DOE regulates and oversees nuclear facilities that are owned by DOE, including being responsible for managing the radioactive wastes generated during DOE's decommissioning. The Nuclear Policy Act of 1982 centralized the long-term management of high level nuclear waste, including spent nuclear fuel from commercial reactors and mandated construction of a safe and permanent nuclear waste repository by DOE. In 1987, the United States Congress amended the Nuclear Policy Act and designated Yucca Mountain as the only site to be considered as a repository. The President's Budget Request to Congress for FY 2011 included a new U.S. policy "*...the Administration determined that developing a repository at Yucca Mountain Nevada is not a workable option and has decided to terminate the Office of Civilian Radioactive Waste Management (OCRWM). The Nation needs a different solution for nuclear waste disposal.*" The Secretary of Energy established a Blue Ribbon Commission on America's Nuclear Future in January 2010 to evaluate alternative approaches for managing spent fuel and HLW from commercial and defense activities. The Blue Ribbon Commission on America's Nuclear Future is conducting a comprehensive review of policies for managing the back end of the nuclear fuel cycle. It will also provide recommendations for "*...developing a safe long-term solution to managing the Nation's used nuclear fuel and nuclear waste.*" A final report will be submitted to the Secretary of Energy within 24 months of the establishment of this Commission (January 2012).<sup>6</sup>

NRC governs the decommissioning process for facilities not owned by the government, and ensures that during the entire decommissioning process the health and safety of the public is not jeopardized. NRC regulations were established to provide safe cleanup of radioactively-contaminated plant systems, structures, and safe removal of radioactive fuel. Similarly, the OSHA is responsible for worker safety and other health aspects during decommissioning activities.

The DNSFB oversees activities across DOE's nuclear weapons complex. The DNSFB is an independent federal agency, established by Congress in 1988, which requires DOE to carry out its activities in a manner that ensures the safety of the public, workers and the environment.

**Regulation of Disposal and Discharges**

When facilities are undergoing decommissioning, radioactive and hazardous waste is present, and must be contained to prevent contamination of the surrounding environment. The EPA's primary responsibility is to protect human health and natural resources. The EPA enforces environmental laws, sets safe levels for contaminants, monitors pollution, performs research and promotes pollution prevention, in an effort to improve and preserve the quality of the environment.

Typically hazardous/radioactive waste is transported to a properly permitted location for safe storage. The DOT, along with NRC and the EPA, regulates the transport of hazardous and radioactive waste, including establishing detailed specifications for shipping

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6. See <http://www.BRC.gov>.

containers. DOT's transportation criteria ensure the safe transport of decommissioning waste on roads and railways.

State governments may also have some regulatory authority over decommissioning activities. These may include material release criteria, storage of radioactive materials, and packaging, transportation and disposal of chemical waste. It is important to note that states' regulations cannot be less restrictive than those set by the EPA.

***Which body(s) owns the facilities?***

The U.S. Government, specifically the DOE and DOD owns defense related nuclear facilities and sites. The sites themselves are generally operated by commercial contractors. This arrangement – Government Owned Contractor Operated – is frequently referred to by the acronym GOCO.

As stated earlier in this document, the nuclear facilities regulated by the NRC are commercial plants. These plants are owned by private sector companies. NRC oversees the decommissioning of these reactors and facilities, but the owners are responsible for choosing the decommissioning strategy and conducting the work

**Describe the responsibilities for funding of the decommissioning plan and disposal plan (including for oversight of funding arrangements and whether or not the funds are managed by the licensee organisation). Are they one and the same body?**

Funding for DOE and DOD facilities is provided by the United States government on an annual basis, provided through the government budget process. Normally, if a decommissioning project is a specific line item in the budget, funding is ensured for completion of the plan. Funding for DOE projects is dependent on congressional imposed budgetary conditions.

Conversely, private companies that have commercial nuclear facilities licensed under the NRC are responsible for funding their decommissioning project. In addition, as a condition for receiving an operating license, private firms must demonstrate that they have adequate funding for implementing and completing the decommissioning process. Five years before the projected end of a facility's operation, licensees are required to prepare a preliminary decommissioning cost estimate. Licensees must demonstrate how the funds will be accumulated and managed to ensure that the decommissioning project does not experience funding shortfalls.