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January 2009

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Executive summary

Several projects concerning the decommissioning of different types of nuclear facilities have shown that technical methods and equipment are available today for safe dismantling of nuclear facilities of any type or size. However, comparison of individual cost estimates for specific facilities exhibit relatively large variations, and several studies have tried to identify the reasons for these variations.

Analysis has shown that decommissioning cost estimates vary depending on a number of factors, including: the boundary conditions and strategy chosen; the cost items taken into account; the origin of the cost estimate; the methodology applied; the political-administrative framework; and the way contingencies are included.

In this study, a comparison has been made between two decommissioning studies in the same country, with more or less same decommissioning schedule and with similar overall ideas on cost estimates. However, the two studies had from the start a different focus and different objectives. One study is intended as a reference study for all BWRs in Sweden, while the other focuses on a full site decommissioning. Furthermore, one of the studies is based on direct dismantling and the other on deferred dismantling. A great deal of work therefore had to be devoted in the present study to giving the studies comparable structures and boundary conditions using the OECD/NEA cost estimate structure.

The boundary conditions in each of the studies have been thoroughly evaluated qualitatively and quantitatively, and the differences have been explained. In the end, values have been set in the quantitative analysis to verify that the studies could be compared, within the accuracy of what is defined in the industry as a “budgetary estimate”.

Differences still exist relating to what has been included in the studies and to the decommissioning plans and the resulting inventory from site characterization. Such differences must be accepted as long as it is clear what is included.

For future cost estimates and in order to permit comparison of results, the power plant owner must clearly specify in the decommissioning plan boundary conditions, what facilities/buildings are included and the decommissioning schedule.

Strategies for how to manage plant staff, as well as how the staff will participate in the decommissioning activities, are the responsibility of the power plant owner.

To facilitate comparison, it is desirable to have a set of similar boundary conditions, end states etc. In reality, different decommissioning projects will be based on different premises, and it is essential that all conditions be documented clearly and transparently.

Experience shows that the method used today, where the estimated decommissioning cost from a reference plant is transferred in almost direct relation to unit size and thermal power, is not accurate, but instead only a small portion is related to thermal power. For this reason, unit- and site-specific decommissioning cost calculations are recommended, based on well defined and transparent documented premises.

A decommissioning project can in many ways be compared to a cross between a maintenance outage and the construction of a nuclear facility. Decommissioning is not so far off in time, and it is therefore surprising that such meagre resources are devoted to the detailed planning of the activities in such costly project.

Our comment from having read and studied the two studies is that the difference lies not so much in how you calculate the cost of the individual decommissioning cost items, but rather more in how you control the basic costs such as the size of the management group in charge of the decommissioning, the time allotted for the project, the basic costs for the support and service staffs engaged in the project, and of course the execution of the actual decommissioning work.

New experience

Experience shows that the method used today, where the decommissioning cost from a reference plant is transferred in almost direct relation to unit size and thermal power, is not accurate, but instead only a small portion is related to thermal power. For this reason, site-specific decommissioning cost analyses are recommended, based on well defined boundary conditions.

Contents

1 Introduction

1.1 Background

Two different decommissioning studies have been performed where the waste volumes and costs from the decommissioning process have been analyzed. The decommissioning studies performed are:

- *Swedish BWR Reference Plant Decommissioning Study* /1/ of the Oskarshamn unit 3. (Westinghouse Electric Sweden AB).
- *Decommissioning Cost Analysis for Barsebäck Nuclear Station* /2/. (TLG Services inc, US).

The Oskarshamn 3 plant is a 1150 MW BWR plant (in operation since 1985, with internal main circulation pumps in the reactor vessel) and has been chosen to be the Swedish BWR decommissioning reference plant for cost calculations. Barsebäck units 1 and 2 are both 615 MW BWRs (unit 1 was commissioned in 1975 and unit 2 in 1977, with four external main circulation loops). The plant was permanently shut down in 1999 (unit 1) and 2005 (unit 2) due to political decisions and is awaiting decommissioning.

The decommissioning studies for Oskarshamn 3 and Barsebäck 1 and 2 have been based on different premises. The Oskarshamn 3 study is the Swedish BWR reference study, reflecting experience from the work done in Sweden in the field of decommissioning, and summarizes several recent studies. As a reference study, it was done with the aim of being able to transfer the decommissioning calculations to the other BWRs, and for this reason certain site-specific cost items are not included in the calculations. However, it is important to bear in mind that these site-specific costs must in some way be incorporated when the total decommissioning cost calculations are done.

The Barsebäck study is based on experience from how cost estimates are done in the USA and concerns the decommissioning of the whole Barsebäck site. The decommissioning costs for the Barsebäck site have been subdivided into Barsebäck unit 1 with common facilities and Barsebäck unit 2.

Historically, the decommissioning costs for the Swedish Nuclear Power Plants (NPPs) have been calculated or correlated to a relationship between unit size and decommissioning cost, see *Teknik och kostnader för rivning av svenska kärnkraftverk* /3/. However, the results of the two decommissioning studies mentioned above indicate that this method involving transfer calculations can be questioned, as there are more significant cost items than thermal power that influence the costs, and they are more related to the individual plants.

1.2 Purpose

The present study analyzes the differences between the two decommissioning studies in /1/ and /2/ and, in addition to costs, focuses on how waste volumes are calculated. This study also identifies differences in the boundary conditions and their consequences.

1.3 Objectives

The objective of the present study is to come to a conclusion and a future recommendation as to how decommissioning costs can be transferred (or not) from one unit to another.

1.4 Structure of the report

This report is structured as follows:

Chapter 1 contains background information and explains the purpose of the present study and its objectives. Chapter 2 explains the approach used in this study and how this approach will permit conclusions to be drawn as a basis for the recommendations. Chapter 3 provides basic information on the two studies and describes the basic scope of each study /1/ and /2/ without any evaluation. Chapter 4 presents a qualitative comparison of boundary conditions and Chapter 5 presents a quantitative comparison of the basic scenario and the boundary conditions. Comparison of costs according to the OECD/NEA structure is done as a part of Chapter 5. Approach correlated to thermal power is discussed in Chapter 6. Chapter 7 presents an analysis of differences and evaluations. The recommendations of this study are presented in Chapter 8. References are listed in Chapter 9.

2 Approach

The objective of the present study is to come to a conclusion and a future recommendation as to how decommissioning costs can generally be transferred (or not) from one unit to another. Furthermore, the study aims at identifying differences in the boundary conditions in the two studies and discussing and evaluating the consequences.

The approach for this comparative study has been,

- to identify differences in the two studies /1/ and /2/,
- to evaluate the differences in a qualitative way with a focus on how they affect the outcome of the respective study,
- to evaluate quantitatively and provide some figures/values to give the differences a measure that can later be used in the comparative analysis,
- to compare with international experience,
- to analyze the identified differences and their consequences,
- to develop recommendations on how decommissioning costs can generally be transferred (or not) from one unit to another, i.e. to determine whether the use of a "reference plant" is sufficient.

The aim of the comparative analysis in this report is not to judge which of the reports yields the "right" result, but rather to evaluate and explain why differences exist and what consequences they have on the uncertainties in the outcomes of the two studies.

The approach used for comparing costs quantitatively is based on the OECD/NEA decommissioning cost structure and studying for each section what cost items have been included in each of the two studies.

3 Basic information

3.1 Basic scope

A comparison is made between the Oskarshamn 3 reference study for boiling water reactors in Sweden /1/ and the study for the Barsebäck site /2/.

Both studies exclude the costs of handling of fuel and nuclear material, as it is considered to have been removed during the shutdown and service operational period by operation staff.

Activities/costs for staff reduction programmes are not included in either of the two studies.

Both studies have been evaluated and the differences and similarities have been analyzed.

Unless otherwise noted, information provided for Barsebäck represents the 2-unit station with common facilities.

3.1.1 Swedish BWR reference plant decommissioning study

This study /1/ was commissioned by Westinghouse Electric Sweden AB as a collective study where other recent studies are included. New knowledge was taken into account and incorporated when writing the report.

The scope of the study was also adjusted to the purpose of using the study for transferring calculation results to another BWR plant. A number of more site-specific facilities/buildings or conditions were therefore excluded in this study.

Premises of the study:

- Direct dismantling, with no or only a very short service operational period.
- Only items that will be paid for by the national fund are included in the study.
- The Oskarshamn study assumes that off-site waste storage facilities of sufficient capacity are available as required.
- The estimate is based upon the removal of the structures to a depth of one metre below grade and the use of clean construction debris (processed concrete) for fill.
- Contingencies are calculated and reported separately.
- The control rods and main circulation pump wheels have been removed during shutdown operation and are regarded as operational waste. Costs for this are not included.
- Decontamination of main systems during service operation is included. The cost of treating the resulting waste is not included.
- Outside transformers have been removed during shutdown operation. Costs for this are not included.
- Regulatory costs are included but reported separately.
- Cost for insurance are included.
- Asbestos is not included in the study as this material was prohibited before the start of construction of Oskarshamn 3.
- Contaminated soil is not included in the study, as it is not identified at the site.
- The decommissioning project has a defined starting point: one year before shutdown.

3.1.2 Decommissioning cost analysis for Barsebäck nuclear station

This study /2/ was commissioned by TLG Services, Inc. USA and is based on experience from cost estimates done in the USA. It covers the decommissioning of the Barsebäck site (units 1 and 2 including common facilities).

Premises of the study:

- Deferred dismantling, with a long service operation period until 2018.
- Common project for Barsebäck units 1 and 2 in order to gain economic benefits by sharing costs between the units and coordinating the sequence of work activities.
- The Barsebäck study assumes that off-site waste storage facilities of sufficient capacity are available as required.
- Common buildings and systems assigned to Barsebäck unit 1.
- Other costs such as emergency response fees, regulatory agency fees, corporate overhead and insurance are generally allocated on an equal basis between the two units.
- Barsebäck unit 1 as the first unit to enter dismantling incurs most of the environmental impact, site characterization and final status survey costs.
- The estimate is based upon the removal of the structures to a depth of one metre below grade and the use of clean construction debris (processed concrete) for fill.
- Contingencies are included but reported separately.
- Several cost alternatives are offered besides the main scenario (i.e. one-piece reactor removal).
- Common buildings inside the industrial fence are included.
- The cost for removal of the control rods from the vessel with the final core load is not included in the estimate. These components are regarded as operational waste.
- All operational waste is transported away and no costs for this are included.
- Regulatory costs are included.
- Cost for insurance are included.
- Asbestos is included in the study as it was allowed to be used at the time of construction of Barsebäck units 1 unit 2.
- Melting is the method for free release of material in Barsebäck.
- Identified contaminated soil is included.
- No dismantling preparations during Service Operation.
- No costs for Service Operation are included in the study.
- The decommissioning project has a defined starting point: 2 years before dismantling.

4 Qualitative comparison

The basic scope of the two studies differs in some significant areas such as:

- Political decisions have been taken to close both units in Barsebäck. This has forced Barsebäck to plan with a long service operation period (18 years) and a period of time for reestablishing the plant. Oskarshamn unit 3 is planned to have a short service operation period, less than 3 years, which is what is planned for the other Swedish plants (the Swedish model).
- Due to delayed dismantling, TLG Services did not recommend full-scope system decontamination due to the decay time at Barsebäck, and therefore did not incorporate any resulting cost impacts.
- Buildings included in the scope of the study.
- Contaminated soil identified in Barsebäck.
- Melting is the method for free release of material in Barsebäck.
- Lessons learned from Barsebäck Kraft's actual service operation period about handling cost items related to regulatory authorities, organization, security and overhead have been incorporated in the Barsebäck study.

Qualitative comparison has been done in the following areas:

- Plant boundaries.
- Programme boundaries.
- Cost calculation boundaries.
- Technical premises.

4.1 Prerequisites

4.1.1 Plant boundaries

Included buildings

Table 4-2 is a comparison between the main buildings (reactor and turbine buildings) at Oskarshamn 3 and Barsebäck 1 and Barsebäck 2 as well as the significant contaminated common buildings that are included in the Barsebäck study.

Table 4-1.

Boundary conditions	Oskarshamn study, SEP 06-055	Barsebäck study, S33-1567-002
Included buildings *(See Table 4-2)*	Plant equipment and buildings inside the unit fence are included. Some site-specific buildings are not included due to the fact that Oskarshamn 3 is a reference plant. No common facilities are included.	Common facilities/buildings for both units are included. The most significant common buildings are: – Liquid waste management building – Waste storage building (ABC-lager) – Service building Common buildings and systems assigned to Barsebäck unit 1 which have a great effect on the total amount of radioactive waste. See waste management for more information. The common buildings also influence costs allocated to project management (sub-projects), free release measurement and site restoration.

Table 4-2.

Main buildings	Oskarshamn 3	Barsebäck unit 1, unit 2
Reactor building		
Construction volume (m^3)	148,000	111,500
External dimensions (m)	60×43	33.55×46.50
Remarks	1 floor below grade and 8 floors above ground level.	2 floors below grade and 9 floors above ground level.
Turbine building		
Construction volume (m^3)	275,000	170,000
External dimensions (m)	115×55	86×53
Remarks	4 floors below grade and 7 floors above ground level.	3 floors below grade and 7 floors above ground level.
Waste Treatment building		See common facilities for Barsebäck.
Construction volume (m^3)		
External dimensions (m)	64×22	
Remarks	3 floors below grade and 3 floors above ground level.Not a common building, serves only Oskarshamn unit 3.	
Common facilities for Barsebäck unit 1 and unit 2 (Contaminated area)		
Liquid waste management building	(Contaminated equipment and areas)	
Construction volume (m^3)	31,000	
External dimensions (m)	68.7×34	
Remarks	3 floors below grade and 3 floors above ground level.Assigned to Barsebäck unit 1.	
Waste storage building (ABC storage)	(Contaminated equipment and areas)	
Construction volume (m^3)	27,800	
External dimensions (m)	29.5×79.7	
Remarks	9 floors altogether, several floors below grade.Assigned to Barsebäck unit 1.	
Service building 1	(Contaminated equipment and areas)	
Construction volume (m^3)	47,000	
External dimensions (m)	71.0×73.3	
Remarks	1 floor below grade and 2 floors above ground level. Assigned to Barsebäck unit 1.	

4.1.2 Programme boundaries

Table 4-3.

Boundary conditions	Oskarshamn study, SEP 06-055	Barsebäck study, S33-1567-002
Decommissioning strategies	Short Service Operation Period, 3 years. (The Swedish Model). – Direct dismantling is the chosen option. – No period for reestablishment needed. – Option to use own staff during shutdown and service operation and also to perform some of the planning and strategical work related to dismantling of the plant. Planning, engineering etc, for decommissioning of the site commences one year before the planned shutdown date. References are made to other studies of the shutdown and service periods, so costs related to shutdown and service operation are not included in this report.	Long period of service operation up to 2018, followed by a period of reestablishment. This is a situation that Barsebäck has been forced into by political decisions. Downsizing of own staff to a minimum: 45 people in Service Operation. – Deferred dismantling is the chosen option. – Period for reestablishment needed. – No option to use own staff for detailed planning, only for overall planning. It is assumed in the Barsebäck study that no preparations for dismantling are made during the service operation period. No cost for service operation is included in the study. The choice of a different decommissioning strategy (deferred dismantling), has an influence on the total decommissioning cost.
Project Management **(See Figures 4-1 and 4-2)**	The cost model assumes that the plant owner/operator oversees site operations and directly places contracts for dismantling activities. The plant owner has overall responsibility for relations with the authorities and the public. – The decommissioning project has a defined starting point: one year before shutdown. Most of the costs for pre-decommissioning activities will be paid by the owner. – The project management is established 3 years before the dismantling period (25–30 project members), see Figure 4-2. – During the Shutdown Operation Period, the Utility Site Organization comprises approximately 30 positions. – During the Dismantling Period, the Utility Site Organization comprises approximately 33 positions. – During the Conventional Demolition Period, the number will decrease to 11 positions.	The cost model assumes that the plant owner/operator oversees site operations and directly places contracts for dismantling activities. The plant owner has overall responsibility for relations with the authorities and the public. – The decommissioning project has a defined starting point. The project management is established 1.5 years before the Unit 1 dismantling period. For each unit, an average of 120 project members are assigned during this period, see Figure 4-2. – During the Dismantling Period, an average of 217 project members are assigned to the project management organization (for the 2-unit station), see Figure 4-2. – During the conventional Demolition Period, the average number will decrease to 70 persons (for the 2-unit station). – The size of the Utility Site Organization is period-dependent, see Figure 4-2. Due to the fact that the project organization is established 2 years before dismantling, it has an influence on the total project management costs and staffing (detailed planning, engineering and site preparation). Some programme management and support costs, particularly costs associated with the more senior positions, can be avoided by decommissioning two reactors simultaneously. As a result, the estimate is based on a “lead” unit that includes these senior positions and a “second” unit that excludes these positions.

Boundary conditions	Oskarshamn study, SEP 06-055	Barsebäck study, S33-1567-002
Radiological criteria	A characterization of the site and the surrounding environs. This includes radiation surveys of work areas, major components (including the reactor vessel and its internals), sampling of internal piping contamination levels, and of the citadel structure. This activity is not allocated to the total decommissioning cost. Decontamination of main systems during service operation is included, (DF=10). For the nuclide-specific free release, Radiation Protection 113 criteria have been used for buildings and building rubble. However, free release of radioactive material from controlled area is regulated by the SSI regulation FS 1996:2 /7/. – Limit for free release: 500 Bq/kg.	A detailed characterization of the site and surrounding environs. This includes radiation surveys of work areas, major components (including the reactor vessel and its internals), sampling of internal piping contamination levels, and of the citadel structure. This activity is allocated to the total decommissioning cost. Due to the delayed dismantling, TLG Services did not recommend full scope system decontamination due to the decay time at Barsebäck. NRC Radiological Criteria for License Termination have been used for releasing a facility for unrestricted use (industrial purpose). Total Effective Dose Equivalent (TEDE) may not exceed 0.25 milli-Sieverts per year, and residual radioactivity must have been reduced to levels that are As Low As Reasonably Achievable (ALARA). Equipment and materials were considered radioactive waste if either the internal surfaces were either known to be or potentially contaminated, or if the materials were located in an area with known or potentially contaminated surfaces. Systems are considered to be internally contaminated or potentially contaminated to the extent that material requires disposal as radioactive waste.
Waste management (See Figure 4-3)	A modular Waste Processing and Packaging Facility (WPPF) can be established in the Turbine Building. All decommissioning waste can go to off-site repositories for final disposal with no timescale or capacity restraints. Thus, there is no need for facilities on site for temporary storage of processed, packaged waste – No costs are included for transportation and final disposal (active waste). – The liquid waste management building assigned to Oskarshamn unit 1 is used during dismantling of active systems at Oskarshamn unit 3.	Construction of temporary facilities and/or modification of existing facilities to support dismantling activities. This may include establishing centralized processing areas to facilitate equipment removal and component preparation for off-site disposal. – No costs are included for transportation and final disposal (active waste). The included common buildings have a great effect on the total amount of the radioactive waste (45%) see Figure 4-3. See also contaminated soil and hazardous waste. The liquid waste managemnet building assigned to Barsebäck unit 1 is not used during dismantling of active systems at Barsebäck unit 1 and unit 2. Instead, a local water collecting system is constructed and put into operation.
Decommissioning schedule	– Dismantling period 5 years, includes free release measurements. – Conventional demolition period 2 years. The critical path of the project is highly concentrated to the activities in the Containment, the Reactor Building and the Turbine Building.	– Dismantling period 5 years, includes free release measurements. – Conventional demolition period 2 years. The critical path of the project is highly concentrated to the activities in the Containment, the Reactor Building, Major Components and the final status survey.
Contaminated soil	Contaminated soil has not been identified at Oskarshamn unit 3 and is therefore not included in the study.	Contaminated soil is included in the study, and identifying and adjusting for potentially contaminated areas was a precondition for the study. Two areas were identified as potentially contaminated: – The liquid waste management building (overfilling of tank cells) – The storage area for the heat exchanger (MÖH) This affects the total amount of radioactive waste. See waste management for more information.
Hazardous waste	No hazardous waste has been evaluated in the study. No asbestos is assumed to be present in Oskarshamn unit 3 , as it was built and taken in operation in 1985. Asbestos was prohibited in Sweden in 1982.	Hazardous waste such as asbestos has been evaluated in the study. Barsebäck unit 1 was built and taken in operation in 1975 and unit 2 in 1977. Asbestos was prohibited in Sweden in 1982.

Decommissioning strategies

Different strategies (direct or deferred dismantling) have an influence on the total decommissioning cost. The very short Service Operation period without any period for reestablishing plant equipment is much more efficient than the strategies that Barsebäck has been forced into by the political decisions to close the plant. All other BWRs will follow the strategies for Oskarshamn 3, the Swedish Model.

The longer the service operation period is, the longer the reestablishment period will be.

Furthermore, the longer the service operation period is, the less possible it is for staff with site-specific experience to participate in the decommissioning work due to retirement. The longer service operation period also creates a greater need for contractors.

Project Management

Project management and support staff in both studies are organized by function throughout each of the decommissioning periods, see Figures 4-1, 4-2 and 4-3.

Reestablishment/Decommissioning preparation period

As a result of a longer service operation period, there is a need for a reestablishment period at the Barsebäck site, with activities for preparing Barsebäck unit 1 for dismantling (see Figure 4-2).

The decommissioning management organization is established 1.5 years before the dismantling period (with an average of 120 project members per unit). Since Barsebäck unit 2 planning and preparation follows Barsebäck unit 1 planning, the total duration of planning is approximately 2.5 years. It includes engineering, planning, a detailed site characterization and preparations for dismantling. Final planning for activities and the writing of activity specifications and detailed procedures are also initiated at this time.

Dismantling period

For Barsebäck units 1 and 2, the average number of project members assigned to the decommissioning management organization during the dismantling phase of the project is approximately 217. Dismantling phase duration is 4.5 years.

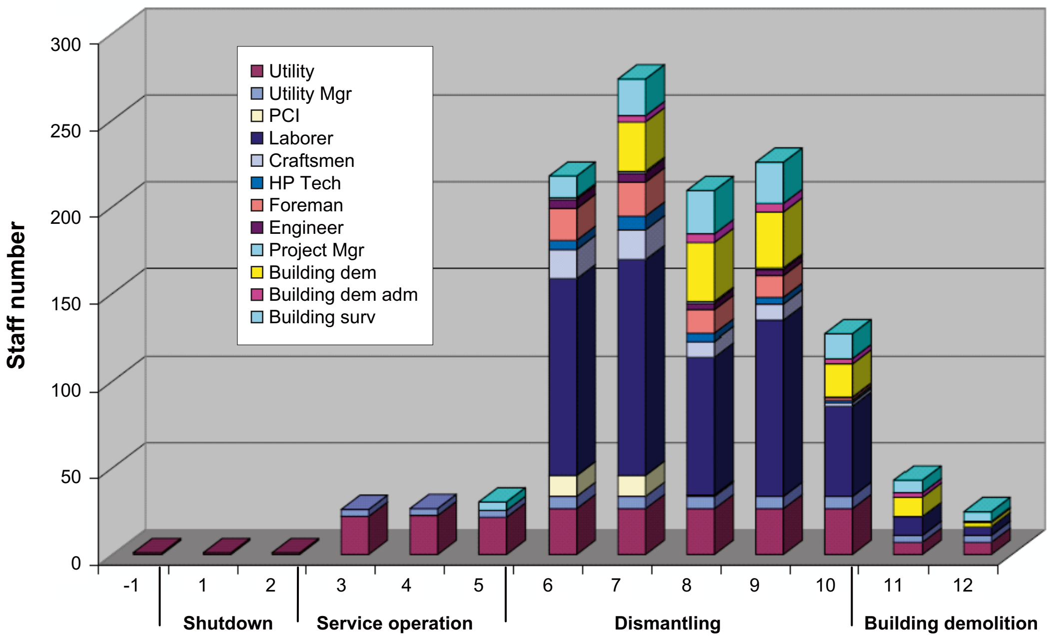


Figure 4-1. *Oskarshamn 3.*

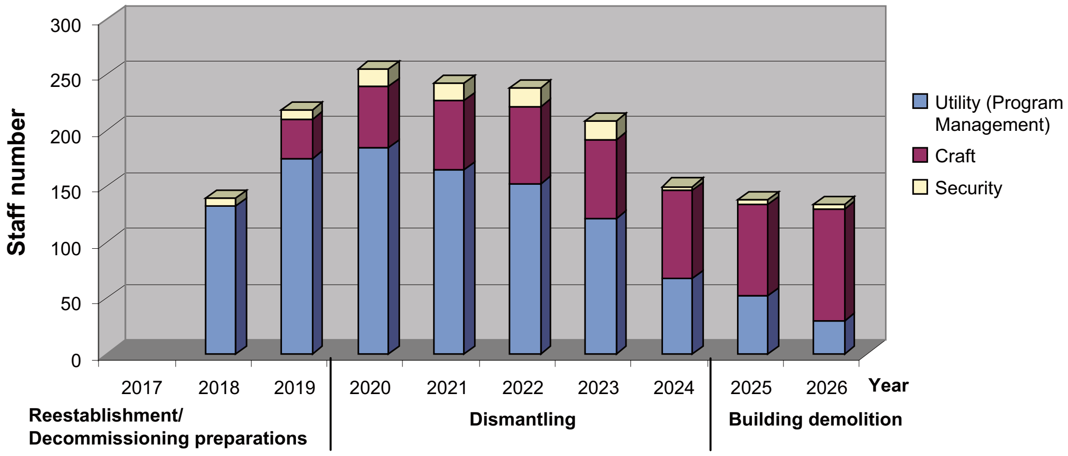


Figure 4-2. Barsebäck 1. Management organization for Barsebäck unit 1. Barsebäck unit 2's management organization is not included.

Building demolition period

For Barsebäck units 1 and 2, the average number of project members assigned to the decommissioning management organization during the demolition phase of the project is approximately 70 persons. Demolition phase duration is 2 years.

Overall decommissioning management organization

For Barsebäck units 1 and 2, the average number of project members assigned to the decommissioning management organization for the entire project is approximately 190 project members. Total project duration is 8.5 years.

Radiological criteria

There are no general regulations regarding limits for free release for decommissioning waste in Sweden today. However, free release of radioactive material from controlled areas is regulated by the SSI regulation FS 1996:2 /7/, where operational waste is dealt with. Under these regulations, material with a maximum specific activity of 500 Bq/kg can be free released.

Waste Management

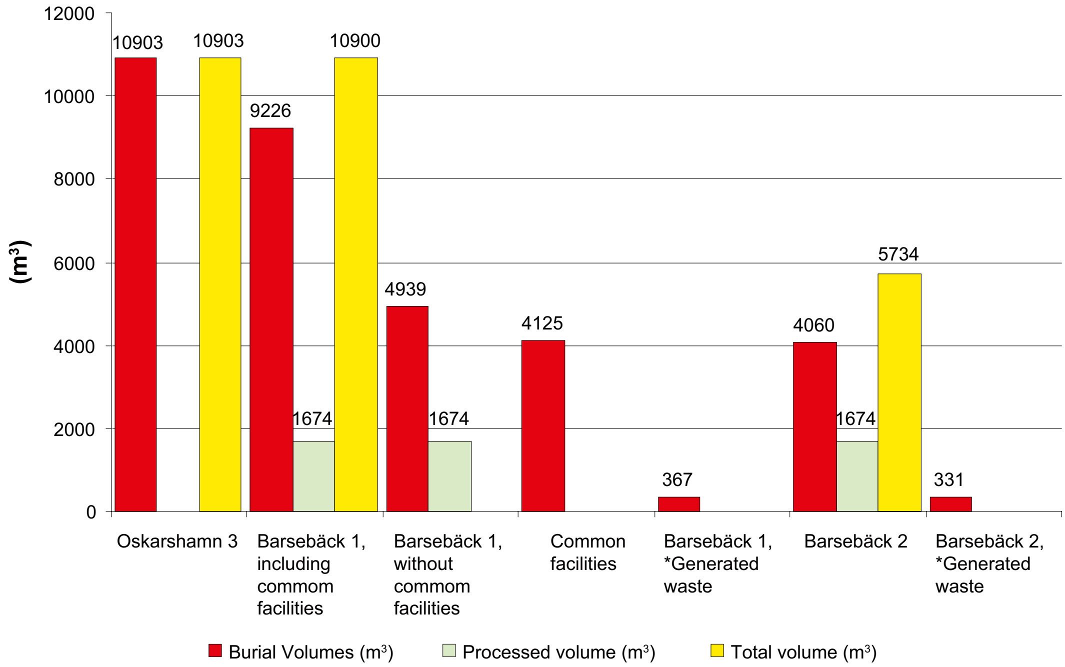
There is a difference between the two studies Oskarshamn 3 and Barsebäck related to the amount of total waste volume and waste packages generated. Figure 4-3 illustrates where the decommissioning waste is generated during the decommissioning of Oskarshamn unit 3, Barsebäck unit 1 and Barsebäck unit 2.

- = Burial volumes (m^3), decommissioning waste for final disposal in SFR*/SFL*.
- = Processed volume (m^3), low contaminated components that have been designated for metal melt processing.
- = Total volume (m^3), includes burial volumes and processed volumes.

* **SFR –** Final repository for short-lived low- and intermediate-level waste.

* **SFL** – Final repository for long-lived low- and intermediate-level waste.

The conclusion from Figure 4-3 is that nearly 45% of Barsebäck unit 1's total decommissioning waste is generated by the included common facilities and contaminated soil.



*Note: Waste generated during decommissioning for Barsebäck unit 1 (367 m^3) and Barsebäck unit 2 (331 m^3). The waste includes resins and filters associated with radioactive water processing, dry waste generated as a result of contamination control measures (plastic, paper, tape, etc) and disposal of contaminated decommissioning equipment.

Figure 4-3.

4.1.3 Cost calculation boundaries

Performance of decommissioning cost calculations

The Oskarshamn 3 study, the work programme and the resulting cash flows are based on the assumption that cash is available on demand. No attempt has been made to smooth cash flows throughout the project, see Figure 4-4.

The Barsebäck study was performed to give the Barsebäck NPP an overview of costs for the decommissioning of the Barsebäck site per year and period, see Figure 4-5.

Salaries

The salary levels for different categories have been compared and have been found to be the same for both studies. Both studies have been based on typical Swedish rates (2005) for the different staff categories. For the preparation phase, the Barsebäck estimate assumes that the project management staff is supplemented by additional contracted engineers. The costs for the contracted engineers include overhead, profit, and travel and living expenses

Contingency

Contingency costs are for unforeseen, uncertain and unpredictable conditions typically encountered in decommissioning. In general, all contingency costs are spent as the project progresses, as these unforeseen events occur throughout the project.

The cost elements in a decommissioning project cost estimate are based on ideal conditions where activities are performed within the defined project scope, without delays, interruptions, inclement weather, tool or equipment breakdown, craft labour strikes, waste shipment problems, or burial facility waste acceptance criteria changes, changes in the anticipated plant shutdown conditions, etc. However, as with any major project, events occur that are not accounted for in the base estimate. Therefore, a contingency factor is applied.

Table 4-4.

Boundary conditions	Oskarshamn study, SEP 06-055	Barsebäck study, S33-1567-002
Scope and premises	Covers costs for decommissioning to the point where the plant is free from nuclear regulatory requirements and the site is restored.	Covers costs for decommissioning from project start to the point where the plant is free from nuclear regulatory requirements and the site is restored. Common buildings and systems assigned to Barsebäck unit 1.
Performance of decommissioning cost calculations	The Oskarshamn 3 study was performed using studies done for specific parts of decommissioning, building demolition and system dismantling and updated when new knowledge is available. All work except vessel and internals removal activities is performed during an 8-hour workday, 5 days per week with no overtime. Reactor and internals removal activities are performed by using separate crews for different activities working on different shifts. Costs have been calculated as cash costs at the 2005 cost level.	The Barsebäck study was performed using the DECCER model, as are the estimates for a majority of the commercial reactors in North America. The content and format of the estimates also comply with the guidelines proposed by the NRC. The DECCER model is updated by the outcome of other decommissioning projects. An activity duration critical path is used to determine the total decommissioning programme schedule. The programme schedule is used to determine the period-dependent costs for programme management, administration, field engineering, equipment rental, quality assurance, and security. Common project for Barsebäck units 1 unit 2 in order to gain economic benefits by sharing costs between the units and coordinating the sequence of work activities. All work except vessel and internals removal activities is performed during an 8-hour workday, 5 days per week with no overtime. Reactor and internals removal activities are performed using separate crews for different activities working on different shifts. Costs have been calculated as cash costs at the 2005 cost level.
Salaries	The cost estimates have been based on typical Swedish rates (2005) for different staff categories. 10% overhead cost and 10% profit is included in RPV and Internal project hourly costs.	The cost estimates have been based on typical Swedish rates (2005) for different staff categories. 10% overhead cost and profit is included in contractors' hourly costs.
Equipment for decommissioning	All equipment costs are presented on the basis of the purchase price in the country of origin converted into SEK at the prevailing rate. Equipment is purchased by the contractors.	All equipment costs are presented on the basis of the purchase price in the country of origin converted into SEK at the prevailing rate. Equipment is purchased or rented directly by the contractors.
Contingency	The total contingency is approximately SEK 100 M,which results in a global contingency factor for the overall project of approximately 7%.	The total contingency is approximately SEK 337 M, which results in a contingency factor for the overall project of approximately 18%.
Types of cost estimate for the study	The Oskarshamn 3 study is based on a budgetary estimate – accuracy –15% to +30%,	The Barsebäck study is based on a budgetary estimate – accuracy –15% to +30%.

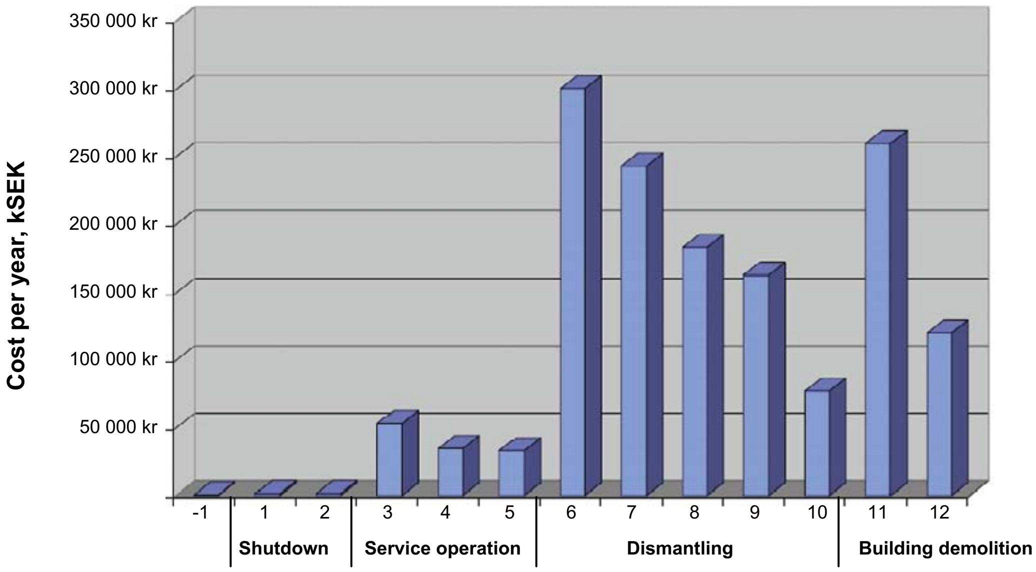


Figure 4-4. Oskarshamn 3.

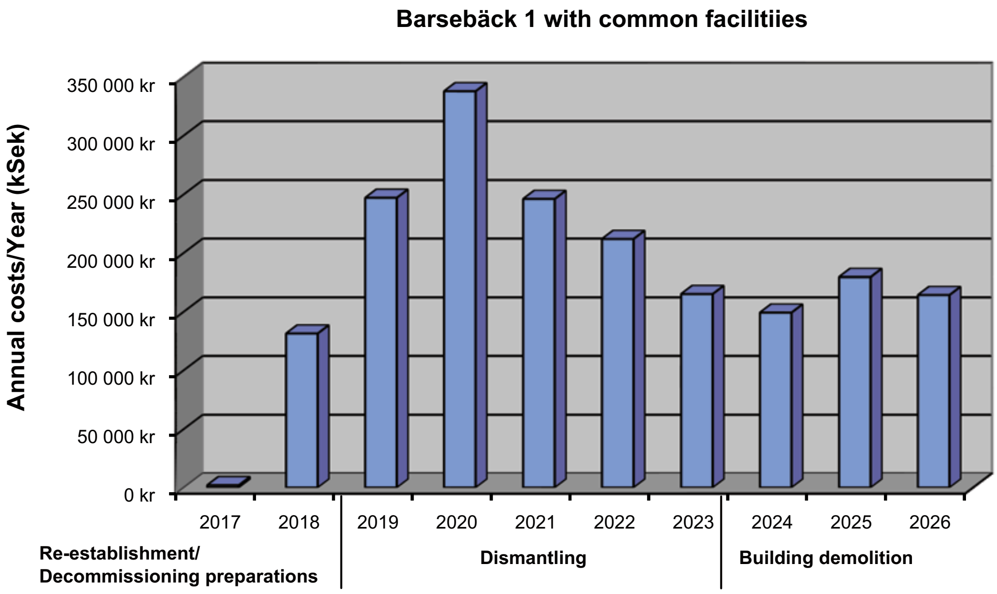


Figure 4-5. Barsebäck 1. Annual costs/year for Barsebäck unit 1. Barsebäck unit 2 is not included.

The most technologically challenging task in decommissioning a commercial nuclear station will be the disposition of the reactor vessel and internal components, which have become highly radioactive after a lifetime of exposure to radiation produced in the core. The disposition of these highly radioactive components forms the basis for the critical path (schedule) for decommissioning operations. Cost and schedule are interdependent and any deviation in schedule has a significant impact on the cost for performing a specific activity.

The contingency values used in the Barsebäck study are as follows, see Table 4-5.

The contingencies have been estimated in percentage values typically used in US estimates. These contingencies are applied on a line-item basis.

Table 4-5.

Barsebäck study	Contingency values in percent
Decontamination	50%
Contaminated Component Removal	25%
Contaminated Component Packaging	10%
Reactor Segmentation	75%
Reactor Waste Packaging	25%
Non-Radioactive Component Removal	15%
Heavy Equipment and Tooling	15%
Supplies	25%
Engineering	15%
Energy	15%
Characterization and Termination Surveys	30%
Taxes and Fees	10%
Insurance	10%
Staffing	15%
Waste Processing (metal melt)	15%

The overall contingency, when applied to the appropriate components of the estimate on a line item basis, results in an average of approximately 18.6%.

The contingency values used in the Oskarshamn 3 study are as follows, see Table 4-6.

The contingencies have been estimated in percentage values for individual cost items on a lower level in the WBS. Then the resulting contingency costs are summed up to the higher level. The percentage is then recalculated considering the cost contribution of each contingency. A condensed version showing the higher WBS level is presented in Table 4-6.

The overall contingency, when applied to the appropriate components of the estimate, results in an average of approximately 7%.

Table 4-6.

Oskarshamn 3 study	Contingency values in percent
Shutdown Operation	4%
Nuclear Dismantling and Demolition	9%
– Plant operation during decommissioning	6%
– Purchasers' project management, administration and technical support	10%
– Dismantling and demolition activities	9%
– Waste management and disposal	11%
Conventional demolition	5%
– Plant operation during decommissioning	3%
– Purchasers' project management, administration and technical support	10%
– Dismantling and demolition activities	5%
– Waste management and disposal	5%
– Site restoration	5%

Types of cost estimates

Three types of cost estimates are normally used and are defined as follows:

1. Order of magnitude estimate – accuracy –30% to +50%
2. Budgetary estimate – accuracy –15% to +30%
3. Definitive estimate – accuracy –5% to +15%

These types of estimates are used depending on how far off you are from decommissioning – the closer you get, the more accurate and fine-tuned the estimate is.

In developing a funding basis for a project, the estimator includes sufficient margin (or contingency) to account for a possible budget overrun.

Both studies have been carried out as a budgetary cost estimate with an accuracy of –15% to +30%.

4.1.4 Technical prerequisites

Table 4-7.

Boundary conditions	Oskarshamn study, SEP 06-055	Barsebäck study, S33-1567-002
Required technical prerequisites	A larger number of prerequisites are specified in the Oskarshamn 3 study, and some of these prerequisites are planned to be paid out of the operational budget.	Costs for prerequisites are included.

Table 4-8. Handling of reactor pressure vessel and internals.

Boundary conditions	Oskarshamn study, SEP 06-055	Barsebäck study, S33-1567-002
Reactor vessel and internals	Segmentation and packed in BFA containers.	Segmentation and packed in BFA containers. Segmenting of the reactor vessel and internals will require the use of special equipment. The cost of procuring that equipment is assumed to be shared on an equal basis between the two units. In addition, the decommissioning project will be scheduled such that Barsebäck unit 2's reactor internals and vessel are segmented immediately after Unit 1's reactor segmentation.

Table 4-9. Waste transport and disposal.

Boundary conditions	Oskarshamn study, SEP 06-055	Barsebäck study, S33-1567-002
Waste transportation and disposal for active waste	– Only to a an on-site disposal location. Costs for transportation and disposal of active waste are not included. – The Oskarshamn 3 study assumes that off-site waste storage facilities of sufficient capacity are available as required and that description of all types of waste packages has been taken care of by SKB.	– Only to a storage place at site, further costs for transportation and disposal is not included. – The Barsebäck study assumes that off-site waste storage facilities of sufficient capacity are available as required and that description of all types of waste packages has been taken care of by SKB.
Waste transportation and disposal for non-active waste	Costs for transportation and disposal of non-active waste are included.	Costs for transportation and disposal of non-active waste are included.

Table 4-10. Decontamination for free release of material.

Boundary conditions	Oskarshamn study, SEP 06-055	Barsebäck study, S33-1567-002
Free release of material	Free release of radioactive material from controlled area is regulated by the SSI regulation FS 1996:2 /7/. Under these regulations, material with a maximum specific activity of 500 Bq/kg (of which maximum 100 Bq/kg α) can be free released. In the Oskarshamn 3 study the following condition has been used for the decommissioning waste: – Limit for free release: 500 Bq/kg.	NRC Radiological Criteria for free release of radioactive material have been used.
Melting	No equipment for melting has been evaluated.	Potential equipment for melting outside the plant has been evaluated in the study and was also a pre-condition for the study. Components that have been designated for metal melt processing at the Studsvik facility include the moisture separator-reheater, the main condenser, high-pressure turbine generator rotor, and the feed water heaters.

4.2 Summary of qualitative comparison

The qualitative comparison between the Oskarshamn 3 study and the Barsebäck study shows that there are differences in premises and boundary conditions set up for the performance of the studies.

These differences in premises and boundary conditions will affect the final decommissioning costs significantly. It is therefore important that these boundary conditions are specified stringently before new decommissioning cost calculations are done.

An unanswered question from the qualitative comparison is the lack of requirements for the final release of land, groundwater and buildings in Sweden. Conditions and requirements from the nuclear industry in the US have been used in the Barsebäck study. These requirements have been developed in a framework by the US nuclear industry and the NRC.

The Oskarshamn study is based on the framework used up to now in the Swedish nuclear power industry. However, a complete set of requirements for free release of a site or an NPP does not exist. A new framework of requirements should be developed in a joint effort between the Swedish nuclear power industry and the regulatory authorities.

The impacts of the differences have been used in Chapter 5 to explain why there are differences in the OECD/NEA structure.

Only the differences in the boundary conditions that will have the greatest impact on decommissioning costs and estimated decommissioning waste are discussed in the following chapter.

4.2.1 Plant boundaries

The following differences in plant boundaries affect the total estimated decommissioning cost and the total estimated waste quantity:

- **Included buildings:** The Barsebäck study includes all common facilities/buildings, which are assigned to Barsebäck unit 1.
- **Included buildings:** As Oskarshamn 3 is a reference plant, no common facilities/buildings are included. Facilities and buildings that are located inside the fence and that only serve the Oskarshamn 3 unit are included.

These differences in plant boundaries have a great effect on the total amount of radioactive waste. The common buildings also affect the cost allocated to project management (sub-projects), free release measurement and site restoration.

However, it is important to bear in mind that these site-specific costs must in some way be incorporated as appropriate when the total site decommissioning cost calculations are done.

4.2.2 Programme boundaries

The following differences in programme boundaries affect the total estimated decommissioning cost and the total estimated waste quantity:

- **Decommissioning strategies:** In the Barsebäck study deferred dismantling is the chosen option.
- **Decommissioning strategies:** In the Oskarshamn 3 study direct dismantling is the chosen option.
- **Project management:** In the Barsebäck study, the project organization is established ~2 years before dismantling (~120 project members), which affects total project management costs and staffing.
- **Project management:** In the Oskarshamn 3 study, the project organization is established 3 years before dismantling (25–30 project members), which affects total project management costs and staffing.
- **Waste Management:** The Barsebäck study includes common contaminated buildings, which affects waste management as well as total project management costs and staffing.
- **Waste Management:** The Oskarshamn 3 study does not include common contaminated buildings, which affects waste management as well as total project management costs and staffing.
- **Waste Management**: The liquid waste management building assigned to Barsebäck unit 1 is not used during dismantling of active systems at Barsebäck units 1 and 2. Instead, a local water collecting system is constructed and put into operation (to reduce dependence on buildings and systems during dismantling of active systems).
- **Waste Management**: The liquid waste management building assigned to Oskarshamn unit 1 is used during dismantling of active systems at Oskarshamn unit 3 (dependencies between other systems and buildings).
- **Contaminated soil:** The Barsebäck study includes contaminated soil, which affects waste management.

These differences in programme boundaries affect total project management costs and staffing. Contaminated soil affects the total amount of radioactive waste, which affects waste management.

A decommissioning project of this size must be aware of all potential risks and minimize all dependencies between the systems and buildings.

4.2.3 Cost calculation boundaries

The following differences in cost calculation boundaries affect on the total estimated decommissioning cost.

- **Scope and premises:** The Barsebäck study covers total project costs for decommissioning from project start (~2 years before dismantling take place with ~223 project members on site) to the point where the plant is free from nuclear regulatory requirements and the site is restored.
- **Scope and premises:** The Oskarshamn 3 study covers total project costs for decommissioning from project start (3 years before dismantling take place with 25–30 project members on site) to the point where the plant is free from nuclear regulatory requirements and the site is restored.
- **Scope and premises:** The common project for Barsebäck units 1 and 2 gains economic benefits by sharing costs between the units and coordinating the sequence of work activities.

- **Scope and premises:** Common buildings and systems on the Barsebäck site are assigned to Barsebäck unit 1, which affects the total decommissioning cost for Barsebäck unit1 compared with Barsebäck unit 2.
- **Equipment for decommissioning:** In the Barsebäck study, contractors purchase or rent the equipment for dismantling and demolition directly, which affects the decommissioning cost.
- **Equipment for decommissioning:** In the Oskarshamn 3 study, contractors purchase the equipment for dismantling and demolition, which affects the decommissioning cost.
- **Performance of decommissioning cost calculations: The** Oskarshamn 3 study was performed using studies done for specific parts of decommissioning, building demolition and system dismantling, and is updated when new knowledge is available.
- **Performance of decommissioning cost calculations**: The Barsebäck study was performed using the DECCER cost calculation model, which is used for the cost estimates for most of the commercial reactors in North America. The content and format of the estimates comply with the guidelines proposed by the NRC. The DECCER model is updated by experience from other completed decommissioning projects.

These differences in cost calculation boundaries affect the total decommissioning cost, especially for a common project with 2 simultaneous reactor units undergoing dismantling at the same time and also at the same site.

It is important that the costs for procurement of dismantling and demolition equipment are calculated separately when the decommissioning cost calculations are done.

4.2.4 Technical prerequisites

The following differences in technical prerequisites affect the total estimated decommissioning cost and the total estimated waste quantity:

- **Required technical prerequisites**: A larger number of prerequisites are specified in the Oskarshamn 3 study, and some of these prerequisites are planned to be paid out of the operational budget.
- **Required technical prerequisites**: Costs for prerequisites are included in the Barsebäck study.
- **Melting:** Potential equipment for melting has been evaluated in the Barsebäck study and was also a pre-condition for the study.

These differences in technical prerequisites affect the total decommissioning cost. Melting of low contaminated material is an option for free release of material. A cost-benefit analysis should be done to determine when it is cost effective to send material for melting instead of final disposal.

5 Quantitative comparison

Various international studies of decommissioning project costs have shown that there are substantial variations in cost estimates for individual installations. Studies attempting to understand the reasons for these differences have been somewhat hampered by the fact that different types of costing methods are used, with different data requirements. Although some uncertainty is inevitable in any costing method, an understanding of the costing methods used in particular projects is useful to avoid key uncertainties. Difficulties of understanding can be encountered and invalid conclusions drawn in making cost comparisons without regard to the context in which the various cost estimates were made.

The European Commission (EC), the International Atomic Energy Agency (IAEA), and the OECD/Nuclear Energy Agency (NEA) have ongoing activities addressing various aspects of decommissioning and decommissioning costs. Based on these activities and common objectives, and on the advantage of having standardized cost items, they agreed to prepare a common list of cost items and related cost-item definitions for decommissioning projects /4/.

5.1 Comparison according to OECD/NEA structure

The quantitative analysis in this report has been done by a comparison of figures from the Oskarshamn 3 /1/ and Barsebäck studies /2/. Both studies were originally carried out in a WBS structure (Work Breakdown Structure), and the results were then transferred to the OECD/NEA decommissioning cost structure /4/, see Table 5-1.

The qualitative comparison in scope and boundary condition contains several identified differences in pre-conditions and boundary conditions that affect the total decommissioning costs. These differences are evaluated and explained in a quantitative way in the OECD/NEA structure.

Table 5-1.

		Oskarshamn 3		Barsebäck 1 with common buildings		Barsebäck 2	
Section	**Activity (description)**	**Total cost (SEK ’000)**	**Material weight (kg)**	**Total cost (SEK ’000)**	**Material weight (kg)**	**Total cost (SEK ’000)**	**Material weight (kg)**
01	Pre-decomissioning activities	3,000	–	120,675	–	50,808	–
02	Facility shutdown activities	36,500	–	0	–	0	–
03	Procurement of general equipment and material	0	–	107,366	–	93,370	–
04	Dismantling activities	582,214	11,584,000	317,393	11,966,120	250,770	5,367,188
05	Waste processing storage and disposal	162,793	9,089	134,017	301,590	115,671	294,554
06	Site security surveilance and maintenance	104,602	–	121,113	–	86,607	–
07	Site restoration cleanup and landscaping	360,579	309,459	298,534	–	212,786	–
08	Project management engineering and site support	215,835	–	504,568	–	425,831	–
09	Research and development	1,548	–	0	–	0	–
10	Fuel and nuclear material	n/a	n/a	n/a	n/a	n/a	n/a
11	Other costs	77,000	–	230,616	–	192,712	–
	Total	**1,544,071**	**11,902,548**	**1,833,981**	**12,267,709**	**1,428,553**	**5,661,742**

Figures 5-1, 5-2 and 5-3 indicates the relative importance of the different sections for Oskarshamn 3, Barsebäck 1 including common buildings and Barsebäck 2 respektively.

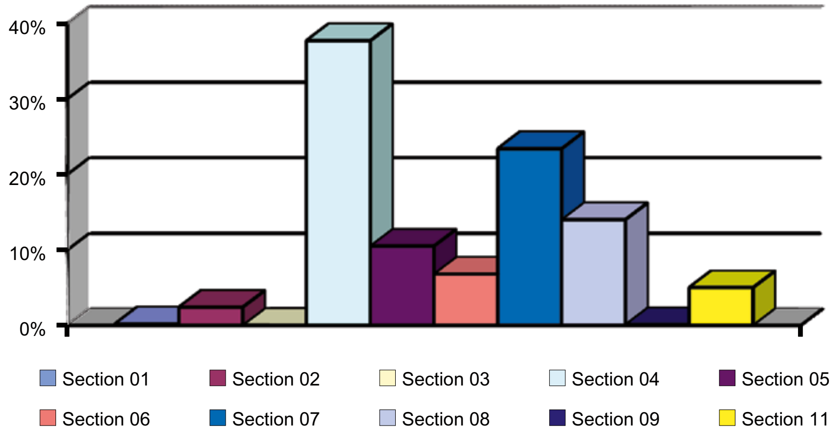


Figure 5-1. *Oskarshamn 3.*

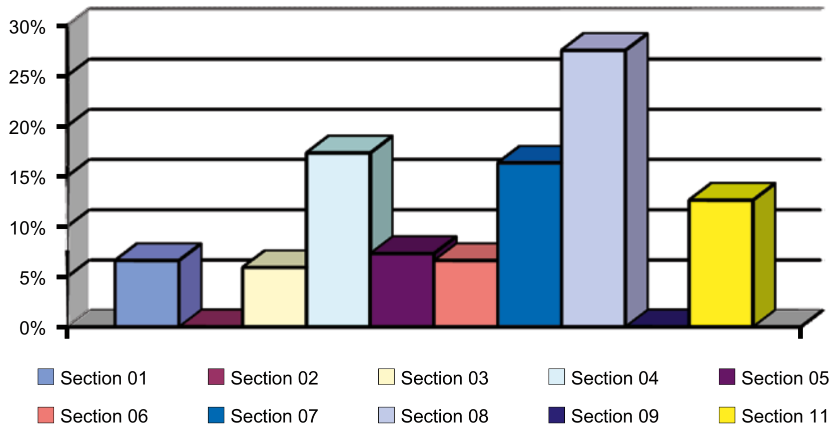


Figure 5-2. *Barsebäck 1.*

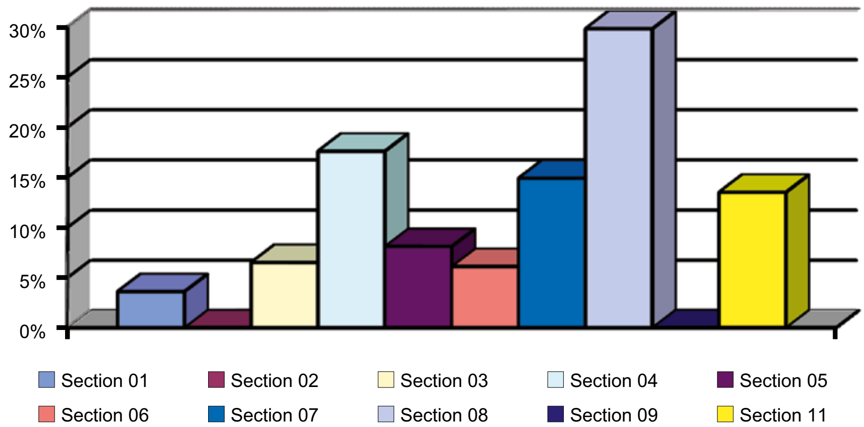


Figure 5-3. *Barsebäck 2.*

5.1.1 Section 01. Pre-decommissioning activities

Section 01 includes all activities carried out in preparation for the actual decommissioning.

It is subdivided into following 5 groups/items:

Table 5-2.

	O3	B1	B2
Decommissioning planning	X	X	X
Authorization	X	X	X
Radiological surveys for planning and licensing	–	–	–
Hazardous-material surveys and analysis	–	–	–
Prime contracting selection	–	–	–

X = included in the studies, – = not covered, Θ = included in other cost groups/items or sections.

Due to differences in program boundaries (4.2.2), different decommissioning strategies and project management, there will be a great difference in cost and included "pre-decommissioning activities".

Costs in the Oskarshamn 3 study related to activities involved in planning and preparations for shutdown operation and/or service operation are paid from the operational budget set aside by the power plant owner. Most of the pre-decommissioning activities are carried out by the plant staff (e.g. detailed planning, engineering) and are therefore excluded from costs related to decommissioning.

Differences in cost calculation of Section 01. Pre-decommissioning activities:

- In the Oskarshamn 3 study, the project management organization is established 3 years before dismantling take place (25–30 project members).
- In the Barsebäck study, the project management organization is established 2 years before dismantling take place (~120 project members). The cost calculation includes pre-decommissioning activities (e.g. detailed planning, engineering).
- In the Oskarshamn 3 study, costs related to activities involved with planning and preparation of shutdown operation and/or service operation are paid from the operational budget set aside by the power plant owner. Most of the pre-decommissioning activities) are excluded from costs related to dismantling.

Furthermore, in the Barsebäck study, the decommissioning management organization for each unit is established 1½ years before dismantling. *For a single unit*, the average number of project members assigned during the preparation phase is 120. This decommissioning management organization is supplemented with approximately 21 contract personnel to support the preparation of plans, specifications, and procedures. This affects the total number of staff in the decommissioning management organization, which leads to higher costs for project management, overheads, energy and water costs.

5.1.2 Section 02. Facility shutdown activities

Section 02 includes activities related to shutdown operation of the facility.

It is subdivided into following 13 groups:

Table 5-3.

	O3	B1	B2
Plant shutdown and inspection	–	–	–
Removal of fuel and/or nuclear-fuel materials	–	–	–
Drainage and drying or blow down of all systems not in operation	–	–	–
Sampling for radiological inventory characterization after plant shutdown, defuelling and drainage and drying or blow down of systems	–	–	–
Removal of system fluids (water, oils, etc)	–	–	–
Removal of special system fluids (D2O, sodium, etc)	–	–	–
Decontamination of systems for dose reduction	X	–	–
Removal of waste from decontamination	–	–	–
Removal of combustible material	–	–	–
Removal of spent resins	–	–	–
Removal of other waste from facility operations	–	–	–
Isolation of power equipment	–	–	–
Asset recovery: Resale/transfer of facility equipment and components as well as surplus inventory to other licensed (contaminated) and unlicensed (non-contaminated) facilities	–	–	–

X = included in the studies, – = not covered, ϴ = included in other cost groups/items or sections.

Due to differences in programme boundaries (4.1.2), decommissioning strategies and radiological criteria, there will be a difference in cost and included "Facility shutdown activities".

TLG Services has not recommended that a full-scope system decontamination should be performed, as the decay time is so long (deferred dismantling, due to the political decision to shut down the plant). The Oskarshamn 3 study includes full-scope system decontamination (FSD) and object decontamination for dose reduction (the Swedish Model).

As for both the Oskarshamn 3 study and the Barsebäck study, given the pre-conditions and the boundary conditions, most of the activities are performed during the shutdown and/or service operation period and are therefore not included in either of the studies. Examples of activities:

- Removal of fuel and/or other nuclear fuel materials.
- Drainage and collection of fuel oils, lubricating oils, and transformer oils for recycle and/or sale.
- Drainage and collection of acids, caustics, and other chemical stores for recycle and/or sale.
- Removal of furniture, tools, mobile equipment such as forklifts, trucks and other items of personal property at no cost or credit to the decommissioning project. Disposition may include relocation to other generating facilities.

5.1.3 Section 03. Procurement of general equipment and material

Section 03 includes activities related to the purchasing of general equipment and materials at site level.

It is subdivided into the following 4 groups/items:

Procurement of special-purpose or other specific equipment is included in the different cost groups/items.

Table 5-4.

	O3	B1	B2
General site dismantling equipment	ϴ	X	X
Equipment for personnel/tooling decontamination	–	–	–
Radiation protection and health physics equipment	ϴ	X	X
Security and maintenance equipment for long-term storage	–	–	–

X = included in the studies, – = not covered, ϴ = included in other cost groups/items or sections.

Due to differences in cost calculation boundaries (Section 4.2.3, Equipment for decommissioning) there will be a great difference in cost and included groups in “Procurement of general equipment and material”.

The costs specified for procurement and general equipment are more detailed in the Barsebäck study. In the Oskarshamn 3 study, costs for general equipment and material are included and estimated in contractors’ fees in section 04 “Dismantling activities”. A higher value is estimated for the Barsebäck study, based on US experience.

5.1.4 Section 04. Dismantling activities

Section 04 includes activities related to the different actual dismantling operations. Depending on the selected option, dismantling activities and related cost items may differ as a result of a dormancy period or other “standard” or specific decommissioning stages.

It is subdivided into the following 24 groups/items:

Table 5-5.

	O3	B1	B2
Decontamination of areas and equipment in all buildings to facilitate dismantling	ϴ	X	X
Drainage of spent-fuel pool and decontamination of linings	ϴ	ϴ	ϴ
Preparation for dormancy	–	–	–
Dismantling and transfer of contaminated equipment and material to containment structure for long-term storage	–	–	–
Sampling for radiological inventory characterization in the installations after zoning	–	–	–
Site reconfiguration, isolation and securing of structures	X	X	X
Facility (controlled area) hardening, isolation or entombment	–	–	–
Radiological inventory categorization for decommissioning and decontamination	X	X	X
Preparation of temporary waste storage area	–	–	–
Removal of fuel-handling equipment	–	–	–
Design, procurement, and testing of special tooling/equipment for remote dismantling	ϴ	X	X
Dismantling operations on reactor vessel and internals	X	X	X
Removal of primary and auxiliary systems	X	X	X
Removal of biological/thermal shield	X	ϴ	ϴ
Removal of other material and equipment from containment structure and all other facilities, or removal of entire contaminated facilities	ϴ	X	X
Removal and disposal of asbestos	–	X	X
Removal of pool linings	ϴ	ϴ	ϴ
Building decontamination	X	X	X
Environmental cleanup	–	X	–
Final radioactivity survey	ϴ	X	X
Radioactive material characterization	–	–	–
Decontamination for recycling and reuse	–	–	–
Personnel training	–	–	–
Asset recovery: Sale/transfer of metal or materials and salvaged equipment or components for recycle or reuse	–	–	–

X = included in the studies, – = not covered, ϴ = included in other cost groups/items or sections.

Due to differences in how costs have been transferred from the different studies’ Work Breakdown Structure (WBS) to the OECD/NEA cost structure, it will be difficult to make a direct comparison between section 04 “Dismantling activities” in the different studies.

In section 04 “Dismantling activities” in the Oskarshamn 3 study, there are cost groups/items included from other sections (sections 06 “Site security, surveillance and maintenance”, 08 “Project management, engineering and site support” and 11 “Other costs”). The Barsebäck study conforms more closely to the OECD/NEA structure.

As for both the Oskarshamn 3 study and the Barsebäck study, given the pre-conditions and the boundary conditions, most of the cost groups/items in this section 04 "Dismantling activities" are calculated and estimated.

Differences in cost calculation for Section 04. Dismantling activities:

- In the Oskarshamn 3 study: Section 04 "Dismantling activities" is calculated for the dismantling period (≈ 5 years).
- In the Barsebäck study: Section 04 "Dismantling activities" is calculated for the preparation, reestablishment and dismantling period (≈ 7 years). Includes activities related principally to decontamination or removal of radioactive materials.

Comparison of dismantling activities during the dismantling period for the Barsebäck study and the Oskarshamn 3 study

The aim is to see if the calculations are performed differently and how this could affect the usefulness of such detailed comparisons.

The Barsebäck and Oskarshamn 3 studies include detailed calculations of dismantling activities.

A comparison has been made for three different dismantling activities in Table 5-6 (heat exchanger, valve and pipe) between the Oskarshamn 3 and Barsebäck studies.

Table 5-6.

Removal of contaminated valves > 355.6 to 508 mm
Removal of a contaminated heat exchanger < 1,359.3 kg
Removal of a contaminated pipe > 355.6 to 508 mm, diameter 0.3 m

The result of the comparison between the cost calculation models shows that more or less the same working procedures are included in the calculation of the dismantling activities.

5.1.5 Section 05. Waste processing, storage and disposal

Section 05 includes a large number of activities aiming at preparing the dismantled components either for final disposal as radioactive waste or for release for restricted or unrestricted recycle or reuse.

It is subdivided into 16 groups/items shown in Table 5-7.

Due to differences in boundaries (included buildings, contaminated soil and melting) and how costs have been transferred from the different studies' Work Breakdown Structure (WBS) to the OECD/NEA cost structure, it will be difficult to make a direct comparison between section 05 "Waste processing, storage and disposal".

In section 05 "Waste processing, storage and disposal" in the Oskarshamn 3 study, there are cost groups/items included from other sections (sections 08 "Project management, engineering and site support" and 11 "Other costs"). In the Barsebäck study, costs for transportation of non-radioactive decommissioning waste are included in section 07, Demolition of the structure. The Barsebäck study generally conforms more closely to the OECD/NEA structure.

As for both the Oskarshamn 3 study and the Barsebäck study, given the pre-conditions and the boundary conditions, most of the cost groups/items in this section 05 "Waste processing, storage and disposal" are calculated and estimated.

Table 5-7.

	O3	B1	B2
Waste processing, storage and disposal safety analyses	ϴ	X	X
Waste transport feasibility studies	–	–	–
Special permits, packaging and transport requirements	–	–	–
Processing of system fluids (water, oils, etc) from facility operations	–	–	–
Processing of special system fluids (D2O, sodium, etc) from facility operations	–	–	–
Processing of waste from decontamination during facility operations	–	–	–
Processing of combustible material from facility operations	–	–	–
Processing of spent resins from facility operations	–	–	–
Processing of other nuclear and hazardous materials from facility operations	–	–	–
Storage of waste from facility operations	–	–	–
Disposal of waste from facility operations	–	–	–
Decommissioning waste processing	X	X	X
Decommissioning waste packaging	ϴ	X	X
Decommissioning waste transport	X	ϴ	ϴ
Decommissioning waste storage	–	–	–
Decommissioning waste disposal	X	ϴ	ϴ

X = included in the studies, – = not covered, ϴ = included in other cost groups/items or sections.

Differences in the cost calculation in section 05.Waste processing, storage and disposal programme:

- In the Oskarshamn 3 study: Section 05 "Waste processing, storage and disposal programme" is calculated for the dismantling and demolition period (5 years).
- In the Barsebäck study: Section 05 "Waste processing, storage and disposal programme", costs are incurred during the preparation, reestablishment and dismantling period (≈ 7 years). Includes preparatory and reestablishment activities.

Comparison of waste packages generated during decommissioning

Decommissioning waste transported for controlled disposal was assumed to be packaged in one of four types of containers. ISO containers (Sea Vans) are assumed to be used for the packaging of most radioactive waste. Decommissioning waste associated with water processing, including filters and resins, are packaged in steel containers/boxes.

Reactor vessel internals are packaged in concrete or steel boxes, with the exception of the most high-level reactor vessel internals, which are packaged in BFA containers. A summary of these waste packages is provided in Table 5-8a.

Larger components can serve as their own containers with proper closure of all openings, access pathways and penetrations.

Table 5-8a.

		Oskarshamn 3		Barsebäck 1		Barsebäck 2	
Waste packages	External dimensions (m)	Number of waste packages	Total external volume (m³)	Number of waste packages	Total external volume (m³)	Number of waste packages	Total external volume (m³)
BFA Containers	3.3×2.3×1.3	17	168	11	109	11	109
Steel Box/Container	1.2×1.2×1.2	686	1,735	141	244	142	245
Concrete Box	1.2×1.2×1.2	–	–	31	54	31	54
ISO Container	6×2.5×1.3	457	9,000	533	8,821	221	3,652
Total		**1,160**	**10,903**	**716**	**9,228**	**405**	**4,059**

Table 5-8b.

Waste Class	Packaged Volume (cubic meters)	Weight (tonnes)
Barsebäck unit 1 with common facilities		
Low-Level (SFR)	9,081	12,081
Intermediate-Level (SFL)	145	187
Total	**9,226**	**12,268**
Barsebäck unit 2		
Low-Level (SFR)	3,913	5,472
Intermediate-Level (SFL)	147	190
Total	**4,059**	**5,662**
Oskarshamn 3		
Low-Level (SFR)	10,735	8,959
Intermediate-Level (SFL)	168	131
Total	**10,903**	**9,090**

5.1.6 Section 06. Site security, surveillance and maintenance

Section 06 mainly includes site protection, control and maintenance activities.

It is subdivided into the following 5 groups/items:

Table 5-9.

	O3	B1	B2
Site security operation and surveillance	X	X	X
Inspection and maintenance of buildings and systems in operation	–	–	–
Site upkeep	–	–	–
Energy and water	X	X	X
Periodic and environmental survey	–	–	–

X = included in the studies, – = not covered, Ɵ = included in other cost groups/items or sections.

Due to differences in programme and cost calculation boundaries and how costs have been transferred from the different studies' Work Breakdown Structure (WBS) to the OECD/NEA cost structure, it will be difficult to make a direct comparison between section 06 "Site security, surveillance and maintenance".

As for both the Oskarshamn 3 study and the Barsebäck study, given the pre-conditions and the boundary conditions, most of the cost groups/items in this section 06 "Site security, surveillance and maintenance" are calculated and estimated.

Differences in the cost calculation in section 06 "Waste processing, storage and disposal programme":

- In the Oskarshamn 3 study: Section 06 "Site security, surveillance and maintenance" is calculated for the dismantling and demolition period (5 years).
- In the Barsebäck study: Section 06 "Site security, surveillance and maintenance" is calculated for the preparation, reestablishment, dismantling and demolition period (7 years). Includes preparatory and reestablishment activities. Based on US experience (cost calculation model)

5.1.7 Section 07. Site restoration, cleanup and landscaping

Section 07 considers the non-radiological portions of plant decommissioning.

It is subdivided into the following 4 groups/items:

Table 5-10.

	O3	B1	B2
Demolition or restoration of buildings	X	X	X
Final cleanup and landscaping	X	X	X
Independent verification of cleanup and/or site reuse standards being met	–	–	–
Perpetuity funding/surveillance for limited or restricted release of property	–	–	–

X = included in the studies, – = not covered, ϴ = included in other cost groups/items or sections.

Due to differences in plant boundaries (included buildings) and how costs have been transferred from the different studies' Work Breakdown Structure (WBS) to the OECD/NEA cost structure, it will be difficult to make a direct comparison between section 07 "Site restoration, cleanup and landscaping".

In section 07 "Site restoration, cleanup and landscaping" in the Oskarshamn 3 study, there are cost groups/items included from other sections (section 08 "Project management, engineering and site support" and section 11 "Other costs"). The Barsebäck study conforms more closely to the OECD/NEA structure.

As for the both Oskarshamn 3 study and the Barsebäck study, given the pre-conditions and the boundary conditions, most of the cost groups/items in this section 07 "Site restoration, cleanup and landscaping" are calculated and estimated.

Comparison of site restoration cost with total decommissioning cost

The aim is to see whether the calculation of site restoration cost is done differently, compared with the total decommissioning cost, between the studies.

Figure 5-4 is based on the WBS structure, upon the removal of the structures to a depth of one metre below grade and the use of clean construction debris (processed concrete) for fill. Cost contributors include craft labour, heavy equipment and the management organization needed to oversee the dismantling processes.

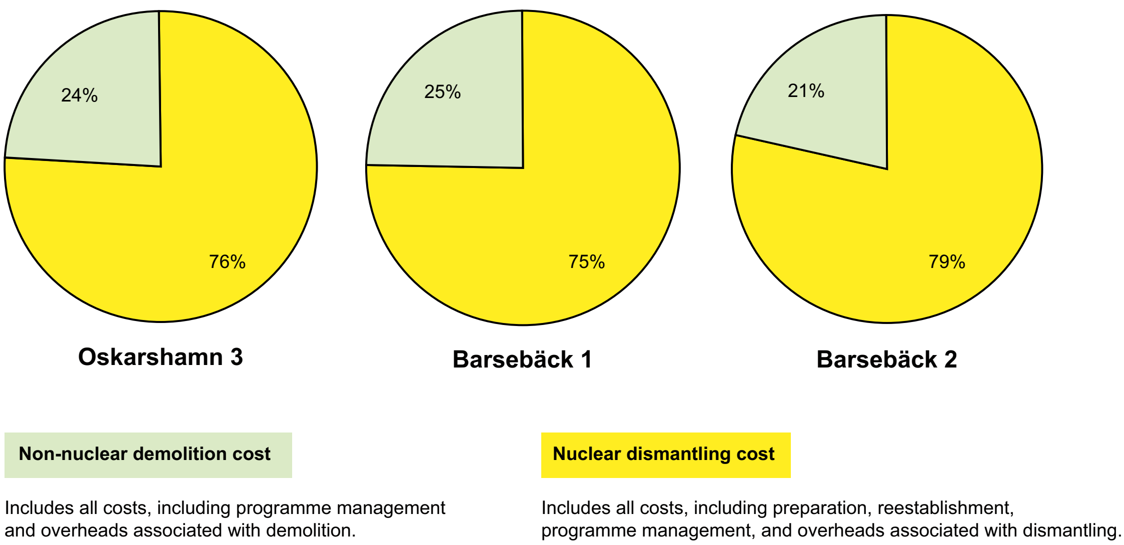


Figure 5-4. *Non-nuclear demolition and nuclear dismantling cost in percent, costs for waste transportation and disposal excluded.*

5.1.8 Section 08. Project management, engineering and site support

Section 08 includes project management and site support services during decommissioning operations.

It is subdivided into the following 6 groups/items:

Table 5-11.

	O3	B1	B2
Mobilization and preparatory work	–	X	X
Project management and engineering services	X	X	X
Public relations	X	X	X
Support services	X	X	X
Health and safety	X	X	X
Demobilization	–	–	–

X = included in the studies, – = not covered, Θ = included in other cost groups/items or sections.

Due to differences in plant, programme and cost calculation boundaries as well as technical prerequisites boundaries, there will be a difference in cost and included groups in section 08 "Project management, engineering and site support".

Depending on how costs have been transferred from the different studies' Work Breakdown Structure (WBS) to the OECD/NEA cost structure, there will be great differences in section 08 "Project management, engineering and site support", making it difficult to make a direct comparison.

In the Oskarshamn 3 study, section 08 "Project management, engineering and site support", there are some cost groups/items that have been transferred to and calculated in other sections (sections 04 "Dismantling activities", 05 "Waste processing, storage and disposal" and 06 "Site security, surveillance and maintenance" and section 07 "Site restoration, cleanup and landscaping"). The Barsebäck study conforms more closely to the OECD/NEA structure.

As for both the Oskarshamn 3 study and the Barsebäck study, given the pre-conditions and the boundary conditions, most of the cost groups/items in this section 08 "Project management, engineering and site support" are calculated and estimated.

Differences in cost calculation in section 08 "Project management, engineering and site support":

- In the Oskarshamn 3 study: Section 08 "Project management, engineering and site support" is calculated for the dismantling and demolition period (5 years).
- In the Barsebäck study: Section 08 "Project management, engineering and site support" is calculated for the preparation, reestablishment, dismantling and demolition period (8 years). Includes preparatory and reestablishment activities. Based on US experience (cost calculation model).
- In the Barsebäck study, more Health and Safety work is calculated for the preparation, reestablishment, dismantling and demolition period (8 years). Based on US experience (cost calculation model).

Furthermore, in the Barsebäck study, the average number of project members assigned to the decommissioning management organization from the start of preparation until the end of site dismantling is approximately 223. The duration of preparations through site dismantling is 6.5 years.

For the Barsebäck station, the average number of project members assigned to the decommissioning management organization during the dismantling phase of the project is approximately 217. Dismantling phase duration is 4.5 years.

For the Barsebäck station, the average number of project members assigned to the decommissioning management organization during the demolition phase of the project is approximately 70 persons. Demolition phase duration is 2 years.

For the Barsebäck station, the average number of project members assigned to the decommissioning management organization for the entire project is approximately 190. Total project duration is 8.5 years.

This has effects on the total number of staff in the decommissioning management organization, which leads to higher costs for project management and total project management cost.

5.1.9 Section 09. Research and development

Section 09 includes expenditures on the development of decommissioning techniques and technologies.

It is subdivided into the following 2 groups/items:

Table 5-12.

	O3	B1	B2
Research and development of decontamination, radiation measurement and dismantling processes, tools and equipment	X	–	–
Simulation of complicated work on models	–	–	–

X = included in the studies, – = not covered, ϴ = included in other cost groups/items or sections.

Many dismantling projects have been carried out over the years, and these projects show that conventional dismantling equipment can be used. For this reason, no higher costs have been budgeted in this section. It is assumed that decommissioning techniques will be available at the time for dismantling and demolition.

5.1.10 Section 10. Fuel and nuclear material

Section 10 includes costs relating to the evacuation of spent fuel elements and/or nuclear material, but excludes costs for reprocessing or final disposal alternatives.

It is subdivided into 5 groups:

- Transfer of fuel or nuclear material from the facility or from temporary storage to intermediate storage.
- Intermediate storage.
- Dismantling/disposal of intermediate storage facility.
- Preparation of transfer of fuel or nuclear material from intermediate storage to final disposal.
- Dismantling/disposal of intermediate storage facility.

Fuel and nuclear material are beyond the scope of the Oskarshamn 3 study and the Barsebäck study, as the units are free from nuclear material due to the fact that fuel and other nuclear material have been transported off the site during the shutdown period. The owner will pay the cost for this section directly.

5.1.11 Section 11. Other costs

Section 11 includes all other costs that cannot be specifically classified in the preceding sections:

It is subdivided into the following 9 groups/items:

Table 5-13.

	O3	B1	B2
Owner costs	–	–	–
Consulting costs	–	–	–
Regulatory fees, inspections, certifications, reviews, etc	X	X	X
Taxes	–	–	–
Insurance	X	X	X
Overheads and general administration	ϴ	X	X
Contingency	(X)	(X)	(X)
Interest on borrowed money	–	–	–
Asset recovery: Resale/transfer of general equipment and material	–	–	–

X = included in the studies, – = not covered, ϴ = included in other cost groups/items or sections.

Due to differences in programme and cost calculation boundaries and how costs have been transferred from the different studies' Work Breakdown Structure (WBS) to the OECD/NEA cost structure, it will be difficult to make a direct comparison between section 11 "Other costs".

In the Oskarshamn 3 study, section 11 "Other costs", some cost groups/items related to overhead and general administration have been transferred to and calculated in other sections (sections 04 "Dismantling activities", 05 "Waste processing, storage and disposal" and 06 "Site security, surveillance and maintenance", section 07 "Site restoration, cleanup and landscaping" and section 08 "Project management, engineering and site support"). The Barsebäck study conforms more closely to the OECD/NEA structure.

As for both the Oskarshamn 3 study and the Barsebäck study, given the pre-conditions and boundary conditions, most of the cost groups/items in this section 11 "Other costs" are calculated and estimated.

Differences in cost calculation in section 11 "Other costs":

- In the Oskarshamn 3 study, overhead costs are calculated and included in other sections (sections 04 "Dismantling activities", 05 Waste processing, storage and disposal" and 06 "Site security, surveillance and maintenance", section 07 "Site restoration, cleanup and landscaping" and section 08 "Project management, engineering and site support") for the dismantling and demolition period (5 years).
- In the Barsebäck study, overhead costs are more stringently calculated, and all project management are calculated and included in this section. Overhead costs are calculated for 8 years (~223 project members).
- In the Oskarshamn 3 study, costs for regulatory fees and insurance are calculated for the dismantling and demolition period (5 years).
- In the Barsebäck study, costs for regulatory fees and insurance are calculated for the reestablishment, dismantling and demolition period (8 years).

5.2 Summary of OECD/NEA quantitative analysis

Each of the sections in the OECD/NEA decommissioning cost structure has been reviewed in detail and due consideration has been given to the possibilities of comparing the content and costs in each section.

The Oskarshamn 3 study and the Barsebäck study use the OECD/NEA decommissioning cost structure differently and allocate the costs to different sections, making comparison difficult.

Due to the different approaches and boundary conditions, certain cost groups/items have in this study required thorough analysis to clarify what is included and/or excluded in what cost groups/items.

Such cost items are:

Section 01. Pre-decommissioning activities

- In the Oskarshamn 3 study, most of the pre-decommissioning activities are carried out by the plant staff (e.g. detailed planning, engineering) and therefore excluded from costs related to decommissioning.
- In the Barsebäck study, pre-decommissioning activities are managed by the decommissioning project organization, established 1½ years before dismantling (~120 project members).

Differences in programme boundaries and cost calculation boundaries affect the costs related to decommissioning and pre-decommissioning activities.

Section 03. Procurement of general equipment and material

- In the Oskarshamn 3 study, general equipment and material are included in contractors' fees in section 04 "Dismantling activities".
- In the Barsebäck study, the costs are specified for procurement and general equipment in a more detailed way. Moreover, a higher value is estimated for the Barsebäck study, calculated separately based on US experience.

Differences in cost calculation boundaries affect the costs related to decommissioning and procurement of general equipment and material.

Section 06. Site Security, surveillance and maintenance

- In the Oskarshamn 3 study, 2–3 guards are used for site security during the decommissioning project. Site security is calculated for the dismantling and demolition period (5 years).
- In the Barsebäck study, the number of needed guards is adjusted to reflect the number of personnel and the level of activity during each of the stages of the decommissioning project. This influences the total number of guards. Site security is calculated for the preparation, reestablishment, dismantling and demolition period (7 years).
- In the Oskarshamn 3 study, costs for energy, gas and water are calculated for the dismantling and demolition period (5 years).
- In the Barsebäck study, the basis for energy, gas and water costs are projected costs for service operation at Barsebäck (actual figures from 2005, lessons learned). Costs for energy, gas and water are adjusted to reflect the number of personnel and the level of activity during each of the stages of the decommissioning project (reestablishment, dismantling and demolition period, 7 years).

Differences in programme boundaries and cost calculation boundaries affect the costs related to decommissioning and site security, surveillance and maintenance.

Section 08. Project management, engineering and site support

- In the Oskarshamn 3 study, costs for project management are based on own staff during decommissioning. Other project management costs are calculated and included in other sections (04 "Dismantling activities" and 05 "Waste processing, storage and disposal"). Project management costs are calcultaed for 8 years (25–30 project members for 3 years before dismantling).
- In the Barsebäck study, costs for project management are more stringently calculated. All project management costs are calculated and included in this section. Project management costs are calculated for 7 years (~223 project members).
- In the Oskarshamn 3 study, costs for health and safety are calculated for the dismantling and demolition period (5 years).
- In the Barsebäck study, costs for health and safety are calculated for the reestablishment, dismantling and demolition period (7 years). The number of staff needed for health and safety is based on US experience.

Differences in programme boundaries and cost calculation boundaries affect the costs related to decommissioning and project management, engineering and site support.

Other costs

- In the Oskarshamn 3 study, overhead costs are calculated and included in other sections (sections 04 "Dismantling activities", 05 "Waste processing, storage and disposal" and 06 "Site security, surveillance and maintenance", section 07 "Site restoration, cleanup and landscaping" and section 08 "Project management, engineering and site support") for the dismantling and demolition period (5 years).
- In the Barsebäck study, overhead costs are more stringently calculated. All project management are calculated and included in this section. Overhead costs are calculated for 7 years (~223 members 2 years before dismantling).
- In the Oskarshamn 3 study, costs for regulatory fees and insurance are calculated for the dismantling and demolition period (5 years).
- In the Barsebäck study, costs for regulatory fees and insurance are calculated for the reestablishment, dismantling and demolition period (7 years).

Differences in programme boundaries and cost calculation boundaries affect other costs.

6 Approach correlated to thermal power

6.1 NRC regulatory activities

6.1.1 NRC approach with "Minimum Financial Assurance" (MFA)

In 1985–1986, the NRC was worried that there would not be sufficient funds to cover future decommissioning costs. A method was developed with "The Formula" for calculating the minimum funds to be set aside for the decommissioning process. The method is described in NUREG-1307 /5/ and NUREG-1713 /6/. NUREG-1713 states:

"Financial Assurance
Licensees of operating nuclear power reactors must provide reasonable assurance that funds will be available for the decommissioning process. For these licensees, reasonable assurance consists of fulfilling a series of steps identified in 10 CFR.50.75(b),(c)(e) and (f).

These steps assure that the licensee can certify that financial assurance is in effect for an amount that may be more but not less than the amount stated in the table in 10 CFR 50.75(c)(1). Specially, this table states that if P equals the thermal power of a reactor in megawatts (MWt), the minimum financial assurance (MFA) funding amount in millions of January 1986 dollars

(1) For a PWR: MFA = (75 + 0.0088P)

(2) For a BWR: MFA = (104 + 0.009P)

For either a PWR or a BWR, if the thermal power of the reactor is less than 1,200 MWt, then the value of P to be used in 1 and 2 is 1,200, and if the thermal power is greater than 3,400 MWt, then a value of 3,400 is used for P. That is, P is never less than 1,200 nor greater than 3,400. The financial assurance amounts calculated in equations 1 and 2 are based on January 1986 dollars, in millions. To account for inflation from 1986 to current year, these amounts must be adjusted annually by multiplying 1 and 2 by an escalation factor (ESC) described in 10 CFR 50.75(c)(2)."

The amount in the formula that is defined as the part that correlates to the size of the plant through a factor of the thermal power is 0.009P. Calculations in Chapter 6.1.2 show that this factor represents about an 11% difference in decommissioning costs between a 3,300 MWt unit and a 1,800 MWt unit.

The NRC MFA value is not intended to include any costs associated with the management of spent fuel or the demolition of buildings/equipment determined to be clean.

"The NRC makes it clear that this formula only represents a funding target that provides a reasonable assurance that the licensee can complete the decommissioning. The NRC requires that a site-specific estimate be submitted five years prior to the end of licensed life, and that the licensee demonstrate how they are going to fund the decommissioning based on the site-specific estimate. The licensee is allowed to declare deferred dismantling at this time (and take advantage of earnings in decommissioning trust funds), but still needs to have minimum funding in compliance with the formula."

Note: there is no differentiation in the NRC model relating to common facilities. The minimum funding formula was based on a single unit, and does not incorporate any reductions due to shared facilities.

The Minimal Funding Formula according to 10 CFR 50.75 (c) has been applied to the Barsebäck study and has resulted in a minimum amount to be set aside in funds that is on the same level as the evaluation in Chapter 7.1 in this study.

6.1.2 NRC approach correlated to thermal power

In this study, a series of calculations has been performed to determine the amount that is defined as the part that correlates to the size of the plant via a factor of the thermal power. Calculations shows that this factor represent about an 11% difference in decommissioning costs between a 3,300 MWt unit and a 1,800 MWt unit, see Table 6-1.

The NRC Minimum Funding Formula should refer to NRC NUREG-1307, Rev. 11 (for 2005 values) and Bureau of Labor Statistics data /5/.

In Table 6-1, a comparison is made between reactor units in US. The reactor units are equivalent in thermal power to Barsebäck units 1 and 2 (1,800 MWt) and Oskarshamn unit 3 (3,300 MWt).

Table 6-1. Barseback units 1 and 2 – 1,800 MWt thermal power. Oskarshamn unit 3 – 3,300 MWt thermal power.

Assumed location (*4)	Thermal power MWt	Waste Disposal site (*2)	Waste Vendors used (*1)	Member of Atlantic Compact? (*3)	Result Millions $'05	Result Millions SEK'05 *	Differences in %
Northeast US	1,800	South Carolina (Barnwell)	No	No	668.75	5,015.63	≈ 11%
Northeast US	3,300	South Carolina (Barnwell)	No	No	743.86	5,578.95	
Northeast US	1,800	South Carolina (Barnwell)	No	Yes	653.39	4,900.40	≈ 11%
Northeast US	3,300	South Carolina (Barnwell)	No	Yes	726.77	5,450.78	
Northeast US	1,800	Washington (US Ecology)	No	n/a	541.48	4,061.07	≈ 11%
Northeast US	3,300	Washington (US Ecology)	No	n/a	602.29	4,517.18	
Northeast US	1,800	Washington (US Ecology)	Yes	n/a	504.40	3,783.01	≈ 11%
Northeast US	3,300	Washington (US Ecology)	Yes	n/a	561.05	4,207.89	
Northeast US	1,800	South Carolina (Barnwell)	Yes	No	427.93	3,209.44	≈ 11%
Northeast US	3,300	South Carolina (Barnwell)	Yes	No	475.99	3,569.90	
Northeast US	1,800	South Carolina (Barnwell)	Yes	Yes	414.28	3,107.10	≈ 11%
Northeast US	3,300	South Carolina (Barnwell)	Yes	Yes	460.81	3,456.07	

* 1 US dollar to 7.5 SEK. 2005.

(*1) Waste Vendors = Off-Site Services Used to Minimize the Volume of Waste by Sorting / Segregating.

(*2) Waste Disposal Site = In the NRC minimum funding model there are two choices, Washington and South Carolina.

(*3) Atlantic Compact = States have formed compacts. If you are in the Atlantic Compact you receive a preferable rate (only South Carolina, Connecticut and New Jersey are in the Compact).

(*4) Assumed Location = NRC has divided the country into four regions.

7 Analysis of differences

The decommissioning studies for Oskarshamn 3 and Barsebäck were carried out for different purposes and have different basic boundary conditions.

A comparison of the calculated costs for sections in the OECD/NEA decommissioning cost structure in Chapter 5 shows that it is possible to compare the cost calculations if the consequences of the qualitative comparison are taken into consideration. However, it is necessary to have good control of the contents of each section and the boundary conditions.

7.1 Evaluation of the consequences of boundary conditions

The boundary conditions have been thoroughly evaluated and the consequences are explained in Chapter 4.

The two studies have been evaluated qualitatively and quantitatively and in the end values have been assigned in the quantitative analysis to verify that the studies could be compared.

The values below have been assigned according to the consequences for Barsebäck unit 1 and Barsebäck unit 2's total decommissioning cost as a result of the qualitative and quantitative comparisons.

- Influence on Project Management cost:
  Approximate for Barsebäck unit 1: *SEK –180 M*
- Influence on Included Buildings cost:
  Approximate for Barsebäck unit 1: *SEK –180 M*
- Influence on Site Security, Energy and Water cost:
  approximate for Barsebäck unit 1. *SEK –50 M*
- Influence on Overhead, Regulatory Fees and Insurance cost:
  Approximate for Barsebäck unit 1. *SEK –50 M*

The influence of the above consequences
for Barsebäck unit 1 is approximately: *SEK –460 M*

To permit a proper comparison between Oskarshamn 3 and Barsebäck studies, the sum of the above influences should be subtracted from the total decommissioning costs for Barsebäck units 1 and 2.

Barsebäck unit 1	Total decommissioning cost is	*SEK 1,834 M*
	Sum of the influence	*SEK –460 M*
Total decommissioning cost		*SEK 1,374 M*
Barsebäck unit 2*	Total decommissioning cost is	*SEK 1,429 M*
	Sum of the influence	*SEK –160 M*
Total decommissioning cost		*SEK 1,269 M*

* economic benefits gained by sharing costs between units 1 and 2 and coordinating the sequence of work activities. Barsebäck unit 1 is the leading unit and therefore takes more of the common costs.

Oskarshamn 3	Total decommissioning cost is	*SEK 1,544 M*

The above comparison above gives the following differences between Oskarshamn 3 (3,300 MWt) and Barsebäck units 1 and 2 (1,800 MWt):

Oskarshamn 3 – Barsebäck unit 1 is approximately ≈ 12%

Oskarshamn 3 – Barsebäck unit 2 is approximately ≈ 21%

7.2 Transferring cost calculations from a reference plant to other plants

In the US, a formula has been developed for calculating the Minimum Financial Assurance (MFA), and in this formula only a small portion of the decommissioning cost is correlated to the size of the plant.

The amount in the formula that is defined as the part that correlates to the size of the plant through a factor of the thermal power is 0.009P. This factor represent about an 11% difference in decommissioning costs between a 3,300 MWt unit and a 1,800 MWt unit. Furthermore there are site-specific conditions that have to be taken into account when performing the decommissioning cost calculation (e.g. included buildings, contaminated soil, spills and leakage and time schedule). It is therefore not advisable to transfer the decommissioning costs solely in relation to unit size and thermal power as is done today.

In discussions, personnel from TLG Services have pointed out that there are other factors that drive the costs, and as an example, contaminated soil is one area that concerns the NRC today.

7.3 Estimate of waste quantity – differences in approach and their consequences

A radiological inventory with categorization and characterization forms the basis for decommissioning.

Knowledge of how the radioactivity is distributed is vital in many respects for a nuclear power plant under decommissioning. Good control of spills, leakages, incidents etc, is therefore imperative. The waste volume calculation must be based on clear specifications of the radiological inventory.

If contaminated soil is identified, it is much more difficult to calculate the waste volume.

Areas in the Barsebäck study that have an impact on estimated decommissioning waste quantity are:

- Contaminated common facilities/buildings.
- Contaminated soil.
- Melting, method for free release of material.

These areas have a great impact of the total amount of radioactive waste, along with how the decommissioning waste is being processed/handled. About 45% of the Barsebäck unit 1's total decommissioning waste is generated from contaminated common facilities and contaminated soil.

An unanswered question from the qualitative comparison is the lack of requirements for the final release of land, groundwater and buildings in Sweden. Conditions and requirements from the nuclear industry in the US have been used in the Barsebäck study.

The Oskarshamn study is based on the framework used up to now in the Swedish nuclear power industry. However a complete set of requirements for free release of a site or an NPP does not exist.

7.4 Contingency

Statement from TLG Service Inc.: An estimate without contingency, or from which contingency has been removed, can disrupt the orderly progression of events and jeopardize a successful conclusion to the decommissioning process.

Different levels of contingencies are used in the compared studies. In the Oskarshamn study 7% is used, and in the Barsebäck study 18% is used. The "Minimum Financial Assurance" used in the US for setting aside the minimum funds assumes 25% for contingencies.

8 Recommendations

The following general rule is applied today in the decommissioning industry:

”The total decommissioning cost is a function of the size and cost of the management organization(s) overseeing the decommissioning as well as the duration allowed for the decommissioning programme.”

This means that a great deal of engineering and planning experience is needed as well as experience from dismantling and demolition activities in order to manage and optimize the decommissioning programme.

The method used today, where decommissioning costs are transferred in direct relation to thermal power, is not accurate according to today's experience, which says that only 11% can be related to thermal power output.

8.1 Recommendations for future cost calculations

This study shows that it is possible to compare calculations if good control is maintained over scope and the boundary conditions. A site-specific cost calculation yields the best results. However, there will be differences in boundary conditions and these will result in discussions and explanations that can be avoided if all future decommissioning cost calculations are performed according to a detailed specification, with well defined boundary conditions and a more stringent accounting model for making appropriate calculations.

Future decommissioning cost studies should include all costs related to decommissioning and be carried out in such a way that they can be compared. Distinguishing between what should be paid by the funds and what should be paid by the plant owner should not affect the possibilities of making a thorough comparison.

8.2 Specification of future cost calculations

The power plant owner has to draw up a specification for the decommissioning project. The specification should incude details on boundary conditions, included facilities/buildings and the decommissioning schedule. The specification has to be detailed to prevent the risk of misinterpretations.

Strategies for how to manage plant staff, as well as how the staff will participate in the decommissioning activities, are the responsibility of the power plant owner.

As there will always be comparisons of decommissioning costs, there is a need to introduce an accounting model that is more stringent than the models used today. The OECD/NEA decommissioning cost structure is one such model, but needs to be updated with experience from this study and then accepted by all users in Sweden.

8.3 Estimating waste volumes

The Swedish nuclear power industry lacks of a complete set of requirements for free release of a site, which could affect the final calculation of waste volumes, costs for treatment and storage, as well as criteria for free release. A new framework of requirements should be developed in a joint effort between the Swedish nuclear power industry and the regulatory authorities.

If contaminated soil is identified, it is much more difficult to calculate the waste volume. A good definition of the impact of spills, leakages, incidents etc, is therefore needed. The waste volume calculation must be based on clear specifications of the radiological inventory.

9 References

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