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Abstract

By Swedish law it is the obligation of the nuclear power utilities to satisfactorily demonstrate how a nuclear facility can be safely decommissioned and dismantled when it is no longer in service as well as calculate the estimated cost of decommissioning of the nuclear facility. Svensk Kärnbränslehantering AB (SKB) has been commissioned by the Swedish nuclear power utilities to meet the requirements of current legislation by studying and reporting on suitable technologies and by estimating the costs of decommissioning and dismantling of the Swedish nuclear power plants.

The present report is an overview, containing the necessary information to meet the above needs, for Clink. Information is given for the site about the inventory of materials and radioactivity at the time for final shutdown. A feasible technique for dismantling is presented and the waste management is described and the resulting waste quantities are estimated. Finally a schedule for the decommissioning phase is given and the costs associated are estimated as a basis for funding.

Contents

Abbreviations

ALARA	As Low As Reasonably Achievable – dose minimisation philosophy
APRM	Average Power Range Monitoring
AWJC	Abrasive Water Jet Cutter
BFA-Tank	Container for core components
BNFL	British Nuclear Fuel Limited
BWR	Boiling Water Reactor
CITROX	A chemical decontamination method named after its main chemical reagent, a mixture of Citric Acid and Oxalic Acid
Clab	The Swedish Central interim storage facility for spent nuclear fuel at Oskarshamn
Clink	The combined Clab and Ink facility
CORD	Chemical Oxidation Reduction Decontamination – Siemens proprietary chemical decontamination process
CS	Carbon Steel
CSH	Core Shroud Head
DF	Decontamination Factor
DfD	Decontamination for Decommissioning – an EPRI licensed chemical decontamination process
DN	Nominal Diameter
EC	European Commission
EIA	Environmental Impact Assessment
EIAD	Environmental Impact Assessment for Decommissioning (as per EU Directive 97/11/EC)
EIS	Environmental Impact Statement
EPRI	Electric Power Research Institute
EW	Exempted Waste
FRW	Free Release Waste
HEPA	High Efficiency Particulate Air (filter)
HLA	Facility for handling of low level waste at Oskarshamn
HP	Health Physics
IAEA	International Atomic Energy Agency
ICFM	In Core Fuel Management
ILW	Intermediate Level Waste
Ink	The future encapsulation plant for spent fuel in Oskarshamn
IRM	Intermediate Range Monitoring
LILW	Low and Intermediate Level Waste
LLA	Facility for storage of low level waste at Oskarshamn
LLW	Low Level Waste
LOMI	A chemical decontamination process; the name is an acronym of Low Oxidation-State Metal Ion
MDM	Metal Disintegration Machining
MLA	Ground repository for low level waste at Oskarshamn
NPP	Nuclear Power Plant
NWC	Natural Water Chemistry
O3	Oskarshamn 3
OFC	Oxy-fuel cutting

OECD/ NEA	Organisation for Economic Co-operation and Development/ Nuclear Energy Agency
PAC	Plasma Arc Cutter
PPE	Personal Protective Equipment
PRM	Power Range Monitoring
RPV	Reactor Pressure Vessel
SEK	Swedish Currency (Krona)
SF	Site Factor
SFL	The Swedish Final Repository for Long-lived Low and Intermediate Level Waste
SFR	The Swedish Final Repository for Short-lived Low and Intermediate Level Waste
SKB	Swedish Nuclear Fuel and Waste Management Co (Svensk Kärnbränslehantering AB)
SS	Stainless Steel
SS	Swedish Standard (Svensk Standard)
SSM	Strålsäkerhetsmyndigheten (*Swedish Radiation Safety Authority*)
STAL	Stal-Laval, Turbine Supplier
SRM	Source Range Monitoring
TIP	Traversing In-core Probe
TONNE	Metric ton (1,000 kg)
WAGR	Windscale Advanced Gas Reactor – UK gas-graphite research reactor decommissioned late 1990's to mid 2000's
WBS	Work Breakdown Structure
WPPF	Waste Processing and Packaging Facility
VS	Heating and Sanitation (**V**ärme och **S**anitet)

1 Introduction

1.1 General

According to Sweden's Act on Nuclear Activities ("*kärntekniklagen*") (SFS 1984:3) it is the obligation of the nuclear facility companies to satisfactorily demonstrate how the facility can be safely decommissioned and dismantled when it is no longer in service. In addition, the Financing Act ("*finansieringslagen*") (SFS 2006:647) states that a facility owner shall calculate the estimated cost of decommissioning of the nuclear facility.

Clink is the name of the combined central interim storage facility for spent nuclear fuel (Clab) and the encapsulation plant (Ink) and is owned by Svensk Kärnbränslehantering AB (Swedish Nuclear Fuel and Waste Management Co, SKB). SKB has been commissioned by the Swedish nuclear facilities to meet the requirements of current legislation by studying, reporting on suitable technologies and by estimating the costs of decommissioning and dismantling.

The Swedish system for handling of radioactive waste is described in Figure 1-1. The short-lived low and intermediate level waste from both nuclear plants and other industries is transported by ship to the final repository for short-lived radioactive waste (SFR) at Forsmark. The spent nuclear fuel is transported by the same ship to Clab at Oskarshamn. The strategy is to encapsulate the spent fuel in copper and send it to the final repository for spent nuclear fuel, approx. 500 meter below ground. Neither the encapsulation plant nor the final repository for spent nuclear fuel is yet constructed.

1.2 Earlier studies

SKB has performed a large number of investigations and studies to establish a reference technology for decommissioning and, based on that, estimate the costs to carry out decommissioning of the Swedish nuclear power plant sites. Examples of such studies are presented in Section 1.5.

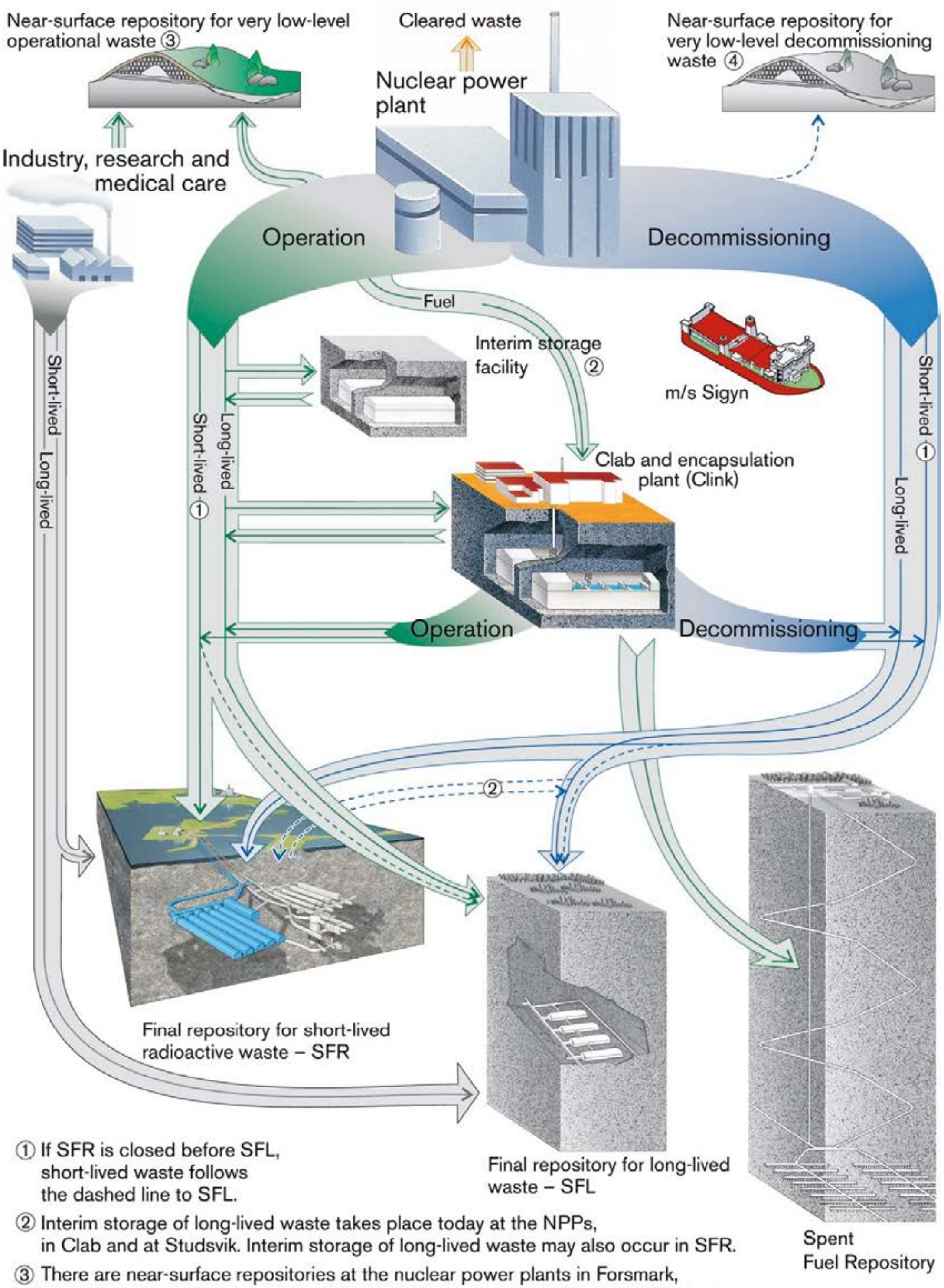
The conclusions have been summarized a number of times, two of the latest being in the reports "Swedish BWR Reference Plant Decommissioning study, June 2006" (Gustafsson et al. 2006) and "Technology and costs for decommissioning Swedish nuclear power plants, June 2004" (Hedin et al. 2004).

The previous decommissioning plans for the Swedish nuclear power plants, which serve as the basis for the SKB cost estimates for the Swedish national back-end funds, are based on several in-depth studies that each of them describes a specific part of the decommissioning technology or programme. Separate studies have in this manner been carried out for areas such as dismantling of process systems, reactor pressure vessels and plant buildings as well as for the plant preparation for dismantling. These studies have been done over a longer period of time (some of the still used reference reports are from the early nineties) and by different authors and organizations. The reports could thus have been made with somewhat different boundary conditions. The emphasis of different aspects could also have been changed or developed over time. The consequence is that the different pieces of information do not necessarily fit perfectly together when they are added into the overall plan. In certain areas there might be an overlap, where the costs are calculated twice, and in other there might be gaps, where the costs are neglected. With this approach it might also be quite complicated to update single pieces of information as the report as a whole needs to be revised in order to change specific data.

1.3 Present study

For the present study, Westinghouse was given the task to use the methodology developed in the previous studies (mainly Gustafsson et al. 2006), apply it on the Clink plant and summarize the findings.

For the reasons stated above the present study is made with the objective to obtain a basis for the time schedule, costs, waste production and waste types for the decommissioning of Clink. The study should summarize and complete the previous studies. It should also be performed in such a way that it becomes apparent which data are included and which are not, so that individual cost items can be easily revised when new information are at hand.



① If SFR is closed before SFL, short-lived waste follows the dashed line to SFL.

② Interim storage of long-lived waste takes place today at the NPPs, in Clab and at Studsvik. Interim storage of long-lived waste may also occur in SFR.

③ There are near-surface repositories at the nuclear power plants in Forsmark, Oskarshamn and Ringhals. There is also a similar near-surface repository at Studsvik, to which some waste from industry, research and medical care is sent.

④ Possible alternative for very low-level decommmissioning waste. A decision has not yet been made on this.

Figure 1-1. *The Swedish system.*

The overall objectives are that the study should provide a base for an extension of the Swedish SFR facility with quantities of decommissioning waste arisings. The study is aiming at providing a final result where:

- … all assumptions that form the basis for the chosen scenario and resulting cost estimates are well documented.
- … the total cost estimate will cover all relevant items regarding decommissioning to be financed by the national waste fund and by the plant owner (each item only calculated once).
- … the cost estimate is transparent so that it is easy to identify what it covers.
- … it is relatively easy to update the total information by replacement of individual data to reflect new experience or new overall strategies.
- …. the cost could also be presented in the OECD/NEA developed format, for the ease of international comparisons and to import other's experience.
- … the technical basis in the form of dismantling procedures and technical solutions are well thought through, based on both national and international experience and adapted to Swedish conditions.
- … the time schedule is well thought through and possible to revise in a detailed level.
- … it is possible to identify the primary dismantling waste and transform it to number of waste containers, in order to provide a basis for calculation of waste transport and disposal costs as well as for the extension of the SFR.
- … the nuclide content of the waste containers is assessed in order to be used as a base for the extension of the SFR.
- … the waste quantities and activities are presented for each type of final repository. Uncertainties adherent to the waste quantities and activities are presented as well.
- … the total decommissioning costs including the preparatory work and planning during operation, service and shutdown will form the base. Operational costs during operation are excluded. The cost compilation is structured according to OECD/NEA's "International Structure for Decommissioning Costing (ISDC) of Nuclear Installations" and in a way that suit SKB's routines (OECD/NEA 2012).

1.4 Prerequisites

The overall prerequisites for the Clink study are summarized in this section.

1.4.1 Plant boundaries

The study will cover the main building complex of the Clink site. The buildings included are described in Section 3.3.3.

1.4.2 Programme boundaries

The study covers the whole decommissioning phase from shutdown after 85 years (Clab) of operation (including the initial planning that might be done during the last five years of operation) to hand-over of the cleared and decontaminated site for other industrial purposes. See Figure 1-2 for the decommissioning phases of Clink.

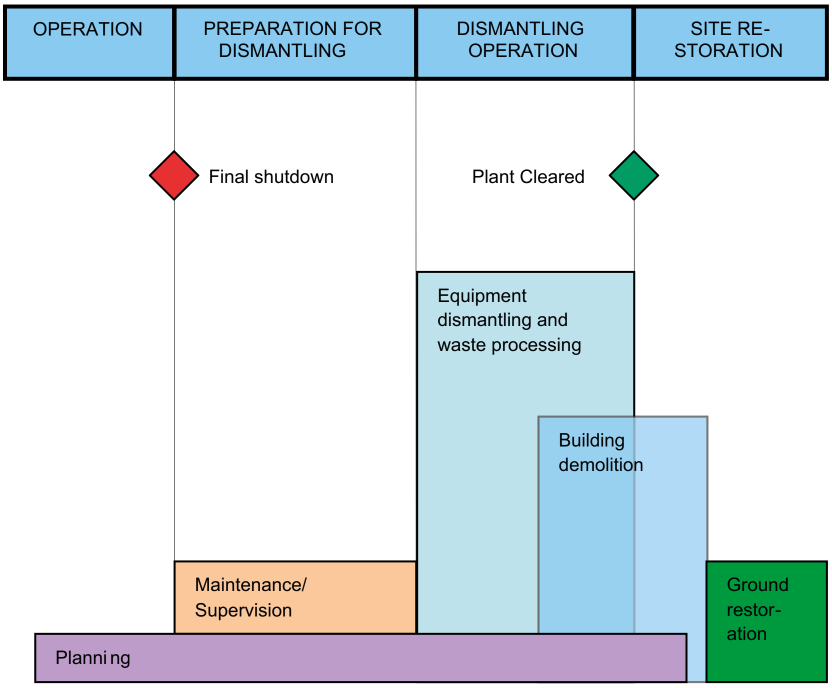


***Figure 1-2.** The decommissioning phases for Clink.*

The phases are defined as follows:

o Preparation for dismantling

Preparation for dismantling begins when all the fuel and core components has been transported away from the site and lasts until more extensive dismantling of process systems and plant components begins (in Swedish: "servicedrift"). Only activities directly related to decommissioning are included. During this period the system decontamination including radiological inventory characterization and the objects decontamination as well as the process and auxiliary system adaption takes place.

o Dismantling operation

Dismantling operation is the operation of the unit during the period from the start of physical dismantling until clearance of the entire plant (in Swedish: "rivningsdrift").

o Building demolition and site remediation

This period covers conventional demolition and remediation of the site area and takes place after the plant is cleared.

o End state

The assumed end-state in this study is cleared, decontaminated and free released facilities demolished with its tunnels, shafts and the foundation backfilled with crushed free-released concrete up to one meter below ground level. The last meter up to ground level is backfilled with some other appropriate material depending on the future use of the land. The site will assumedly be used for other industrial purposes.

1.4.2.1 Decommissioning phases chronology

For different reasons the plant may not be dismantled immediately after removal of the fuel. Instead, a number of years of so called preparation for dismantling would be required when the plant is prepared for dismantling and the plant functions that are going to be used during dismantling are maintained. Different scenarios of preparation for dismantling have been studied in a separate report (Pålsson et al. 2003).

The following conditions would have to be fulfilled before entering the dismantling operation period:

- The project organization for managing dismantling activities is established.
- The most significant dismantling packages are purchased.
- Investments in equipment for treatment and measurement of dismantling waste are prepared.
- Necessary plant documentation is identified and arranged in a specific decommissioning archive.
- All operational waste and storage boxes for spent fuel have been removed so that only decommissioning waste is still present in the plant.
- The decommissioning plan and the environmental impact assessment are approved. An application for a dismantling permit has been made.
- The radiological survey has been completed.
- Decontamination of the process systems has been carried out and the decontamination waste has been taken care of.
- Individual decontamination has been carried out for selected components.
- Systems not to be utilized during the dismantling phase are drained of its medium, if necessary dried, and the waste is taken care of.
- Electrical equipment that is no longer needed is disconnected.
- Existing systems, lifting devices etc that are needed during the dismantling phase are in proper condition and if needed rebuilt to suit the need from the dismantling operations.
- Staffs with proper competence for operation and maintenance of the plant are available.
- Temporary systems and equipment necessary during decommissioning are installed.

1.4.3 Cost calculation boundaries

The cost summary will contain all cost items that the plant owner is responsible for during the decommissioning except for the operational costs during operation.

Cost items associated with activities after the radiological declassification of the plant, i.e. non-radioactive building demolition and restoration of the ground to a state adapted to the further use of the site can be regarded as a sole interest of the site owner, not necessarily to be covered by mutual funds, and will thus be presented separately.

Costs for fees to authorities are not part of the study, as these are not normally covered in the Plan reports. Instead, these are discussed separately.

It is foreseen that the plant owner carries out the plant operation during the dismantling phase partly with its own personnel. These efforts might consist of overall project management, public information activities, plant surveillance, maintenance, plant operation, physical protection, entrance control, housekeeping etc. Other parts of the decommissioning programme, such as the main dismantling work packages are the responsibility of specialized contractors.

1.4.4 Technical prerequisites

In this study it is assumed that all process equipment is made of steel.

1.4.4.1 Waste transport and disposal

The costs for transport and final disposal of the radioactive dismantling waste are presented separately in the Plan reports. These activities and corresponding costs are not handled in this study; the waste transports ends with the containers being delivered to the dock of the site. However, handling of non-radioactive waste and free release material is covered by the study.

1.4.4.2 Decontamination for Free Release of Materials

The level of ambition for efforts aiming at allowing material to be regarded as non-radioactive should be based on ALARA considerations, environmental impacts as well as an economical evaluation of the costs for decontamination versus the costs for final disposal of radioactive waste. For this study it is assumed that moderate decontamination efforts are justified, i.e. normally with only simpler cleaning methods (water flushing, moderate blasting etc.). For large amounts of heavy goods with smooth surfaces, more extensive and time-consuming treatment is justified, while smaller objects with complicated geometry would not be treated at all.

1.5 Reference reports

The present study is to a large extent based on the data that has been developed for SKB in previous studies. The main reports from the previous studies are the following:

- Report Westinghouse SEP 06-055, Swedish BWR reference plant decommissioning study (Gustavsson et al. 2006).
- Report Westinghouse NM 94-627, Rivningsstudie för Oskarshamn 3 – Processutrustning (study of process systems) (Lönnerberg 1994).
- Report Westinghouse SEP 03-503, Studie av byggnadsrivning av de svenska kärnkraftverken – Slutrapport (study of building demolition) (Ericsson 2005).
- Report Westinghouse SEP 03-508, Studie av avställnings- och servicedrift för svenska kärnkraftverk (study of defueling and shutdown operation) (Pålsson et al. 2003).
- Report Westinghouse SEP 04-214, Studie av anläggningsdrift vid rivning och återställande av anläggningsplatsen (study of dismantling operation) (Pålsson and Hedin 2005).
- Report SKB 1359832, Avveckling och rivning av kärnkraftsblock (Dismantling and decommissioning of nuclear power plants) (SKBdoc 1359832).
- Report SKB P-08-034, Preliminär avvecklingsplan för Clink (Preliminary decommissioning plan of Clink) (Hallberg and Eriksson 2008).
- Report Vattenfall T-CKV 2006-026, SYRIC – Systemrivning av Clab (System dismantling of Clab) (Haglind 2006).

1.6 Structure of the report

The report is organized with a structure and content according to the following:

2. Methodology

The applied overall methodology for the study is defined in this chapter.

3. General description of the Clink plant

Clink is characterized by a general description of the plant, both from the physical and from the operational point of view. The characterization is intended to provide general data for the plant decommissioning analysis and to give a basis for comparison with other plants. The description will include the following aspects:

- Plant
- Site
- Buildings and Structures
- Systems.

4. Plant radioactivity characterization

The assessment of the different decommissioning and dismantling alternatives for a plant requires a characterization of the nature and extent of contamination at the different areas of the facility under consideration. A characterization based on the expected levels of radioactivity one year after plant shutdown is provided under this chapter. Nuclide vectors for different types of waste as well as limits for the free release of waste will also be presented in this chapter.

5. General inventory of systems, components and structures

The plant materials inventory data of building elements, equipment and components necessary for the estimate of waste production, time schedule and dismantling costs are presented in this chapter. It is done according to the same structure as in Gustavsson et al. (2006). The inventory is provided by SKB.

6. Radioactivity inventory

The materials inventory provided in Chapter 5 is completed with a classification into different contamination categories so that the amount of material in each radiological classification can be estimated. Based on the inventory data, the number of waste containers of different types is calculated and the nuclide content is specified. The container types are specified by SKB.

7. Dismantling techniques, sequences and logistics

Suitable techniques for plant dismantling and decontamination are suggested under this chapter. The techniques are chosen from experiences of similar plants and objects. Demands for competence and equipments, waste production and production costs are assumed for the decommissioning objects.

The logistics for the decommissioning operations are evaluated and suitable sequences for the decommissioning are suggested.

This chapter will mainly be based on the techniques and methods described in Gustavsson et al. (2006).

8. Management of residual materials

Suitable techniques for handling, treatment, measurement and sorting of decommissioning waste are suggested. A customized waste flow with necessary handling and sorting stations is suggested for the plant as well as systems for nuclide and dose rate measurements. For each type of waste the proper waste container to be used is specified. Some of the waste treatment strategy is provided by SKB.

9. Decommissioning programme

The decommissioning programme is based on previous studies (Gustavsson et al. 2006, Ericsson 2005, Hallberg and Eriksson 2008, Haglind 2006). A general dismantling programme, based on Section 2.2, is developed, covering all relevant phases, in sufficient detail for overall planning and the cost estimation. The organization during the decommissioning period and the duration of the defueling operation is provided by SKB.

The WBS structure is similar to the one used in Gustavsson et al. (2006).

10. Decommissioning cost estimates

With the frame defined and all information generated in the previous chapters, the total dismantling and demolishing costs for the plant are estimated and calculated in this chapter.

From the chosen technique and the inventory of the plant, the resource and equipment needs for each activity are defined at a suitable level in the cost estimation.

The cost analysis is structured according to the WBS and to the method that EC, IAEA and OECD/NEA present in "International Structure for Decommissioning Costing (ISDC) of Nuclear Installations" 2012. This is to guarantee that all aspects are covered and to facilitate an international comparison.

11. Summary results and conclusions

The main results, uncertainties and conclusions of the study are summarized in this chapter. Some suggestions for optimizations are given.

Designs, outlines and tables as well as a list of the references used in the study are presented. The result from the cost estimation is presented in table format.

2 Methodology

2.1 Introduction

2.1.1 Purpose of the chapter

The purpose of this chapter is to give an overview of the methodology used in the present study with special focus on the costs and the amount and type of waste to be disposed of. As an introduction, general aspects on nuclear plant decommissioning cost estimating methodology and definitions are discussed.

2.1.2 General aspects on cost estimating methodology

Reliable cost estimating is one of the most important elements of decommissioning planning. Alternative technologies may be evaluated and compared based on their efficiency and effectiveness, and measured against a baseline cost as to the feasibility and benefits derived from the technology. When the plan is complete, those cost considerations ensure that it is economically sound and practical for funding.

Estimates of decommissioning costs have been performed and published by many organizations. The results of an estimate may differ because of different work scopes, different labour force costs, different money values because of inflation, different oversight costs, the specific contaminated material involved, the waste stream and peripheral costs associated with that type of waste, or applicable environmental compliance requirements. A reasonable degree of reliability and accuracy can only be achieved by developing decommissioning cost estimates on a case-by-case site-specific basis. There is no universally accepted standard for developing cost estimates, or for that matter, any clear reference for terminology used in decommissioning.

One significant factor to consider in the cost estimation process is if there is a final repository available for the short-lived low and intermediate level waste, the long-lived low and intermediate level waste and the high level radioactive waste. In Sweden, final repositories will be available at the time of decommissioning, which brings with it that free releasing of materials must not be done at all cost, but some of the low level waste that could otherwise be decontaminated and free released can be deposited in the final repository. This has a huge impact on the cost estimation for the whole decommissioning programme.

2.1.2.1 Types of cost estimates

There are three types of cost estimates that can be used and each have a different level of accuracy (Taboas et al. 2004). These cost estimate types and corresponding accuracies, estimated with today's prerequisites such as authority requirements and value of money, are summarized in the following paragraphs.

- Order-of-Magnitude Estimate: One without detailed engineering data, where an estimate is prepared using scale-up or -down factors and approximate ratios. It is likely that the overall scope of the project has not been well defined. The level of accuracy expected is –30% to +50%.
- Budgetary Estimate: One based on the use of flow sheets, layouts and equipment details, where the scope has been defined but the detailed engineering has not been performed. The level of accuracy expected is –15% to +30%.
- Definitive Estimate: One where the details of the project have been prepared and its scope and depth are well defined. Engineering data would include plot plans and elevations, piping and instrumentation diagrams, one-line electrical diagrams and structural drawings. The level of accuracy expected is –5% to +15%.

It is apparent from these estimate types and levels of accuracy expected that even in the most accurate case, a definitive estimate is only accurate to –5% to +15%. The cost estimator needs to exercise his/her judgment as to the level that the input data will support. In developing a funding basis for a project, the estimator includes sufficient margin (or contingency) to account for a potential budget overrun to account for this level of uncertainty.

2.1.2.2 Developing the cost estimate

Costs may be estimated in a number of ways. Recorded experience from other decommissioning projects, estimating handbooks and equipment catalogue performance data are some of the sources used to develop cost data. The techniques used for preparing cost estimates will necessarily vary with the project's degree of definition; the state-of-the-art of the project; the availability of databases, cost estimating techniques, time, and cost estimators; and the level of engineering data available. Some of the more common estimating techniques are described in the following paragraphs.

- Bottom-up Technique: Generally, a work statement and set of drawings or specifications are used to extract material quantities required for executing each discrete task performed in accomplishing a given activity. From these quantities, direct labour, equipment, and overhead costs can be derived.
- Specific Analogy Technique: Specific analogies depend upon the known cost of an item used in prior estimates as the basis for the cost of a similar item in a new estimate. Adjustments are made to known costs to account for differences in relative complexities of performance, design and operational characteristics.
- Parametric Technique: Parametric estimating requires historical databases on similar systems or subsystems. Statistical analysis is performed on the data to find correlations between cost drivers and other system parameters, such as design or performance. The analysis produces cost equations or cost estimating relationships that may be used individually or grouped into more complex models.
- Cost Review and Update Technique: An estimate may be constructed by examining previous estimates of the same or similar projects for internal logic, completeness of scope, assumptions and estimating methodology.
- Expert Opinion Technique: This may be used when other techniques or data are not available. Several specialists may be consulted iteratively until a consensus cost estimate is established.

The method widely adopted in estimating and which is used in this study is the bottom-up technique, based on a building block approach known as the work breakdown structure (WBS). The building block approach follows the same logic whether the estimate is being generated to support a demolition or construction scenario. Using this approach, a decommissioning project is divided into discrete and measurable work activities. This division provides a sufficient level of detail so that the estimate for a discrete activity can apply to all occurrences of the activity.

2.1.2.3 Cost element definitions

It is constructive and helpful to group elements of costs into categories to better determine how they affect the overall cost estimate. To that end, the cost elements are broken down into activity-dependent, period-dependent, and collateral costs as defined in the following paragraphs. Contingency, another element of cost, is applied to each of these elements on a line-item basis (is described separately) because of the unique nature of this element of cost.

Activity-dependent costs:

Activity-dependent costs are those costs associated with performing decommissioning activities. Examples of such activities include decontamination; removal of equipment; and waste packaging, shipping and burial. These activities lend themselves to the use of unit cost and work productivity factors (or work difficulty factors) applied against the plant and structure's inventories to develop the decommissioning cost and schedule.

Period-dependent costs:

Period-dependent costs include those activities associated primarily with the project duration: engineering, project management, dismantling management, licensing, health and safety, security, energy, and quality assurance. These are primarily management staffing level costs, developed by estimating the manpower loading and associated overhead costs based on the scope of work to be accomplished during individual phases within each period of the project.

Collateral and special item costs:

In addition to activity and period-dependent costs, there are costs for special items, such as construction or dismantling equipment, site preparation, insurance, property taxes, health physics supplies, liquid radioactive waste processing and independent verification surveys. Such items do not fall in either of the other categories. Development of some of these costs, such as insurance and property taxes, is obtained from owner-supplied data.

Contingency:

Contingency can be defined as "a specific provision for unforeseeable elements of cost within the defined project scope, particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events that increase costs are likely to occur."

The cost elements in a decommissioning cost estimate are based upon 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.

Early decommissioning cost estimates included a contingency of 25% that was applied to the total project cost. More recent and accurate approaches apply contingencies on a line item basis, yielding a weighted average contingency for the cost estimate.

Scrap and salvage:

The cost estimate includes an evaluation of the scrap and/or salvage values from material that are determined to be clean, or that were never exposed to radioactive or hazardous material contamination. The evaluation is based on recent cost data obtained from one or more of the references included in this section.

Salvage is defined as removed material that has an identified market for resale or reuse at a specific facility. Accordingly, pumps, motors, tanks, valves, heat exchangers, fans, diesel engines and generators, etc are the types of components that are candidates for salvage. Scrap is defined as removed material that is certified to be non-contaminated or -activated, and may be sold to a scrap dealer for ultimate recycling as a raw material.

Examples of scrap material are copper wires and bus bars, stainless steel plates and structural members, carbon steel and stainless pipes, carbon steel structural shapes, beams, plates, etc.

The market for salvageable material from facilities that have used radioactive material is limited, owing to the very specific purpose for which they were intended. Market prices fluctuate depending on the buyer's expense to remove the component intact and to package it and transport it to its new application in a reusable condition. These expenses reduce the resale value of salvaged material.

For steel scrap, material is sold on an as-is, where-is basis. There are no warrantees or representations as to the reusability of the item. Market prices are usually posted daily in newspapers and journals. Site reuse for new productive applications after decommissioning is another way of partly offsetting decommissioning costs.

Work Breakdown Structure (WBS):

The WBS is used to categorize cost elements and work activities into logical groupings that have a direct or indirect relationship to each other. The work groupings are usually related to the accounting system, or chart of accounts used for budgeting and tracking major elements of the decommissioning costs.

WBS levels:

The WBS elements are generally arranged in a hierarchal format similar to a company's organization chart. The topmost level of the WBS would be the overall project. The second level would be the major cost groupings under which project costs would be gathered. The next level would be the principal component parts of each direct or indirect cost category for that cost grouping. Subsequent levels are often used to track details of the component parts of the grouping so that a clear understanding of all the cost bases can be made.

2.1.2.4 Cost estimating process

A thorough cost estimating process flows from an overview of the project, to the scenarios evaluated or selected, to the assumptions critical to the approach, to the details of the cost elements and the work schedule, and then to a summary of the principal cost elements. While there are no hard and fast rules for formatting the process, there are logical guidelines to follow so that cost estimates can be easily tracked and compared.

Scope of work:

The scope of work for the project needs to be clearly stated at the outset of the estimate to ensure the estimator and reader understands what is included in the estimate, and the extent of effort required. The scope identifies assumptions and exclusions of the systems and structures to be removed and dismantled, and the amount of site restoration required.

Decommissioning strategies:

The decommissioning strategies to be evaluated are immediate dismantling, deferred dismantling or entombment.

Collection of information:

A unit-specific estimate uses defined engineering data, including site and plot plans, general arrangement and architectural drawings, piping and instrument diagrams, one-line electrical diagrams, equipment specifications, reference manuals, etc to provide a basis for the facility systems and structures requiring decontamination and dismantling. Data collection includes the site radiological and hazardous material characterization information; site specific inventory of systems and structures; local labour costs for skilled labour and management; local consumables and materials costs; and taxes, insurance, engineering and regulatory fees.

Preparation of the cost estimate:

The application of unit costs to the inventory of systems and structures for each dismantling activity provides the activity-dependent costs. The estimate of the project management staff costs for the duration of the project provides the period-dependent costs. Collateral costs and contingency are added to develop the total decommissioning cost.

Preparation of the schedule:

The overall schedule is developed from a logical and planned sequence of activities. The duration of each activity is estimated from the individual activity steps, and the sequence evaluated to obtain the critical path (longest time) to accomplish the work. Iterations are often necessary to arrive at a reasonable schedule. This work is usually performed using scheduling computer software. The decommissioning cost estimate and schedule are not stand-alone documents; they are an integral part of the planning for a project from the concept to the final implementation. The cost estimate and schedule are linked inseparably, as changes to the cost affect the schedule as to when activities may be accomplished, and changes to the schedule affect the overall cost. An accurate cost estimate and schedule provide the ability to track costs and project trends.

2.1.3 General aspects on waste amount estimation methodology

The accurate estimate of the waste quantities and activities to be generated during the dismantling operations and of the associated radiological burden requires a thorough and comprehensive inventory of all the plant system components and structures subject to potential radioactive contamination.

This information has been completed with data obtained from the plant owner SKB and from previous studies, Haglind (2006) and Hallberg and Eriksson (2008). In those instances where the inventory fails to include required data, e.g. equipment weights or piping length runs, the corresponding estimates are based on the application of duly justified criteria, assumptions and extrapolations. Engineering judgement has also been used to fill the gaps encountered in the available information. Building data are mainly obtained from system descriptions and layout drawings.

2.2 Methodology applied in the present study

2.2.1 Introduction

This section presents an overview of the methodology used in the present study of Clink with special focus on the costs estimate and the amount of waste to be disposed of. The methodology on a more detailed level can be found in the individual chapters.

The methodology used is similar to the methodology used in the Reference Plant Decommissioning Study (Oskarshamn 3) (Gustafsson et al. 2006).

2.2.2 Identifying the scope of work

The scope of work for the decommissioning work project needs to be clearly stated at the outset of the study to ensure that the author, cost estimator and reader understand what is included in the study, and the extent of effort required. The scope identifies assumptions and exclusions of the systems and structures to be removed and dismantled, and the amount of site restoration required. It also identifies the time period and the cost categories to be considered including the plant and site status at the starting point as well as the ultimate aim of the decommissioning. Also, the decommissioning strategies (immediate dismantling, deferred dismantling or entombment) have to be defined.

The scope is presented in Chapter 1, Section 1.4.

2.2.3 Inventory of systems, components and structures

2.2.3.1 Plant metal inventory

The inventory of process and electrical equipment, piping, cables, insulation and all structures was obtained from the plant owner SKB. It is denominated as Plant Metal Inventory. This information was then supplemented by information from system descriptions, component specifications and drawings and stored in detailed form as MS-Excel lists. By using Pivot Table Reports the information has been compiled and on suitable levels presented in Chapter 5, Section 5.3.

2.2.3.2 Building data and concrete inventory

The Building data and Concrete Inventory has been obtained from SKB. A summary of the information is presented in Chapter 5, Section 5.4.

2.2.4 Radiological characterization and inventory

The nature and extent of contamination at the different areas of the facility under consideration have been characterized. The characterization is based on the expected levels at time for decommissioning. Nuclide vectors for different types of waste with activated corrosion products and fission products and actinides are presented in Chapter 4.

The materials inventory presented in Chapter 5 has been completed with a classification into contamination categories and the amount of material in each radiological classification has been estimated. The waste classification has been based on specific activity data from the databases used in Chapter 5 together with some complementary information and engineering judgements. By using pivot table reports the information has been compiled and presented in Chapter 6. Finally, the numbers of waste containers have been calculated from the amount of waste, packing density, container volumes and load capacity.

The activity inventory was obtained from Westinghouse (Oliver 2013).

2.2.5 Identifying suitable dismantling techniques

Information on the typical tools and techniques that could be used during the decommissioning of Clink has been compiled. In general the techniques have been selected on the basis of previous experience on both national and international decommissioning projects, particularly US experience as more decommissioning projects have been completed or are in progress there. In some cases, the chosen technique may not be the same as might be chosen if a similar task were to be performed during a plant refurbishment or upgrade. This is a reflection of the less precise nature of the dismantling work and the fact that the plant will not need to be restored to an operational state upon completion, either by reinstatement of equipment or clean-up to the as-operated condition. Experience values have been used so the costs have not been overestimated in that regard.

Preferred sequences of decommissioning tasks and the required logistics, e.g. for waste item and waste package movement within the plant have been identified. This was based on previous experience or detailed studies made for other plants, suitably modified to reflect the specifics of the Clink plant.

The philosophy adopted within the present study has been that only proven existing techniques are employed. This is so that:

- SKB can be confident that the technique described is suitable for the task and has already been used for a similar application, generally in the US where more decommissioning has been completed to date.
- There will be little or no tooling development works required, which would lead to development cost and time plus potential cost/programme risk to the delivery of the project if tools could not be developed and deployed in accordance with the overall project programme.

2.2.6 Identifying suitable waste management techniques

The options for the decommissioning of areas and for the management of the associated wastes have been evaluated at a conceptual level.

The waste management technique chosen for this study is a fit-for-purpose, modular waste screening facility constructed within one of the bigger rooms inside Clink or a similarly sized building. The facility makes use of re-usable modular containment and shielding, combined with the use of existing waste treatment buildings and their waste screening, size reduction, packaging and shipping systems. The option has been evaluated in the context of the anticipated waste amounts, waste monitoring and packaging requirements and relevant legal and regulatory considerations, see Chapter 8.

A second option is described in Appendix A3.3 which is a fully engineered waste management facility contained within a purpose-built, dedicated structure.

2.2.7 Preparation of decommissioning programme

The time schedule has been structured according to the project WBS. The milestones have mainly been collected from the study of dismantling operation (Pålsson and Hedin 2005) and from Hallberg and Eriksson (2008).

For dismantling activities, like removal of ordinary sized process equipment (pumps, tanks, valves, pipes etc.), a specific model has been used. This model was established during the Process System Dismantling Study (Lönnerberg 1994) and is mainly based on a combination of theoretical analysis and field experience, mostly from dismantling of equipment during repair work. Finally, the duration of the building demolition and site remediation activities have been based on the study of building demolition (Ericsson 2005).

2.2.8 Preparation of cost estimate

2.2.8.1 Introduction

The cost estimate can, in general, be regarded as a budgetary estimate, i.e. it is mainly based on the use of flow sheets, layouts, databases and equipment details. The scope has been defined but the detailed engineering has not been performed. However, the building demolition costs can be regarded as more accurate.

The Bottom-up Technique mentioned in Section 2.1.2.2 has mainly been used, in some cases in in combination with expert opinions with the Specific Analogy Technique and expert opinions.

2.2.8.2 Establishing a work breakdown structure

Many different criteria could be applied when establishing a Work Breakdown Structure (WBS) for a large project. The following have been considered in the present study:

- The top level items should be divided by time-depending milestones and this leads to the division into the main phases: operation, preparation for dismantling, nuclear dismantling and conventional demolition. For all phases, except for the dismantling and conventional demolition phases, only activities related to dismantling and demolition activities should be included. For Clink there will be no defueling (Hallberg and Eriksson 2008).
- The classification of activities that has been used in the study of dismantling operation (Pålsson and Hedin 2005), and information in the study of personnel during decommissioning operation (SKBdoc 1359832) should also be used here, as far as reasonable. This implies that the classification of costs into own personnel, operational costs, fixed costs, organizational costs and project costs should not be changed.
- WBS items, whose sizes are dependent on time, should be separated from items whose sizes are dependent on the actual work or activities that are carried out.
- WBS items related to so-called conventional dismantling and demolition should be separated. With conventional dismantling is understood all dismantling/demolition that is executed after that the particular building has been classified as non-radioactive.
- A WBS item, after break-down to the most detailed level, should be able to be clearly linked to a single item in the OECD/NEA structure (for explanation, see Section 10.4.2).
- Similar WBS structure as for other studies is a benefit as it enables comparisons.
- Break-down should be done to a level that enables existing data in the form of inventory lists etc to be used with reasonable additional efforts for data separation per building or similar.
- The basis for each item should be traceable.

It has been assumed that the plant owner has their own staff for operation of the site during the dismantling phase and that the project organization is established early in the process. This organization will purchase all services needed, mainly through larger contractors.

Based on the above mentioned criteria, a WBS has been established. The time schedule mentioned in the previous section has also been structured according to this WBS.

2.2.8.3 Utility personnel costs

The utility personnel costs have been calculated from a given organization combined with the duration and the direct yearly costs for the personnel categories in question. The number of personnel has been collected from studies of personnel during decommissioning operation (SKBdoc 1359832) of nuclear power plants and sites and adjusted to the Clink facility.

2.2.8.4 Operational costs

Some of the operational costs have been calculated from yearly costs given in the study of dismantling operation (Pålsson and Hedin 2005) combined with the duration. The costs include operation and maintenance, organizational costs and fixed costs. Some personnel costs have been collected from studies of personnel during decommissioning operation (SKBdoc 1359832) of nuclear power reactors and sites and adjusted to the Clink facility.

2.2.8.5 Project management and administration costs

The project management and administration costs have been calculated from a given utility project organization combined with the duration and the direct yearly costs for the personnel categories in question. The number of personnel has been collected from studies of personnel during decommissioning operation (Taboas et al. 2004, SKBdoc 1359832) of nuclear power reactors and sites and adjusted to the Clink facility.

2.2.8.6 Dismantling and demolition costs

Process equipment

In order to calculate the work associated with the dismantling of the process equipment the plant metal inventory has been divided into so-called macro-components. This implies that components, piping etc have been subdivided into intervals with respect to size and for each interval a characteristic quantity like length or weight have been calculated. The duration of the dismantling activities have then been calculated by means of efficiency figures and site factors, based on analyses and experiences and, by combining with work team compositions and hourly costs for various personnel categories, the work (manhours) and costs have been obtained. A detailed description of the methodology is given in Chapter 10, Section 10.3.8.2.

The project management and administration work within the process dismantling contractor's organization has been collected from Lönnerberg (1994) and so have also the costs for the procurement and consumption of tools.

Building demolition and site remediation

The costs for the building demolition have been collected from the study of building demolition (Ericsson 2005) and are made up from basic costs and general site expenses and contractor fees.

The basic costs have been derived by means of a so called production cost estimate, which implies that the costs are determined at activity level. The need for material, work and equipment is assessed for each activity and then the cost is estimated. However, relevant experience values from a project of this nature are not available. Instead, information from large conventional (non-nuclear) demolition projects has been used after appropriate adaptation.

"General site expenses and contractor fees" includes costs for the resources necessary for the general work and facilities necessary for the primary demolition work.

The work necessary for cleaning and clearance of controlled area buildings has also been collected from Ericsson (2005).

2.2.8.7 Waste related costs

The cost for waste processing and packaging consists of equipment costs including installation and dismantling of the equipment and operating costs. The equipment costs have been estimated based on information from suppliers. The operating costs have been calculated from the amount of waste processed, similar to the process equipment dismantling costs.

The costs for the waste containers with radioactive waste, transports of conventional waste to landfill and landfill fees have been calculated from the number of containers, transports etc and the unit costs.

2.2.8.8 Contingency

Costs in the present study have been calculated without associated contingency factors. Thus, in a further analysis it is possible to apply different contingencies depending on the particular case that is being studied. There is otherwise a risk that factors are applied on each other in several steps, reflecting an unjustified level of risk. Suitable contingencies have been estimated and presented separately. It should be observed that contingencies are highly relevant for calculated cost figures while an estimated figure, based on experience, naturally includes most of the contingency in itself. That is, if the conditions and contexts are similar for the item that is estimated and the item that is experienced.

3 General description of Clink

3.1 Introduction

This chapter describes “Clab”, the central intermediate storage for spent nuclear fuel, and “Ink”, the future encapsulation facility. In the establishment handling, storage and encapsulation of spent nuclear fuel, but also handling and storage of core components, from the Swedish NPPs are taking place.

The spent nuclear fuel is stored in an intermediate storage in Clab, in pools placed in rock shelters about 30 m under ground. In the storage most of the radiation in the fuel is subsided. The storage is under continuous surveillance and control in order to protect the surroundings from emissions. In the encapsulation building the spent nuclear fuel is encapsulated in copper canisters.

3.2 Main data

3.2.1 Clab – main process

Clab consist of receiving and handling building and intermediate storage of spent nuclear fuel and handling of radioactive waste. After cooling down at the NPPs for about one year the spent nuclear fuel is delivered to the receiving building and placed in cassettes. The cassettes are transported to the rock shelters for intermediate storage for 30 years before they are sent to Ink for encapsulation. The radioactive operational waste from Clab is handled and packed for transport to SFR. Figure 3-1 describes the normal handling of the spent fuel in Clab.

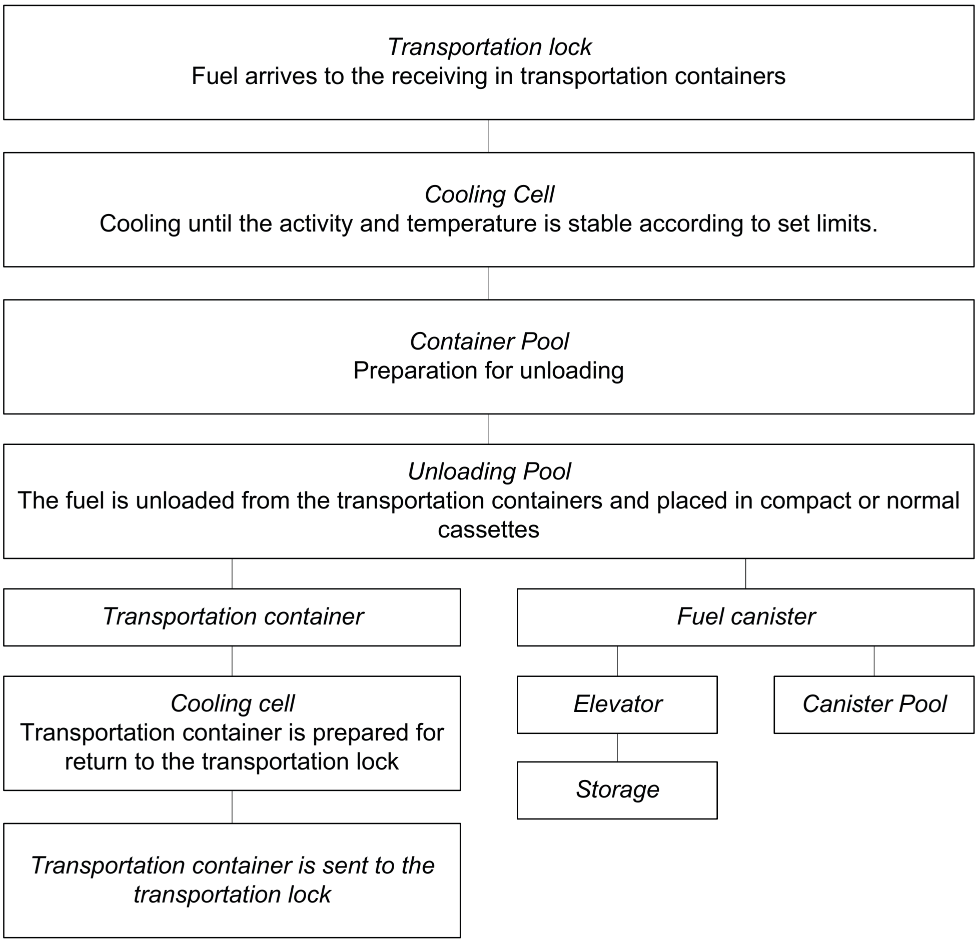


Figure 3-1. *Normal handling of fuel in Clab.*

3.2.2 Ink – main process

The main process of Ink comprises handling and encapsulation of spent nuclear fuel. In the encapsulation sections handling pool the spent fuel is moved from the fuel canisters to the transportation container. The transfer containers are then moved to the handling cell where the spent fuel is dried and place in the copper canisters (SKB 2006). The copper canisters containing the spent fuel is then further prepared and sealed. After sealing the copper canister is controlled and cleaned before it is transported to the final repository outside of Clink. The radioactive waste that arises from the encapsulation is handled, packed and transported to SFR. A flow chart of the main steps of the encapsulation of spent fuel is shown in Figure 3-2, see also Appendix 1, Figure A1-2.

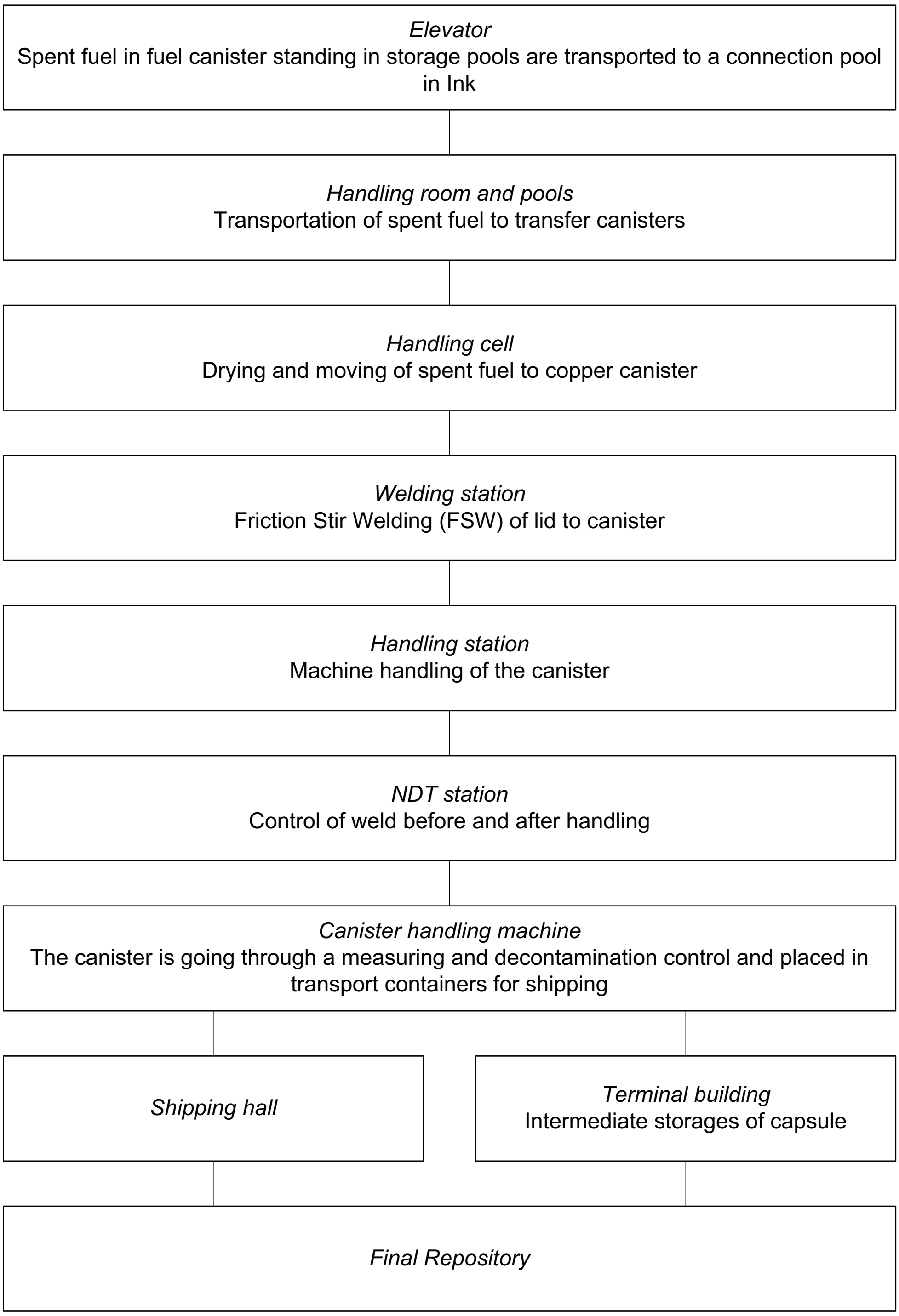


Figure 3-2. *Normal handling of spent fuel in Ink.*

3.3 Functionality

The establishment is divided into seven main parts:

- Receiving Building
- Storage Building
- Electrical Power Building
- Supporting Systems Building
- Encapsulation Building
- Terminal Building
- Staffing Building.

There are also some additional buildings as garages etc within the premises. The receiving building, electrical power building and the encapsulation building are above ground. The fuel elevator is adjacent to the receiving building and is the link between the receiving building, the underground storage room and the encapsulation building. The supporting systems building and the storage building are connected with a vertical shaft for personnel and process and services systems.

3.3.1 Buildings and rock shelters

In Table 3-1 the Clink buildings and their content is summarized.

Table 3-1. Buildings in Clink, with their system numbers and content.

Building	System number	Controlled / uncontrolled area	Content
Main Buildings at ground level:			
Receiving building (M)	121	Controlled	Equipment and pools for spent fuel transport containers and spent fuel
Supporting Systems Building (H)	122	Controlled	System for: – Cooling and cleaning of pool water and spent fuel transport containers – Cleaning of process and floor drainage water – Taking care of active waste – Ventilation of the controlled area
Electrical Power Building (E)	123	Uncontrolled	– Electrical supply and control – Ventilation system for non controlled area – Control room – Intermediate cooling system pumps and heat exchangers – Compressed air system
Encapsulation Building (A)	124	Controlled	Equipment and pools for encapsulation of spent fuel in copper canisters
Terminal Building (B)	146	Controlled	Reloading and storage room for copper canisters, storage of transportation containers.
Buildings under ground:			
Storage Building (F)	131	Controlled	– Tunnel with transportation between two storage buildings and the fuel elevator – 4 storage pools in each storage building – 1 smaller pool in each storage building – Service pool for the fuel elevator trolley in the transportation channel
Transportation tunnels (T)	135	Uncontrolled	System of tunnels leading from ground level outside the main building to the two rock shelters and the lower supporting system building.The tunnels emanate from a joint entrance and branch off below ground.
Lower Supporting Systems Building (H)	122	Controlled	Level tank and pumps for the cooling system of the storage tank.
Other buildings:			
Personnel and Entrance Building (P)	141	Uncontrolled	Offices and staff spaces including changing-rooms. Separate passages for controlled and non controlled areas.
Garage, Storage (G) and Service (S) Buildings	142	Uncontrolled	Garage, storage rooms, workshop, cleaning facility.
Guardian Building (V)	144	Uncontrolled	Surveillance, entrance control
Admission Building (R)	145	Uncontrolled	At the sea border south of the premises and contains water inlet, cleaning and cooling water pumps.

3.3.2 Pools

General

The retention of water is essential from a safety perspective. All pools are equipped with sealing plates of metal and leaking detection systems and collection systems for the water.

No penetrations to the pools are placed at a level below the lowest water level of the pool. In order to have enough shielding a minimum of 2 meters of water coverage is needed.

The different pools shall influence the each other as little as possible. Each pool is isolated from the other pools by steel plated doors with rubber sealing strips. The door sill is higher than the upper level of the stored spent fuel.

Storage pools and channels (System 151)

The storage pools will under a long time serve as storage of canisters with spent fuel assemblies and core elements. The storage pools are located in the storage building about 30 m below ground level. The system consists of eight storage pools and two other pools placed in two different rock shelters. The storage pools are connected to each other with a transportation channel. The transportation channel can be isolated from the storage pools by doors in each end. The storage pools in the first rock shelter are connected with the fuel elevator.

The pools in the storage building contain storage places for the fuel canisters and canister racks (System 245). The canister racks have strearing cones on the bottom of the pool and supporting bars.

Pools in the receiving building (System 154)

The pools in the receiving building, Table 3-2, are container pools (M03.23, M03.26), which are storage pools for transporting containers at unloading and the unloading pool (M03.24, M03.27). From the container pool the spent fuel or the core components are lifted to the unloading pool. Another pool in the receiving building is the linking pool (M03.28), which links all pools together. Each pool can be isolated with doors. In the receiving building the fuel canister pool (M03.30) is the storage place for empty fuel canisters and also the buffer storage for filled fuel canisters. The service pool (M03.25) in the receiving building stores equipment for measuring the nuclear decay heat on spent fuel assemblies.

Pools in the encapsulation building (System 152)

The pools in the encapsulation building are on ground level and are accessed from the receiving building (System 121) and the Storage building (System 131) via the fuel elevator (System 233). The water level of the Ink pools is at the same level as the receiving pools. The principle of the pools can be seen in Table 3-2. There is a linking pool which links the fuel elevator in Clab to the handling pool. In the handling pool there is equipment for measuring the decay heat of the spent fuel (system 253) and canister racks (System 226).

Table 3-2. Pools in the receiving building.

Pool	Number
Container Pools	M03.23, M03.26
Unloading Pool	M03.24, M03.27
Linking Pool	M03.28
Canister Pool	M03.30
Service Pool	M03.25

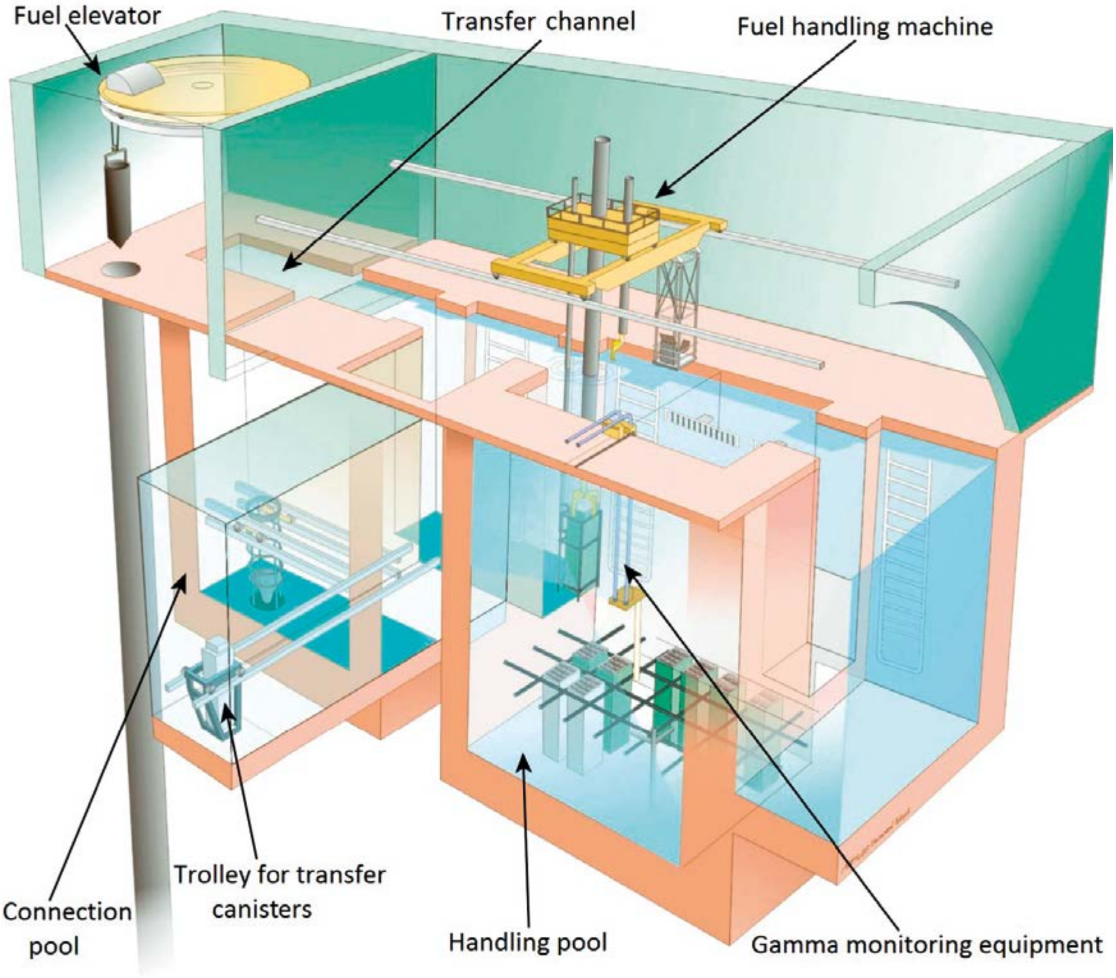


Figure 3-3. *Pools in the encapsulation building.*

3.3.3 Site

The boundaries for the decommission study of Clink consist of everything within 30 m from the outer fence, the storage building (F) for spent fuel below ground level and the admission building (R) which situated at the sea border. A good overview of the boundaries in this study can be shown in Figure A3-1 and Figure 3-4.

Clink site

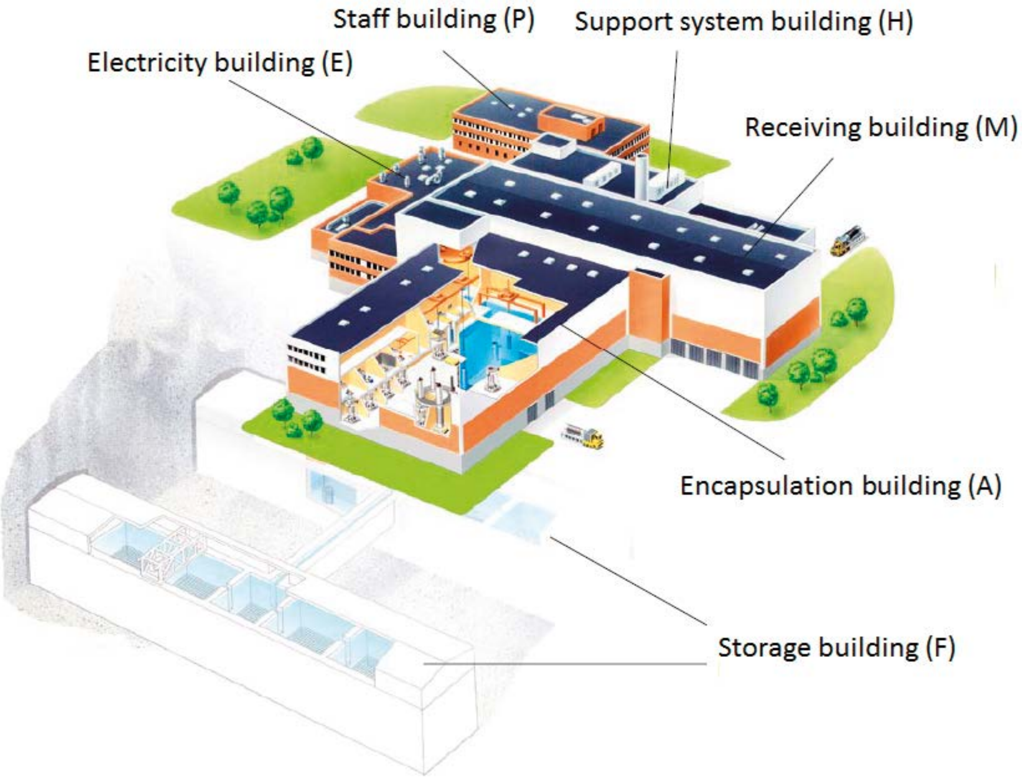


Figure 3-4. *Clink site with ground and underground levels.*

4 Plant radioactivity characterization

4.1 General

To assess the contribution of Clink to the final repository of SFR concerning total activity and amounts of decommissioning waste, the levels of activity and contamination in Clink has been studied. This chapter presents the radiological characteristics of the decommissioning waste for Clink. The total activity inventory, the activity inventory per system and the number of waste containers are given in Chapter 6.

4.2 Process equipment contamination

The activity estimations for Clink is described in Oliver (2013) where also all systems that are needed to be stored in the final repository are described together with systems that are assessed to be able to be decontaminated and the decommissioning waste to be free released.

4.2.1 General prerequisites

The main activity source that is considered to contribute to the decommissioning waste in Clink is the activity in the fuel crud that can be released from the fuel during its handling and storage time in Clink. The fuel crud consists of activated corrosion products and residues of fission products and actinides from fuel failures. Fission products can also be dissolved from damaged fuel that is handled in Clink, where Cs-137 is assumed to be the dominating fission product and other fission products are considered to be orders of magnitude lower than Cs-137.

The main part of the released crud and released nuclides will be captured in the filters and ion-exchange resins in the different cleaning systems in Clink during operation, but some will deposit on components surfaces which will contribute to the decommissioning waste of Clink. Due to the high solubility of cesium in water, no cesium is assumed to be deposited on the system surfaces. Note that neutron activation processes are not needed to be considered in Clink due to insignificant neutron flux in the plant compared to a nuclear reactor.

Clink is planned to be decommissioned 30 years after the last spent fuel batch is transferred to Clab. The last reactor planned to be shutdown in Sweden is Oskarshamn 3 (O3), which is planned to close January 2045. The spent fuel can be moved from O3 one year after shutdown, i.e. January 2046 and thus Clink is assumed to be able to be decommissioned in the year 2076. This means that the freshest fuel in Clab will be able to decay for 30 years before Clink is decommissioned. The year 2076-01-01 is set as a reference year 0 throughout this study since the date for decommission of Clink is not certain.

4.2.2 Process equipment activity levels

The following systems need to be considered for the final repository and thus a total activity is estimated for these systems.

- Surface contamination of all systems in contact with radioactive water (311, 313, 324, 371, 372)
- Contaminated concrete in the pools 151, 152 and 154 (caused by leaks in the pool liners)
- The leak detection system for pools (247)
- Spent resin storage system (373)
- The waste solidification plant (343).

In Ink, only contaminated concrete from system 152 (the pool) and the cooling- and clean-up system (313), which is used for both Clab and Ink, are assessed to be needed to be deposited in the final repository. All other systems are assumed to be able to be decontaminated and free released. The handling cell and the fuel drying system (system 255 and 351) in Ink are systems where fuel will be dry-handled and there will thus be a higher risk for contamination from release of crud during the handling. Based on experience from Studsvik (Ekberg 2002), these systems are however assessed to be able to be decontaminated but when operating experience from Ink is available this assumption should be re-evaluated. The hotcell in Clab (system 267) is assumed to be free released in this report.

The activity levels in the different systems in Clink in year 0 are based on the estimations presented in Oliver (2013). The total activity in each system can be seen in Table 4-1.

The total surface activity of each system can be calculated by dividing the total activity with the total system surface area. The contribution from valves has been assumed to be negligible in comparison with other components due to their small surface area and weight. The nuclide spectra for different systems are summarized in Table 4-2 and Table 4-3.

Table 4-1. Total activity levels in the different systems in Clink as of year 0 (after decay correction but before decontamination).

System in Clab	Total System Surface Area (m^2)	Total System Activity Before Decon (Bq)
247	20	1,1E+08
311	554	7,9E+11
313	483	6,2E+09
324	1,468	3,2E+09
343	3	4,6E+08
371	347	1,9E+09
372	283	1,5E+08
373	41	1,1E+10

Table 4-2. Nuclide spectra for the different process cleaning systems in Clab, in year 0 (before decontamination).

Nuclide	System 311 Tubes (Bq/m^2)	System 311 Heat Exchangers (Bq)	System 313 Tubes (Bq/m^2)	System 313 Heat Exchangers (Bq)	System 324 Tubes (Bq/m^2)	System 324 Heat Exchangers (Bq)	System 247 Tubes (Bq/m^2)
Mn-54	4,2E-02	4,5E-02	4,2E-04	2,9E-04	1,5E-04	3,4E-04	1,5E-04
Fe-55	1,1E+07	1,2E+07	1,1E+05	7,7E+04	4,1E+04	8,8E+04	4,1E+04
Co-58	1,7E-38	1,8E-38	1,7E-40	1,2E-40	6,2E-41	1,3E-40	6,2E-41
Co-60	4,4E+08	4,8E+08	4,4E+06	3,1E+06	1,6E+06	3,6E+06	1,6E+06
Ni-59	7,4E+06	8,0E+06	7,4E+04	5,2E+04	2,7E+04	5,9E+04	2,7E+04
Ni-63	9,0E+08	9,8E+08	9,0E+06	6,3E+06	3,4E+06	7,3E+06	3,4E+06
Mo-93	4,4E+04	4,8E+04	4,4E+02	3,1E+02	1,6E+02	3,6E+02	1,6E+02
Nb-93m	1,0E+08	1,1E+08	1,0E+06	7,3E+05	3,9E+05	8,4E+05	3,9E+05
Nb-94	3,6E+05	3,9E+05	3,6E+03	2,5E+03	1,3E+03	2,9E+03	1,3E+03
Zr-93	3,1E+04	3,4E+04	3,1E+02	2,2E+02	1,2E+02	2,5E+02	1,2E+02
Tc-99	6,7E+03	7,2E+03	6,7E+01	4,7E+01	2,5E+01	5,4E+01	2,5E+01
Ag-108m	9,5E+05	1,0E+06	9,5E+03	6,6E+03	3,5E+03	7,7E+03	3,5E+03
Ag-110m	6,6E-06	7,2E-06	6,6E-08	4,6E-08	2,5E-08	5,3E-08	2,5E-08
Sb-125	6,0E+04	6,5E+04	6,0E+02	4,2E+02	2,2E+02	4,9E+02	2,2E+02
Ta-182	4,7E-21	5,0E-21	4,7E-23	3,3E-23	1,7E-23	3,8E-23	1,7E-23
Pu-238	6,8E+03	7,4E+03	6,8E+01	4,8E+01	2,5E+01	5,5E+01	2,5E+01
Pu-239	1,2E+03	1,2E+03	1,2E+01	8,1E+00	4,3E+00	9,3E+00	4,3E+00
Pu-240	1,6E+03	1,7E+03	1,6E+01	1,1E+01	5,9E+00	1,3E+01	5,9E+00
Pu-241	3,9E+04	4,3E+04	3,9E+02	2,8E+02	1,5E+02	3,2E+02	1,5E+02
Am-241	1,1E+03	1,2E+03	1,1E+01	8,0E+00	4,2E+00	9,2E+00	4,2E+00
Am-243	9,0E+01	9,8E+01	9,0E-01	6,3E-01	3,4E-01	7,3E-01	3,4E-01
Cm-242	2,3E-19	2,5E-19	2,3E-21	1,6E-21	8,7E-22	1,9E-21	8,7E-22
Cm-244	2,1E+03	2,2E+03	2,1E+01	1,4E+01	7,7E+00	1,7E+01	7,7E+00
Total	**1,5E+09**	**1,6E+09**	**1,5E+07**	**1,0E+07**	**5,5E+06**	**1,2E+07**	**5,5E+06**

Table 4-3. Nuclide spectra for the different waste systems in Clab, in year 0 (before decontamination).

Nuclide	System 343 Tubes (Bq/m^2)	System 371 Tubes (Bq/m^2)	System 372 Tubes (Bq/m^2)	System 373 Tubes (Bq/m^2)
Mn-54	7,0E-10	1,5E-04	1,5E-05	7,7E-03
Fe-55	1,2E+04	4,1E+04	4,1E+03	2,0E+06
Co-58	3,3E-70	6,2E-41	6,2E-42	3,1E-39
Co-60	5,9E+06	1,6E+06	1,6E+05	8,2E+07
Ni-59	1,4E+06	2,7E+04	2,7E+03	1,4E+06
Ni-63	1,5E+08	3,4E+06	3,4E+05	1,7E+08
Mo-93	8,2E+03	1,6E+02	1,6E+01	8,2E+03
Nb-93m	8,2E+06	3,9E+05	3,9E+04	1,9E+07
Nb-94	6,6E+04	1,3E+03	1,3E+02	6,7E+04
Zr-93	5,8E+03	1,2E+02	1,2E+01	5,8E+03
Tc-99	1,2E+03	2,5E+01	2,5E+00	1,2E+03
Ag-108m	1,7E+05	3,5E+03	3,5E+02	1,8E+05
Ag-110m	2,3E-15	2,5E-08	2,5E-09	1,2E-06
Sb-125	6,6E+01	2,2E+02	2,2E+01	1,1E+04
Ta-182	5,8E-41	1,7E-23	1,7E-24	8,7E-22
Pu-238	1,2E+03	2,5E+01	2,5E+00	1,3E+03
Pu-239	2,1E+02	4,3E+00	4,3E-01	2,1E+02
Pu-240	2,9E+02	5,9E+00	5,9E-01	2,9E+02
Pu-241	2,8E+03	1,5E+02	1,5E+01	7,3E+03
Am-241	2,1E+02	4,2E+00	4,2E-01	2,1E+02
Am-243	1,7E+01	3,4E-01	3,4E-02	1,7E+01
Cm-242	1,4E-33	8,7E-22	8,7E-23	4,3E-20
Cm-244	1,8E+02	7,7E+00	7,7E-01	3,8E+02
Total	**1,6E+08**	**5,5E+06**	**5,5E+05**	**2,7E+08**

The dominating nuclides in the activity inventory at the decommissioning date year 0 are Co-60 and Ni-63. Their contribution is 92% of the total activity.

The nuclide vectors (related to Co-60) after 30 years of decay in year 0, are given in Table 4-4 and Table 4-5. The concrete is related to the sediment in the storage pools in Clab and are therefore based on the nuclide vector described in PSAR for the storage pools in Clab (Oliver 2013).

4.2.3 Decontamination

Thorough system decontamination is assumed for the systems 247, 311, 313, 324, 343, 371, 372 and 373. A decontamination factor (DF) of 10 has been assumed. The nuclide spectrum after decontamination is presented in Table 4-6 and Table 4-7. In Table 4-8 the specific activity is presented including both before and after decontamination.

Table 4-4. Nuclide vectors for process cleaning systems (related to Co-60) after 30 years of decay in year 0.

Nuclide	System 247	System 311	System 313	System 324
Mn-54	9,4E-11	9,4E-11	9,4E-11	9,4E-11
Fe-55	2,5E-02	2,5E-02	2,5E-02	2,5E-02
Co-58	3,8E-47	3,8E-47	3,8E-47	3,8E-47
Co-60	1,0E+00	1,0E+00	1,0E+00	1,0E+00
Ni-59	1,7E-02	1,7E-02	1,7E-02	1,7E-02
Ni-63	2,1E+00	2,1E+00	2,1E+00	2,1E+00
Mo-93	1,0E-04	1,0E-04	1,0E-04	1,0E-04
Nb-93m	2,4E-01	2,4E-01	2,4E-01	2,4E-01
Nb-94	8,1E-04	8,1E-04	8,1E-04	8,1E-04
Zr-93	7,1E-05	7,1E-05	7,1E-05	7,1E-05
Tc-99	1,5E-05	1,5E-05	1,5E-05	1,5E-05
Ag-108m	2,2E-03	2,2E-03	2,2E-03	2,2E-03
Ag-110m	1,5E-14	1,5E-14	1,5E-14	1,5E-14
Sb-125	1,4E-04	1,4E-04	1,4E-04	1,4E-04
Ta-182	1,1E-29	1,1E-29	1,1E-29	1,1E-29
Pu-238	1,5E-05	1,5E-05	1,5E-05	1,5E-05
Pu-239	2,6E-06	2,6E-06	2,6E-06	2,6E-06
Pu-240	3,6E-06	3,6E-06	3,6E-06	3,6E-06
Pu-241	8,9E-05	8,9E-05	8,9E-05	8,9E-05
Am-241	2,6E-06	2,6E-06	2,6E-06	2,6E-06
Am-243	2,1E-07	2,1E-07	2,1E-07	2,1E-07
Cm-242	5,3E-28	5,3E-28	5,3E-28	5,3E-28
Cm-244	4,7E-06	4,7E-06	4,7E-06	4,7E-06

Table 4-5. Nuclide vectors for waste systems (related to Co-60) after 30 years of decay in year 0.

Nuclide	System 343	System 371	System 372	System 373
Mn-54	1,2E-16	9,4E-11	9,4E-11	9,4E-11
Fe-55	2,0E-03	2,5E-02	2,5E-02	2,5E-02
Co-58	5,6E-77	3,8E-47	3,8E-47	3,8E-47
Co-60	1,0E+00	1,0E+00	1,0E+00	1,0E+00
Ni-59	2,3E-01	1,7E-02	1,7E-02	1,7E-02
Ni-63	2,5E+01	2,1E+00	2,1E+00	2,1E+00
Mo-93	1,4E-03	1,0E-04	1,0E-04	1,0E-04
Nb-93m	1,4E+00	2,4E-01	2,4E-01	2,4E-01
Nb-94	1,1E-02	8,1E-04	8,1E-04	8,1E-04
Zr-93	9,9E-04	7,1E-05	7,1E-05	7,1E-05
Tc-99	2,1E-04	1,5E-05	1,5E-05	1,5E-05
Ag-108m	2,9E-02	2,2E-03	2,2E-03	2,2E-03
Ag-110m	3,9E-22	1,5E-14	1,5E-14	1,5E-14
Sb-125	1,1E-05	1,4E-04	1,4E-04	1,4E-04
Ta-182	9,9E-48	1,1E-29	1,1E-29	1,1E-29
Pu-238	2,0E-04	1,5E-05	1,5E-05	1,5E-05
Pu-239	3,6E-05	2,6E-06	2,6E-06	2,6E-06
Pu-240	5,0E-05	3,6E-06	3,6E-06	3,6E-06
Pu-241	4,7E-04	8,9E-05	8,9E-05	8,9E-05
Am-241	3,5E-05	2,6E-06	2,6E-06	2,6E-06
Am-243	2,8E-06	2,1E-07	2,1E-07	2,1E-07
Cm-242	2,3E-40	5,3E-28	5,3E-28	5,3E-28
Cm-244	3,0E-05	4,7E-06	4,7E-06	4,7E-06

Table 4-6. Nuclide spectra for the wastes from the different cooling- and clean-up systems in Clink, in year 0 (after decontamination).

Nuclide	System 247 (Bq)	System 311 (Bq)	System 313 (Bq)	System 324 (Bq)
Mn-54	3,0E-04	2,2E+00	1,8E-02	9,1E-03
Fe-55	8,0E+04	5,9E+08	4,6E+06	2,4E+06
Co-58	1,2E-40	9,0E-37	7,0E-39	3,6E-39
Co-60	3,2E+06	2,4E+10	1,9E+08	9,6E+07
Ni-59	5,4E+04	4,0E+08	3,1E+06	1,6E+06
Ni-63	6,6E+06	4,9E+10	3,8E+08	2,0E+08
Mo-93	3,2E+02	2,4E+06	1,9E+04	9,7E+03
Nb-93m	7,6E+05	5,6E+09	4,4E+07	2,3E+07
Nb-94	2,6E+03	1,9E+07	1,5E+05	7,8E+04
Zr-93	2,3E+02	1,7E+06	1,3E+04	6,8E+03
Tc-99	4,9E+01	3,6E+05	2,8E+03	1,5E+03
Ag-108m	6,9E+03	5,1E+07	4,0E+05	2,1E+05
Ag-110m	4,8E-08	3,6E-04	2,8E-06	1,4E-06
Sb-125	4,4E+02	3,3E+06	2,5E+04	1,3E+04
Ta-182	3,4E-23	2,5E-19	2,0E-21	1,0E-21
Pu-238	5,0E+01	3,7E+05	2,9E+03	1,5E+03
Pu-239	8,4E+00	6,2E+04	4,9E+02	2,5E+02
Pu-240	1,1E+01	8,5E+04	6,6E+02	3,4E+02
Pu-241	2,9E+02	2,1E+06	1,7E+04	8,6E+03
Am-241	8,3E+00	6,1E+04	4,8E+02	2,5E+02
Am-243	6,6E-01	4,9E+03	3,8E+01	2,0E+01
Cm-242	1,7E-21	1,3E-17	9,8E-20	5,1E-20
Cm-244	1,5E+01	1,1E+05	8,7E+02	4,5E+02
Total	**1,1E+07**	**7,9E+10**	**6,2E+08**	**3,2E+08**

Table 4-7. Nuclide spectra for the wastes from the different waste handling systems in Clink, in year 0 (after decontamination).

Nuclide	System 343 (Bq)	System 371 (Bq)	System 372 (Bq)	System 373 (Bq)
Mn-54	2,0E-10	5,4E-03	4,4E-04	3,2E-02
Fe-55	3,3E+03	1,4E+06	1,2E+05	8,4E+06
Co-58	9,4E-71	2,1E-39	1,8E-40	1,3E-38
Co-60	1,7E+06	5,7E+07	4,6E+06	3,4E+08
Ni-59	3,9E+05	9,5E+05	7,8E+04	5,6E+06
Ni-63	4,2E+07	1,2E+08	9,5E+06	6,9E+08
Mo-93	2,3E+03	5,7E+03	4,7E+02	3,4E+04
Nb-93m	2,3E+06	1,3E+07	1,1E+06	8,0E+07
Nb-94	1,9E+04	4,6E+04	3,8E+03	2,7E+05
Zr-93	1,7E+03	4,1E+03	3,3E+02	2,4E+04
Tc-99	3,5E+02	8,7E+02	7,1E+01	5,1E+03
Ag-108m	4,9E+04	1,2E+05	1,0E+04	7,3E+05
Ag-110m	6,6E-16	8,5E-07	7,0E-08	5,1E-06
Sb-125	1,9E+01	7,8E+03	6,3E+02	4,6E+04
Ta-182	1,7E-41	6,0E-22	4,9E-23	3,6E-21
Pu-238	3,3E+02	8,8E+02	7,2E+01	5,2E+03
Pu-239	6,1E+01	1,5E+02	1,2E+01	8,8E+02
Pu-240	8,3E+01	2,0E+02	1,7E+01	1,2E+03
Pu-241	8,0E+02	5,1E+03	4,2E+02	3,0E+04
Am-241	5,8E+01	1,5E+02	1,2E+01	8,7E+02
Am-243	4,8E+00	1,2E+01	9,5E-01	6,9E+01
Cm-242	3,9E-34	3,0E-20	2,4E-21	1,8E-19
Cm-244	5,1E+01	2,7E+02	2,2E+01	1,6E+03
Total	**4,6E+07**	**1,9E+08**	**1,5E+07**	**1,1E+09**

Table 4-8. Total activity and specific activity for the different systems in Clab in year 0.

System in Clab	Total System Surface Area (m²)	Total System Activity Before Decon (Bq)	Total System Mass (kg)	System Specific Activity Before Decon (Bq/kg)	DF	Total System Activity After Decon (Bq)	Specific Activity After Decon (Bq/kg)
247	20	1,1E+08	311	3,5E+05	10	1,1E+07	3,5E+04
311	554	7,9E+11	19 823	4,0E+07	10	7,9E+10	4,0E+06
313	483	6,2E+09	37 630	1,6E+05	10	6,2E+08	1,6E+04
324	1 468	3,2E+09	85 789	3,7E+04	10	3,2E+08	3,7E+03
343	3	4,6E+08	350	1,3E+06	10	4,6E+07	1,3E+05
371	347	1,9E+09	18 633	1,0E+05	10	1,9E+08	1,0E+04
372	283	1,5E+08	53 196	2,8E+03	10	1,5E+07	2,8E+02
373	41	1,1E+10	1 771	6,3E+06	10	1,1E+09	6,3E+05

4.3 Building contamination

The pools in the Clink facility have stainless steel liners, which protect the concrete structure of being contaminated by direct contact with the pool water. The protective steel liners have been shown to be easily decontaminated and will thus be assumed to be free released in this study. However, in case of a leak through the liner it is highly likely that the concrete structure behind it will be contaminated.

The estimation of the amount and activity in the contaminated concrete is described in Oliver (2013). In order to estimate the activity in the storage pools, the nuclide data for the sediment in the storage pools given in PSAR was used as a basis (Oliver 2013). The nuclide vector is shown in Table 4-9.

According to the operational- and decommissioning times described in Section 4.2, a decay time of 30 years is applied on the different nuclides.

The major contribution to the activity in the concrete after 30 years of decay time originates from Cs-137 (44%), Ni-63 (35%), and Co-60 (17%). These major contributors represent more than 95% of the total activity in the year 0.

Table 4-9. Nuclide vector for contaminated concrete at year 0.

Nuclide	Nuclide Vector Related to Co-60
Mn-54	1,9E-10
Fe-55	2,5E-02
Co-58	4,3E-47
Co-60	1,0E+00
Ni-59	1,7E-02
Ni-63	2,1E+00
Mo-93	1,0E-04
Nb-93m	2,4E-01
Nb-94	8,1E-04
Zr-93	7,1E-05
Tc-99	1,5E-05
Ag-108m	2,4E-03
Ag-110m	1,5E-14
Sb-125	1,5E-04
Ta-182	1,1E-29
Pu-238	1,5E-05
Pu-239	2,6E-06
Pu-240	4,5E-06
Pu-241	9,0E-05
Am-241	2,6E-06
Am-243	2,1E-07
Cm-242	5,1E-28
Cm-244	4,7E-06
Sr-90	1,7E-02
I-129	2,0E-06
Cs-134	3,5E-05
Cs-137	2,6E+00

The following assumptions and/or extrapolations are found in Oliver (2013) and are used in this study:

- The source terms for Co-60 and Cs-137 in contaminated concrete that has been used in the decommissioning study for the Swedish nuclear power plant (Jonasson 2012), are also used in the analysis for Clink.
- It is most unlikely that all pools and channels in the Clink plant will have leaks. The Clink plant is assessed to have 5 leaks in total at end of operation. This is based on an extrapolation from the amount of leaks in Clab since its start of operation and to the decommissioning data including an uncertainty factor.
- In accordance with previous decommissioning studies, 2 cm of the concrete will be grinded off for disposal in the final repository. The contamination depth in the concrete is around 1 cm and to keep some conservatism, 2 cm is assumed to be grinded off.
- The density for the non-reinforced concrete, that will be grinded off, is assumed to be 2,400 kg/m^3. A density of 1,500 kg/m^3 is used for the grinded concrete due to voids when disposed in the waste containers.
- A decay time of 30 years is assumed (related to the estimated shutdown date of O3 and the decommissioning date of the Clink plant i.e. no fresh spent fuel coming in during the last 30 years).

4.3.1 Activity in the ventilation system including dry-handling systems in Ink

The ventilation system (742) in Ink and Clab has the risk of contamination due to that both fuel pool handling in Clab/Ink and the dry handling in Ink has been considered.

For estimating the contamination during the dry-handling in Ink and in the ventilation system in Clink, a comparison with the Hot-cell laboratory at Studsvik Nuclear AB was performed (Ekberg 2002). Surface dose rate measurements performed in Clab was also used in the assessment.

Measurements in the ventilation system (system 742) at Clab show that the surface dose rates are generally below 5 µSv/h (Andersson B 2012, personal communication). A dose rate of 5 µSv/h is conservatively assumed to correspond to a surface activity inside the ventilation duct that is slightly higher than the limit for free release. Since the available measured surface dose rate data from Clab is given as a maximum level, some part of the ventilation system could have considerably lower dose rates and could be considered to be free released. It is thus assessed that the ventilation system in the Clab-part of the Clink could be free released.

There are however, certain parts of the ventilation system where surface dose rates up to 15–20 mSv/h have been measured. These levels correspond to parts of the system where ion exchange resin has accidently entered the ventilation system. If no additional ion exchange resins will enter the ventilation systems, the now existing deposits of resin will decay to considerably lower dose rates (30–40 µSv/h) until year 0 when decommissioning will take place. Such levels are easier to handle and decontaminate.

These contaminated areas of the ventilation system are however assumed to be able to be decontaminated and thereafter free released. A more detailed study of these particular areas of the ventilation system is needed to see if free release is feasible.

5 General inventory of systems, components and structures

5.1 Introduction

The accurate estimate of the waste quantities and activities to be generated during the dismantling operations and of the associated radiological burden requires a thorough and comprehensive inventory of all the plant system components and structures subject to potential radioactive contamination.

Besides, a reasonably accurate accounting of all conventional non-contaminable materials and structures of the plant is a prerequisite for the performance of reasonable cost and schedule estimates for the whole plant dismantling and demolition.

This chapter presents the results obtained in the evaluation of the overall inventories of systems, components and structures of the Clink plant.

The different sections of this chapter present, in tabular form, the results of these evaluations. The chapter is subdivided into two large parts, one dealing with metal components, which form most or all of the elements to be removed during dismantling, while the other is devoted to concrete, steel etc in building structures, subject to demolition.

The information presented in this chapter is then used to establish numerical values for the variables defining the different macro-components used in Chapter 9 and 10 by the model for estimating costs and schedule requirements.

5.2 Source of information

The information listed in the following sections is mainly obtained from data obtained from the plant owner SKB.

In those instances where the above inventory fails to include required data, e.g. equipment weights or piping length runs, the corresponding estimates are based on the application of duly justified criteria, assumptions and extrapolations.

The system inventory made for Ink is performed using drawings, system inventories and engineering judgements has also been used to fill the gaps encountered in the available information.

The system inventory made for Clab is mainly based on Haglind (2006) and on the Excel files with component data that have been used as an input to the report. The majority of the data used in the report is extracted from Clab's data base and has, to a certain extent, been completed by traditional inventory at the Clab facility. Most of the inventory has been made for the controlled area, since the majority of the process systems are part of this area. The assumptions made for Clab deal mostly with factors that have been added to initial figures for estimating weights of components of the uncontrolled area, and are stated in Haglind (2006). The existing data, for the purpose of this study, has been classified into component groups, as been made in earlier decommissioning studies.

The estimated accuracy of the inventory is presumed as follows:

- ± 20% for the low contaminated components, i.e. in the activity categories yellow and green.
- ± 30% for the non-contaminated components, i.e. in the activity categories blue and white.

The accuracy of the building inventory is made with different priorities:

- Possibly contaminated steel constructions and surfaces in controlled areas have an accuracy of ± 20%.
- Non-contaminated concrete, reinforcement, embedded plates and steel constructions in controlled areas have an accuracy of ± 30%.
- Buildings in uncontrolled areas have an accuracy of ± 30%.

The ventilation inventory has an accuracy of ± 20% for contaminated areas and ± 30% for uncontaminated areas.

The accuracy of the electrical systems is at least ± 30%.

5.3 Plant metal inventory

The following categories of elements have been used to estimate metal quantities in the Clink plant:

- **Mechanical and Piping Systems**, including all plant process fluid systems, with its associated equipment, piping, valves and accessories.
- **Structural and Various Steel**, including handling equipment, cranes, liners, supports and miscellaneous steel.
- **Air Treatment Systems** including its associated ducts, equipment, dampers and accessories.
- **Electrical Equipment and Cabling**, including cables, cable trays and conduits, as well as all electrical and I&C significant equipment.

These categories have been defined in this way to reflect the structure of the used databases and to facilitate the comparison with other similar studies. It also facilitates the extraction process required to fill the macro-components data fields.

Plant areas

In this section the plant buildings and rooms are divided into two areas[1]. See Chapter 3 for a key of the building designations.

Area K – Rooms in controlled area (A, B, E, F, H, and M).

Area OK – Rooms in uncontrolled area incl. the yard (G, P, R, S, T and V).

5.3.1 Mechanical and piping systems inventory

The inventories presented in this subsection correspond to the Clink plant fluid processing systems. A summary description of the most important systems is given in Chapter 3, Section 3.3.

5.3.1.1 Valves and actuators

The valves and actuators are separated in one group for large valves (> DN50) and one for small valves (< DN50). For Ink the large actuators are included in the weight of the valves. Small valves are included actuators.

Table 5-1 presents the summary of the valve and actuator inventory for the Clink plant.

There are a total of 676 valves that weigh 29 tonnes, and the actuators are 67 in total and weigh 4 tonnes.

Table 5-1. Valve and actuators inventory.

			Area		
Category	**Size**	**Data**	**K**	**OK**	**Total**
Actuator	> DN50	Weight, kg	3,811	92	3,904
		Number	65	2	67
Valve	≤ DN50	Weight, kg	4,922	275	5,197
		Number	117	12	129
	> DN50	Weight, kg	18,051	5,445	23,495
		Number	397	150	547
	Total	Weight, kg	22,973	5,720	28,692
		Number	514	162	676

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[1] The areas used here are defined specific for this study. The area designations should not be mixed up with building designation letters.

5.3.1.2 Heat exchangers

Table 5-2 presents the summary of the heat exchanger inventory for the Clink plant.

The inventory comprises of 19 heat exchangers that weigh 45 tonnes in total.

Table 5-2. Heat exchanger inventory.

Size	Data	Area K	OK	Total
≤ 500 kg	Weight, kg	606	0	606
	Number	6	0	6
500-3,500 kg	Weight, kg	6,728	2,724	9,452
	Number	8	1	9
> 3,500 kg	Weight, kg	17,280	17,280	34,560
	Number	2	2	4
All	Weight, kg	24,614	20,004	44,618
	Number	16	3	19

5.3.1.3 Pumps

Table 5-3 presents the summary of the pump inventory for the Clink plant.

The inventory comprises of 120 pumps that weigh 34 tonnes.

Table 5-3. Pump inventory.

Pump size	Data	Area K	OK	Total
≤ 500 kg	Weight, kg	7,037	3,099	10,135
	Number	89	23	112
> 500 kg	Weight, kg	16,516	7,686	24,202
	Number	5	3	8
All	Weight, kg	23,553	10,785	34,337
	Number	94	26	120

5.3.1.4 Tanks

Table 5-4 presents the summary of the tank inventory for the Clink plant.

The inventory consist of 71 tanks that weigh 92 tonnes with a shell area of 728 m^2 in total.

Table 5-4. Tank inventory.

Size	Data	Area K	OK	Total
≤ 200 kg	Weight, kg	3,606	0	3,606
	Number	29	0	29
	Shell area, m^2	58	0	58
> 200-750 kg	Weight, kg	5,016	864	5,880
	Number	11	2	13
	Shell area, m^2	86	16	102
> 750 kg	Weight, kg	81,608	1,320	82,928
	Number	28	1	29
	Shell area, m^2	553	16	569
All	Weight, kg	90,230	2,184	92,414
	Number	68	3	71
	Shell area, m^2	696	32	728

5.3.1.5 Pressure vessel

Table 5-4 presents the summary of the pressure vessel inventory for the Clink plant.

The inventory consists of 29 pressure ves sels that weigh 60 tonnes.

Table 5-5. Pressure vessel inventory.

Size	Data	Area K	OK	Total
≤ 500 kg	Weight, kg	840	625	1,465
	Number	2	4	6
> 500–1,500 kg	Weight, kg	9,496	1,200	10,696
	Number	9	1	10
> 1,500–5,000 kg	Weight, kg	9,540	3,900	13,440
	Number	5	2	7
> 5,000 kg	Weight, kg	22,000	12,000	34,000
	Number	5	1	6
All	Weight, kg	41,876	17,725	59,601
	Number	21	8	29

5.3.1.6 Piping and components

The piping and component inventory for the Clink plant is included in Table 5-6.

Table 5-6. Piping inventory.

Diameter		Area K	OK	Total
≤ DN 25	Weight, kg	15,931	42	15,973
	Length, m	18,147	157	18,304
> DN 25–DN 50	Weight, kg	29,285	16	29,302
	Length, m	9,459	4	9,463
> DN 50–DN 300	Weight, kg	72,181	1,101	73,283
	Length, m	9,061	163	9,224
> DN 300	Weight, kg	36,765	0	36,765
	Length, m	831	0	831
Total	Weight, kg	154,163	1,159	155,322
	Length, m	37,497	324	37,821

The total piping inventory for the Clink plant has a length of 37,800 m and weighs 155 tonnes.

The piping inventory is also illustrated in Figure 5-1 and Figure 5-2.

5.3.1.7 Miscellaneous equipment

Miscellaneous equipment comprise of various equipment not included in the above described categories. The component types are mainly small tanks, filter vessels, coolers, strainers and cranes, handling device equipment.

Table 5-7 presents the summary of the miscellaneous equipment inventory for the Clink plant.

The miscellaneous equipment inventory comprises of 326 components that weigh 2,723 tonnes.

5.3.1.8 Insulation

The inventory is deficient and data for Clab is missing completely. According to Hallberg and Eriksson (2008) there are 250 tons of mineral wool in Ink but no information about the location. The lack of information of insulation will be handled as an uncertainty.

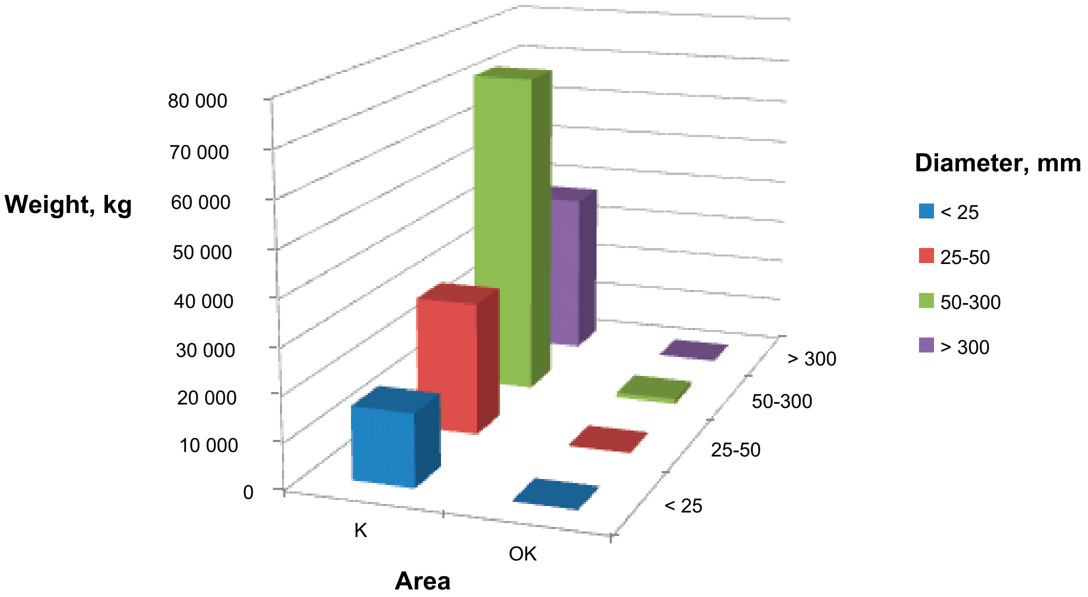

Figure 5-1. Piping Weight Distribution.

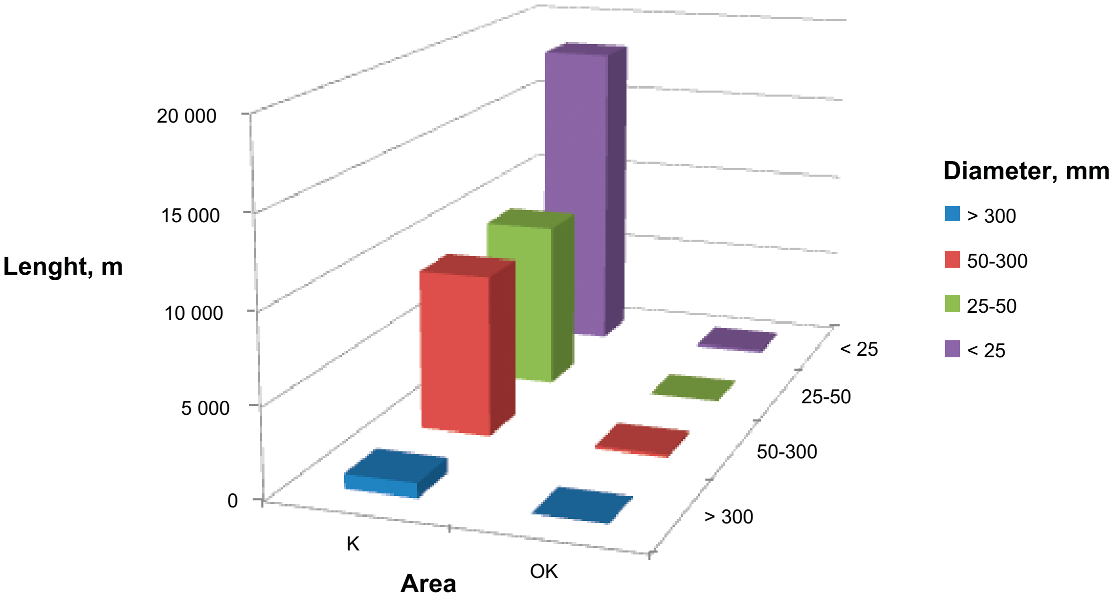

Figure 5-2. Piping length distribution.

Table 5-7. Miscellaneous equipment inventory.

Category		Area K	OK	Total
Equipment	Weight, kg	2,677,366	45,695	2,723,061
	Number	297	29	326

5.3.2 Structural and various steel components inventory

5.3.2.1 Overhead cranes

Table 5-8 presents the summary of the overhead cranes inventory for the Clink plant.

The number of overhead cranes is 42 units and weigh in total 239 tonnes.

Table 5-8. Overhead cranes inventory.

Category	Area K	OK	Total
Weight Cranes, kg	231,724	7,440	239,164
Number	34	8	**42**

5.3.2.2 Pool liner

Pool liner refers to the stainless steel liner covering the surfaces in the pools.

Table 5-9 presents the summary of the pool liner for the Clink plant.

The pool liners weigh 445 tonnes with a total area of 12,000 m^2.

Table 5-9. Pool liner.

Category	Material	Area, m^2	Weight, kg
Pool lining	SS	12,427	444,926

5.3.2.3 Supports and other structural equipment

Table 5-9 presents the summary of the steel for the Clink plant. Some data of the steel inventory are included in miscellaneous process components.

The steel weigh 74 tonnes with a total number of 25 units.

Table 5-10. Supports and other structural equipment.

Category	Area K	OK	Total
Weight Steel, kg	73,613	311	73,924
Number	24	1	25

5.3.3 Air treatment systems inventory

Table 5-11 presents the summary of the ventilation duct and component inventory for the Clink plant. The inventory has no information about the insulation so this is also an uncertainty in the results.

The ventilation systems are 985 units with a total weight of 355 tonnes.

Table 5-11. Ventilation inventory.

Category	Data	Area K	OK	Total
Duct and Component	Weight, kg	210,598	144,264	354,863
	Number	547	438	985

5.3.4 Electrical equipment inventory

5.3.4.1 Cables and cable trays

Table 5-12 presents the summary of the cable inventory for the Clink plant.

The cable weighs 421 tonnes in total.

Table 5-12. Cable inventory.

Category	Area K	OK	Total
Weight Cable, tonne	258	163	421

5.3.4.2 Cubicles and large electrical components

Table 5-13 present the summary of the cubicle and large electrical component inventory for the Clink plant.

The electrical cubicle inventory comprises of 356 cubicles and large electrical components with a weight of 180 tonnes.

Table 5-13. Cubicle inventory.

Category		Area K	OK	Total
Cubicles	Weight, kg	5,700	5,532	11,232
	Number	15	4	19
Large Electrical Components	Weight, kg	34,533	134,159	168,692
	Number	190	147	337
All	Weight, kg	40,233	139,691	179,924
	Number	205	151	356

5.3.5 Plant metal summary

A summary of all plant metal is presented in Figure 5-3.

The total metal inventory of Clink weighs 4,856 tonnes.

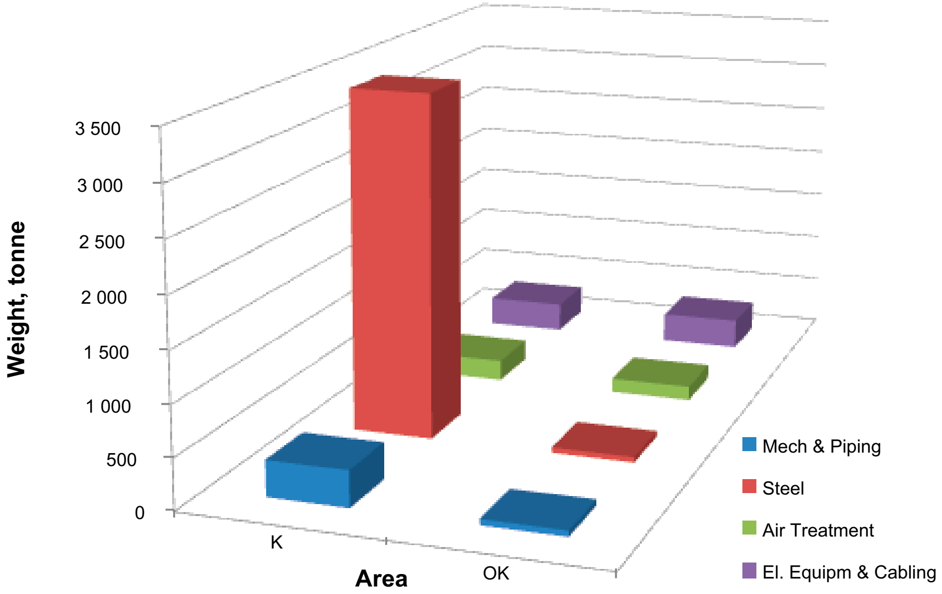

Figure 5-3. *Plant Metal Inventory.*

5.4 Plant building data and concrete inventory

The estimate of the radioactive wastes, expected to be generated during building demolition activities, requires the knowledge of the internal exposed surface areas for each building. These are used to estimate, in conjunction with the information given in Chapter 4, the surface area for which actions (survey, scarification, scrabbling, etc) will be required prior to demolition, as well as the expected amount of radioactive waste resulting from those operations. A summary description of the buildings is given in Chapter 3, Section 3.4.

The following subsection presents the result from these evaluations for the Clink plant.

5.4.1 Building data

The data presented in this subsection is derived from the inventory for Ink while Clab lack information on building data regarding concrete and reinforcement. Information about Clab has therefore been calculated by using preliminary data from Hallberg and Eriksson (2008). The summary of Clab and Ink correspond to the totality of the Clink building data and is presented in Table 5-14.

The total concrete volume for Clink buildings is 127,720 m^3 with a weight of 306,520 tonnes included 13,340 tonnes of reinforcement. The inner surface area for all the buildings is 305,900 m^2 and include floors, roofs, and walls.

Table 5-14. Plant building data for Clink.

	Inner surface K m^2	Inner surface OK m^2	Reinforcement tonne	Concrete tonne	Concrete volume m^3	Contaminated Concrete tonne	Contaminated Concrete volume m^3
Clab	185,900	46,100	9,093	208,945	87,060	110	46
Ink	120,000	0	4,247	97,577	40,657	0	0
Total	305,900	46,100	13,340	306,522	127,717	110	46

6 Radioactivity inventory

6.1 Introduction

This chapter present a classification of the dismantling and the demolition waste material quantities of the Clink plant introduced in Chapter 5 into activity categories. The activity categorization is based on specific activity data. The reference date for the activity estimations is year 0. Information regarding nuclide spectra of process and structural materials is presented in Chapter 4.

According to IAEA the radioactive waste can be divided into the typical waste categories (IAEA 1994): *High level waste (HLW), Low and Intermediate level waste (LLW, ILW and in combination LILW) and Free released waste (FRW). HLW is defined as waste which has a thermal power above 2 kW/m^3 and is in practice not applicable for decommissioning waste. ILW is defined as radioactive waste which requires shielding but needs little or no provision for heat dissipation. LLW has been defined in the past as radioactive waste that does not require shielding during normal handling and transportation. A contact dose rate of 2 mSv/h of the waste package is generally used to distinguish between ILW and LLW.*

LILW is according to IAEA divided into short-lived (LILW-SL) and long-lived (LILW-LL) waste. *Short-lived low and intermediate level waste contain low concentrations of long-lived radionuclides (half-lives in excess of 30 years). Although the waste may contain high concentrations of short-lived radionuclides, significant radioactive decay occurs during the period of institutional control. Long-lived low and intermediate level waste contain long-lived radionuclides in quantities that need a high degree of isolation from the biosphere.*

Free released waste (FRW) has activity levels below the clearance level and thereby contains so little radioactive material that it cannot be considered "radioactive" and might be free released from nuclear regulatory control. That is to say, although it still can be radioactive from a physical point of view, this waste may be safely disposed of, applying conventional techniques and systems, without specifically considering its radioactive properties.

Free release of radioactive material from controlled area is regulated by SSM (SSMFS 2011:2). The free-release level of material from decommissioning waste and controlled areas is nuclide specific with a general specific activity of 100 Bq/kg. The following assumption has been used in this study for the decommissioning waste:

- Limit for free release: 500 Bq/kg.

To include the waste that originates from uncontrolled areas the activity category non-active material with colour code white has been added to the specific activity levels presented in Table 6-1. The waste in this category is by origin non-active and does not need to be monitored.

All waste in the categories blue and white is assumed to be recycled or disposed of at a municipal deposit.

To simplify the categorization of the waste the colour codes described in Table 6-1 is used in Chapter 6 and 8.

Table 6-1. Activity categorization.

Waste Category	Specific activity Category [Bq/kg]	Description
Red	> 10^6	Radioactive material requiring radiation shielding
Yellow	10^4–10^6	Radioactive material not requiring radiation shielding.
Green	500–10^4	Potentially free-release material after treatment
Blue	< 500	Non-active material, controlled area
White	–	Non-active material, uncontrolled area

6.2 Source of information

The surface activity estimations are based on calculations made in Oliver (2013) and Runevall (2013).

Closer to the decommissioning date, a more refined assessment of the activity inventory in the decommissioning waste is recommended. To achieve a more realistic surface contamination estimation inside different components it is recommended that nuclide specific surface activity measurements are performed on critical components/systems.

6.3 Radioactivity levels

Most of the radioactive systems are assessed to be able to be decontaminated. These assessments are based on the assumption that the released crud is mainly particulate deposits and not as tenacious as for example crud on the fuel surface or from systems operating at higher temperatures. Many of the components in Ink are also assumed to be designed to be easily decontaminated and have e.g. electro-polished surfaces. Westinghouse experience concerning contamination of tools used in e.g. spent fuel pools at NPP:s shows that decontamination of such equipment is feasible. Experience from Studsvik also indicates that particulate contamination when fuel is dry-handled is easily decontaminated (Ekberg 2002). Cleaning of several of the pools in Clab has been performed and has shown that activity levels on the pool surfaces can be considerably reduced by simple decontamination.

6.4 Plant activity inventory

This section describes the different sources of waste and its associated activity. The plant activity inventory can be divided into three categories:

- Process equipment waste, which is the waste from components in the facility such as pipes, tanks, heat exchangers, etc.
- Concrete waste, which includes the concrete walls and structures around the storage pools.
- Decontamination waste, which is the ion exchange resins from the primary system decontamination.

6.4.1 Process equipment waste

System 372 was initially assessed not to be able to be decontaminated for free release, but the activity calculations presented in Oliver (2013) show activity levels after decontamination below the limit for free release.

Other main components not included in the analysis have been considered as possible to decontaminate and then to free-release. Such process equipment waste is e.g. pool linings and piping and components in heating and sanitary system. Valves have not been included since their contribution has been assumed to be negligible in comparison with other components due to their small surface and weight.

6.4.2 Contaminated concrete waste

The pools in the Clink facility have stainless steel liners, which protect the concrete structure from being contaminated by direct contact with the pool water. Moreover, behind the liners there is a system of leak testing channels, which will detect leaks and lead away as well as collect the leaked water. The protective steel liners have been shown to be easily decontaminated and will thus be assumed to be free released in this study.

Based on current knowledge, at least one pool (bottom and one side in storage pool nr 14) have had a leak in Clab during the first 26 years of operation. When taking into account that the expected lifetime of Clab is 85 years, it is possible to estimate by linear extrapolation the total amount of leaks to 3.3. However, it can be argued that the real amount of leaks is higher than the detected amount and/or that an older facility will have more leaks than a new one due to corrosion and wear. Therefore, in order to take into account the possible formation of new leaks or unknown leaks and in order to add additional conservatism to the calculation, an uncertainty factor was introduced. A reasonable value on the uncertainty factor was considered to be 1.5. This would imply that Clab would have 5 leaks at end of operation. In this study it was assumed that 4 normal sized storage pools like pool nr 11 have a leak (assuming that all new leaks appear in a new pool, hence adding further conservatism) plus the storage pool nr 14 that have already been observed to have a leak. In this study the storage pools nr 11–15 are considered to have leaks, see Table 6-2. The pools nr 11–15 are situated under ground in Storage Building (F) shown in Chapter 3, Figure 3.4.

In accordance with previous decommissioning studies the density for the non-reinforced concrete part of the wall, that will be grinded off, was assumed to be 2,400 kg/m^3.

When taken together, the total amount of contaminated concrete from the Clink facility at end of life that will be sent to the final disposal is estimated to 110 tonne.

6.4.3 Decontamination waste

The systems in contact with radioactive water (cooling- and cleaning systems etc) has been assumed to be decontaminated using a DF of 10.

The decontamination will generate waste in form of filters, and possibly also ion exchange resins, which will contain a total activity around $7.4 \cdot 10^{11}$ Bq, based on the activity estimations given in Chapter 4. The total surface areas for these systems in Clink are approximately 3,200 m^2.

The decontamination waste in the decommissioning studies from the Swedish nuclear reactors (Barsebäck 1–2) was assessed to result in 7 waste containers with mainly ion exchange resins mixed with cement. The total activity in the decontamination waste was $2.2 \cdot 10^{12}$ Bq and $3.7 \cdot 10^{12}$ Bq, for Barsebäck 1 and 2 respectively, and the total area that was decontaminated was 1,500 m^2 in each reactor.

Since the deposits to be removed from surfaces in Clink are assumed to be mainly particulates, the generated decontamination waste will mainly be filters that would result in smaller waste volumes. The total activity in the decontamination waste is also assessed to be lower in Clink. To preserve some conservatism and to be able to also include additional decontamination waste from systems described in Oliver (2013), the same number of waste containers of decontamination waste is assumed in Clink as for the NPPs. The decontamination waste for the NPPs is based on experience from Oskarshamn and Barsebäck decontamination campaigns. The decontamination waste from Clink is thus estimated to 7 waste containers to be stored in silos in SFR.

Table 6-2. Considered measures for storage pools with leaks and the depth of contaminated concrete.

Pool nr	Length (m)	Width (m)	Depth (m)	Contaminated Concrete Depth (m)	Contaminated Surface Area (m²)	Contaminated Volume (m³)
11	18,2	13,8	12,5	0,02	479	9,6
12	18,2	13,8	12,5	0,02	479	9,6
13	13,8	13,8	12,5	0,02	363	7,3
14	18,2	13,8	12,5	0,02	479	9,6
15	18,2	13,8	12,5	0,02	479	9,6
Total					**2,279**	**46**

6.5 Waste containers

6.5.1 Process equipment waste

The process equipment waste from Clink consists of short-lived (SL) waste. The short-lived waste in the red activity category (> 10^6 Bq/kg) is assumed to be transported and stored in 5 mm thick steel containers (large steel boxes) with the outer dimensions 2.40×2.40×1.20 m and the maximum total weight 20 tonne. The maximum total weight is assumed to be 20 tonne based on the limitation of today's lifting devices at the final repository. The short-lived waste is assumed to be transported in shielded transport containers and disposed of in SFR.

When calculating the number of waste containers needed for process equipment waste in the red activity category, a packing degree of 1.1 tonne/m^3 is used. This packing degree estimation is based on amongst others Spanish experiences, e.g. ENRESA assumed a packing degree of 1.1 tonne/m^3 for metal scrap waste in steel containers with the outer dimensions 1.74×0.87×0.87 m.

In total 10 ISO-containers and 3 large steel box containers have been calculated to be needed for the process systems in Clink for the final repository in SFR, the individual contribution can be seen in Table 6-3.

In Table 6-4 the waste activity data for process equipment waste is shown.

6.5.2 Concrete waste

The concrete waste in the green activity category originates from the area behind the protective pool steel liners. As Table 6-5 shows, 7 ISO containers in the green waste category are estimated for final repository in SFR.

Table 6-3. Waste container data: Process equipment waste after decontamination for combined systems.

Suggested Disposal Facility	Net disposal Volume (m³)	Number of Waste Containers	Container	Waste Category	Outside measurements (m)
SFR	21	3	Large steel box	Red	2.40×2.40×1.20
SFR	177	9	ISO-type Container	Yellow & Green	6.06×2.50×1.30
Recycling	21,523	1,093	ISO-type Container	Blue & White	6.06×2.50×1.30

Table 6-4. Waste activity data: Process equipment waste after decontamination.

No	System	Nuclide vector	Normal-ized Against	Activity of Normalised Nuclide	Total Waste Weight (tonne)	Mean Specific Activity (Bq/kg)	Container	No of Containers	Waste Category
1	247	1	Co-60	3,2E+06	0,3	3,5E+04	ISO-type Container	0,02	Yellow
2	311	1	Co-60	2,4E+10	20	4,0E+06	Large steel box	2,6	Red
3	313	1	Co-60	1,9E+08	38	1,6E+04	ISO-type Container	2,3	Yellow
4	324	1	Co-60	9,6E+07	86	3,7E+03	ISO-type Container	5,2	Green
5	343	2	Co-60	1,7E+06	0,4	1,3E+05	ISO-type Container	0,02	Yellow
6	371	1	Co-60	5,7E+07	19	1,0E+04	ISO-type Container	1,1	Yellow
7	373	1	Co-60	3,3E+08	2	6,3E+05	ISO-type Container	0,1	Yellow

Table 6-5. Waste container data: Concrete waste for Clink.

Suggested Disposal Facility	Net disposal Volume (m³)	Number of Waste Containers	Container	Waste Category	Outside measurements (m)
SFR	138	7	ISO-type Container	Yellow & Green	6.06×2.50×1.30
SFR	0	0	ISO-type Container	Blue & White	6.06×2.50×1.30

The waste material will most likely be in the form of crushed concrete and a total packing degree of approx.1.5 tonne/m^3 is assumed (Ericsson 2005). The total amount of free released concrete from Clink is approx. 306,500 tonnes. The underground volume of the buildings in Clink is however very large, and it is expected that all free released concrete from Clink can be used as filling material on site. Tunnels, shafts and the foundation will be backfilled up to one meter below ground level.

The activity calculations for the concrete in Clink are presented in Table 6-6.

Table 6-6. Waste activity data: Concrete waste.

No	System	Nuclide vector	Normalized Against	Activity of Normalized Nuclide	Total Waste Weight (tonne)	Mean Specific Activity (Bq/kg)	Container	No of Containers	Waste Category
9	All	3	Co-60	4,4E+07	110	2,4E+03	ISO-type Container	6,1	Green

6.5.3 Decontamination waste

Since the deposits to be removed from surfaces in Clink are assumed to be mainly particulates, the generated decontamination waste will mainly be filters that would result in smaller waste volumes. The total activity in the decontamination waste is also assessed to be lower in Clink. To preserve some conservatism and to be able to also include additional decontamination waste, the same number of waste containers of decontamination waste is assumed in Clink as for the nuclear reactors. The decontamination waste from Clink is thus estimated to 7 waste containers to be stored in silos in SFR which is presented in Table 6-7.

The activity calculations for the decontamination waste in Clink are presented in Table 6-8.

Table 6-7. Waste container data: Decontamination waste for Clink.

Suggested Disposal Facility	Net disposal Volume (m³)	Number of Waste Containers	Container	Waste Category	Outside measurements (m)
SFR	12	7	Steel box	Red	1.20×1.20×1.20

Table 6-8. Waste activity data: Decontamination waste.

No	System	Nuclide vector	Normalized Against	Activity of Normalised Nuclide	Total Waste Weight (kg)	Mean Specific Activity (Bq/kg)	Container	No of Containers	Waste Category
1	247	1	Co-60	2,9E+07	2	4,1E+07	Steel box	0,001	Red
2	311	1	Co-60	2,2E+11	17,977	4,1E+07	Steel box	6,851	Red
3	313	1	Co-60	1,9E+09	156	4,1E+07	Steel box	0,060	Red
4	324	1	Co-60	2,2E+09	177	4,1E+07	Steel box	0,067	Red
5	343	2	Co-60	1,5E+07	10	4,1E+07	Steel box	0,004	Red
6	371	1	Co-60	5,1E+08	42	4,1E+07	Steel box	0,016	Red
8	373	1	Co-60	4,1E+07	3	4,1E+07	Steel box	0,001	Red

7 Dismantling techniques, sequences and logistics

7.1 Introduction

The purpose of this chapter is to provide information on the typical tools and techniques as they are today that could be used during the decommissioning of Clink. In general the techniques have been selected on the basis of previous experience on international decommissioning projects and national segmentation projects. In some cases, the chosen technique may not be the same as might be chosen if a similar task were to be performed during a plant refurbishment or upgrade. This is a reflection of the less precise nature of the work and the fact that the plant will not need to be restored to an operational state upon completion, either by reinstatement of equipment or clean-up to the as-operated condition.

In addition this chapter will present initial conclusions on the preferred sequences of decommissioning tasks and the required logistics, e.g. for waste items and waste packages movement within the plant. These will again be based on previous experience or detailed studies made for other plants, suitably modified to reflect the specifics of Clink.

The references to this chapter are mostly Westinghouse internal documents, and are thus not presented in the reference list.

7.2 Dismantling techniques

Due to the variety of dismantling tasks to be carried out during the decommissioning of Clink, it is expected that a wide range of dismantling techniques will be employed, each selected for its suitability for the task in question.

The philosophy adopted within this study is that only proven existing techniques will be employed. This is so that:

- SKB can be confident that the technique described is suitable for the task and has already been used for a similar application, generally in the USA where more decommissioning has been completed to date.
- There will be little or no tooling development works required, which would lead to development cost and time plus potential cost/programme risk to the delivery of the project if tools could not be developed and deployed in accordance with the overall project programme.

In some instances, the most appropriate technique for dismantling an item will be the same technique as was used for maintenance when the plant was operational. Taking advantage of installed lifting equipment such as the overhead traveling cranes, and using a proven dismantling technique familiar to the plant staff and already covered by existing written instructions. The disassembled pieces would then be segmented for packaging or disposal as appropriate. For other tasks, segmentation or other destructive techniques will be faster and more appropriate given the material and its intended disposal route after removal. Given the wide range of equipment and material to be removed, a range of techniques will be required, each appropriate to the task. The following sections describe suitable techniques for each task or group of tasks.

7.2.1 Large diameter pipe work

A number of techniques are available for segmentation of large diameter pipe work. The preferred technique will generally be selected on the basis of the radiological condition of the pipe to be cut and the working area around it.

For higher dose rate areas it is generally preferable to use techniques that can be quickly set up on the pipe and then remotely operated by the decommissioning personnel from a lower dose rate area. A number of these “non-contact” techniques are available. For lower dose rate working areas contact working methods are acceptable.

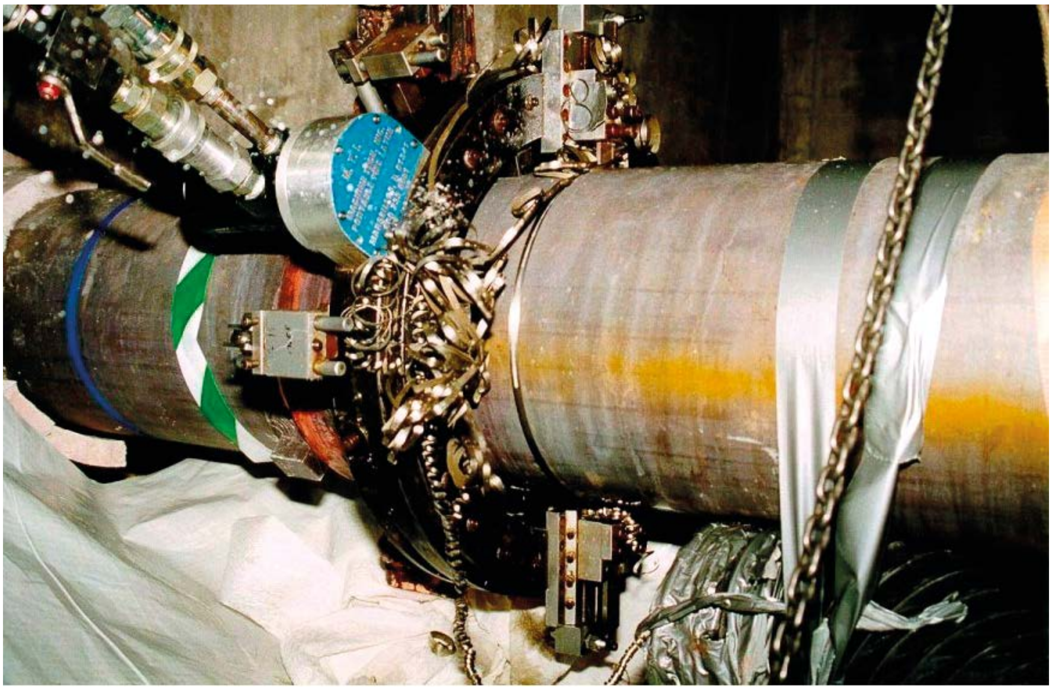

Figure 7-1. *"Clam Shell" Pipe Cutter in Operation.*

7.2.1.1 Clam Shell Pipe Cutter

Clam Shell Cutters, or split frame pipe lathes as seen in Figure 7-1 and Figure 7-2, are a reasonably inexpensive mechanical method for cutting large bore pipes. They are ideal for cutting highly radioactive pipes and produce a sufficiently good quality cut so that end caps or other features can be welded onto the cut pipe with minimal additional preparation.

From a radiological standpoint they are desirable since they are not surface destructive and do not generate the airborne radioactivity or fume associated with thermal cutting methods. They are also quickly installed and allow the operator to move away from the workpiece during the cut, thereby avoiding unnecessary dose. The cutters require a radial clearance of 180 mm around the pipe to allow the cutting tool to move around the pipe and make the cut.

From a safety point of view, the cutters do not generate flames or applied heat, and therefore do not require a fire-watcher as part of the work team. They are also easy to use and quick to train operators in their use, compared to thermal cutting devices.

For decommissioning work in lower dose rate areas the clam shell cutters are less appropriate for thick components and do not cut as fast as plasma and oxy-fuel cutters. The overall time for each cut is longer than for hand held thermal cutters because of the set up time required.

Table 7-1 provides information regarding one High Speed Clam Shell Cutter.

7.2.1.2 Diamond wire saw

As an alternative to the Clam Shell Cutter, diamond wire saws can be used. These would be used in situations where contact working would not be advisable and there is either not enough space around the pipe to install a Clam Shell Cutter or where the pipe wall thickness is greater than the Clam Shell capacity.

The use of wire saws to cut metals is less common than for cutting concrete (see Section 7.2.7.1) and tends to be used in particular situations, e.g. when contact working is not preferred due to radiological conditions and the metal to be cut is beyond the capability of clam shell cutters. Because of this, and the fact that it is a relatively recent application of the wire saw technique, little comparative data is available.

Table 7-1. Information regarding High Speed Clam Shell Cutter.

Item	High Speed Clam Shell Cutter	Notes
Manpower Requirements	2 Operators	Plus labor as required to handle waste material
Equipment Cost	$25,300 for 460 to 610 mm (18 to 24 inch model) plus $12,500 for power pack, hoses etc	1998 values equipment can be rented at approx. one-fifth purchase cost per month
Capacity/performance	250 mm to 1.22 m (10 to 48 inch) and above 16 min for 610 mm (24 inch) diameter cut 16–24 min dismantle/set up time between cuts	No production rate data (other than that shown left) is available for this tool. However, based on the figures shown, a production rate of 5–6 large diameter cuts per day would appear reasonable.
Utility Requirements	240 / 440 V AC for the power pack	Internal batteries last 0.25 hrs of continuous operation, add on auxiliary battery provides an additional 0.8 hrs.
Weight	94 kg	
Secondary Wastes	Metal swarf	

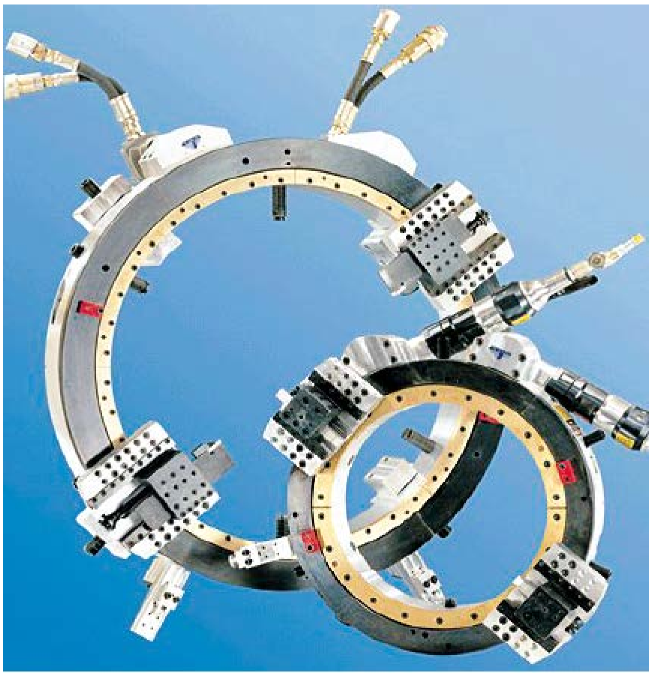

Figure 7-2. *Manufacturers Photograph of Clam Shell Cutters.*

As an example, the San Onofre Unit 1 Reactor Vessel nozzles were cut using diamond wire saws, see Figure 7-3.

7.2.1.3 Thermal Cutting

Clearly, production rates will be highly variable depending on pipe size, and perhaps more importantly, the working conditions such as confined spaces, work at height etc. For larger pipe work sizes, oxy-fuel cutting tends to be more productive that plasma cutters though it produces more fume. Production rates of 0.65 man-hours per meter of pipe work have been reported for oxy-fuel cutting.

A Track Cutting System for Plasma or Oxy-Fuels is illustrated in Figure 7-4.

Figure 7-3. *San Onofre Unit 1 Reactor Vessel Nozzles after cutting with a diamond wire saw.*

Figure 7-4. *Track Cutting System for Plasma or Oxy-Fuels.*

7.2.2 Small diameter pipe work

7.2.2.1 Mechanical shears

A suitable tool for cutting of small-bore pipe work and other similar sized steel supports, uni-strut etc, is the Mechanical Pipe Shears. They were developed as an alternative to the more common reciprocating blade cutters. There are a number of different devices available.

The Blade Plunging Cutter BPC-4, see Figure 7-5 and Figure 7-6 was used extensively during the decommissioning of the Big Rock Point BWR. It is a hydraulic power cutting tool capable of cutting ~75 mm (3 inch) pipe work and above. It has a 100 mm (4 inch) blade and is a piston-forced plunging cutter. The cutter weighs approximately 12.7 kg (28 pounds) and is 710 mm (28 inch) long. It requires one operator.

It is powered by a trolley mounted Hydraulic Power Unit which powers the tool with an operating pressure between 5,000 and 6,000 PSIG. The Hydraulic Power Unit requires 3 phase 440VAC/ 20 amps, and it weighs 159 kg and can be located remotely from the cutter, for example, in a non-contaminated area.

Information regarding the Blade Plunging Cutter is given in Table 7-2.

The advantage of this type of cutter is that it offers a higher production rate than other methods of pipe cutting such as reciprocating saws. It also produces no secondary waste in the form of metal swarf or other cutting debris. It is also safer and quieter than other devices.

Its main disadvantage is that its weight makes it difficult to use above waist height (though it can be slung from a suitable support point and it can be hooked over the pipe being cut). Its weight also makes it heavy for continued use by the same operator.

The machine is a mainly electric powered device. Battery powered models are also available though the battery increases the weight. The battery is typically worn on a belt.

Figure 7-5. *Blade Plunging Cutter.*

Figure 7-6. Blade Plunging Cutter being used to cut 2.5 inch OD pipe.

Table 7-2. Information regarding Blade Plunging Cutter BPC-4.

Item	Blade Plunging Cutter BPC-4	Notes
Manpower Requirements	1 Operator	Plus labor as required to handle waste material
Equipment Cost	$31,000	2001 values
Capacity/performance	Up to 75 mm (3 inch) pipe 46 sec for 50 mm cut 20 sec for 25 mm cut	Typical reported production rates for mechanical cutting of small pipe work are ~1.0 man-hours per meter of pipe removed (including waste handling)
Utility Requirements	3-phase 440V AC / 20 Amps	
Weight	12.7 kg for the cutter plus 159 kg hydraulic power pack	
Secondary Wastes	Spent cutting blades	

7.2.2.2 Portable saw

Portable reciprocating saws use the mechanical action of a hardened steel saw blade to cut metals. The major advantage of this type of tool is the absence of the fumes produced by thermal cutting. Saws are usually used for cutting soft metals such as carbon steel, aluminum or copper.

The saws can be operated by clamping them onto a work piece and using the weight of the device to advance it into the metal. Saws may be electric or pneumatically powered and can be set up to operate without operator assistance.

Portable powered hacksaws that can cut piping up to 300 mm in diameter are available. A 200 mm pipe can typically be cut in around 6–8 minutes; a simple rule of thumb is that such saws take a minute for each inch of pipe diameter (based on Schedule 40 pipe).

7.2.3 Other steelwork

Other steelwork will generally be segmented using one or more of the thermal or mechanical techniques discussed above. The final selection will generally depend upon the location and size of the steelwork to be cut.

Some steelwork items may also be removed efficiently and safely by dismantling, particularly auxiliary structural items such as stairs and platforms that were originally assembled using bolts. Powered nut-runners such as those used in car workshops may be used to remove bolts quickly for disassembly. This does not reflect a need to remove these items intact but the fact that they may often be removed quicker and with less secondary waste in this way than by cutting them in situ.

In the case of surface contaminated steel work, sprayed coatings may be applied to fix contamination prior to dismantling in order to minimize generation of airborne contamination.

Production rates for steelwork removal have been reported as around 11 man-hours per tonne contaminated steel and 3.6 man-hours per tonne for clean material.

7.2.4 Ventilation

Ventilation ducts etc will be removed by unbolting (or disassembly appropriate to the duct construction) where the ductwork construction makes this possible.

Contaminated ductwork will be sprayed with contamination fixing spray coatings and then removed by unbolting the duct sections. The removed sections will then be crushed flat for packaging. The duct sections will only be cut where the size or geometry of the removed section makes it too big for packaging in the selected container. Where necessary, cutting will be carried out using shears or saws.

Clean or very lightly contaminated ducting may be cleaned by wiping if this will be sufficient to allow release. Other more aggressive techniques may be applied depending on the cost benefit and the availability of appropriate waste disposal routes.

7.2.5 Cables etc

Segmented cables and cable trays etc will be removed by first ensuring that the cable is safely isolated from the system and then segmenting it using heavy duty cable cutters (similar to bolt cutters) into lengths suitable for disposal as required. Even in relatively high contamination areas, plastic sheathed cables represent an opportunity for recycling of a relatively high value scrap material as the copper cable itself is protected by the plastic. Cable clips can be cut to release the cable from the tray, the cable can then be wiped to remove surface contamination and where this is successful the cut cable lengths can be offered for recovery of the copper. External steel armored cables will be more difficult to handle so they would only be offered for recycling from non-radiological areas of the plant.

Automated copper cable recycling systems are available which are portable enough to be set up on site for a recycling campaign. These systems separate the plastic insulation from the copper and convert each into plastic and copper beads. An economic assessment would need to be done to determine the value of this option.

7.2.6 Surface concrete removal

At various places within the plant contaminated and possibly activated concrete will need to be removed for controlled disposal. It is generally not possible to clean contaminated concrete, so decommissioning projects make use of techniques which remove the contaminated concrete with a view to leave behind a clean structure suitable for demolition using conventional techniques.

It is expected that various concrete removal techniques will be required for the decommissioning project. These can be broken down into two main categories:

- Techniques that remove a surface layer of concrete (e.g. contaminated concrete) until the clean concrete beneath is revealed.
- Techniques that remove bulk concrete, for example in the situation that contamination penetration is sufficiently deep so that the entire structure or a significant depth of contaminated or activated concrete must be removed.

This section will consider surface concrete removal with bulk concrete removal in the section immediately following.

There are a wide variety of surface concrete removal techniques available that have been deployed, with some degree of success, on a decommissioning project. In some cases the techniques have been adapted to provide both a fast technique suited to a wide-area and a smaller scale, slower technique for smaller areas or areas that wide-area techniques cannot reach, e.g. concrete removal close to embedded features.

7.2.6.1 Manual techniques

Simple processes, such as brushing, washing and scrubbing, and vacuum cleaning, have been widely used since the need for decontamination/cleaning was first noted in the nuclear industry. These processes are generally labor-intensive and have the potential to increase worker dose, but they have the advantages of being versatile and leaving the concrete surface intact. They can be effective on very lightly contaminated concrete, concrete where the surface is very smooth and in good condition or on painted/epoxy coated concrete. In some cases they may remove the majority of the contamination leaving only some smaller areas requiring mechanical decontamination using either a simple abrasive grinding wheel or a manually operated version of one of the techniques described below.

They are also used as the first step (e.g. to vacuum dust and remove loose contamination) before or during dismantling, to prepare items for more aggressive decontamination using stronger mechanical processes as they reduce the potential for airborne contamination during those aggressive techniques.

7.2.6.2 High pressure water washing

This technique, also known as Hydro lazing, involves directing high-pressure water at the surface being decontaminated. Typically, the equipment is a hand held lance supplied by pumps delivering water at pressure; the pressure being dependent on the exact type of equipment used but typically between 3,500–350,000 kPa (500–50,000 psi). The technique is suitable for removal of surface or near surface contamination, in particular where the surface is inaccessible to the manual techniques above or is too large for the manual techniques to be easily or economically applied. Using Hydro lazing on concrete surfaces that is not painted is not appropriate.

The technique does produce secondary waste in the form of the water used. The water needs to be retained by temporary bunds and collected for controlled disposal or cleaning to remove any solid material it has picked up. Typically for every 1,000 liters of water used, 1 liter of solid material will be produced. As an additional precaution against spread of activity, the area for the pressure water washed concrete should be isolated from the surrounding area by screens or other enclosure.

7.2.6.3 Scabbling

Scabbling is a scarification process used to remove concrete surfaces. Scabbling tools typically incorporate several pneumatically operated piston heads striking (i.e. chipping) a concrete surface. Available scabblers range from one to three headed hand-held scabblers to remotely-operated scabblers, with the most common versions incorporating three to seven scabbling pistons mounted on a wheeled chassis. Scabbling bits have tungsten carbide cutters, the bits having an operating life of about 80–100 h under normal use. Both electrically and pneumatically driven machines are available. Because scabbling may cause a cross-contamination hazard, vacuum attachments and shrouding configurations have been incorporated. According to the claims of at least one manufacturer, this enables scabbling to take place with no detectable increase in airborne exposures above background level, though filtered and ventilated enclosures can be used if airborne contamination is likely to be produced.

In practice, large area floor scabblers may only be moved to within some 50 mm of a wall. Other hand-held scabbling tools are therefore needed to remove the last 50 mm of concrete flooring next to a wall, as well as remove surface concrete on walls and ceilings.

Scabbling is a dry decontamination method – no water, chemicals or abrasives are required. The waste stream produced is only the removed debris. Work rates vary widely because of variations in concrete composition and characteristics, depth of contamination, as well as to the different types of bits that may be used. Typical removal rates against depth are shown in Table 7-3.

Table 7-3. Variation of scabbler production rates with depth.

Removal Depth (mm)	Production Rate (m^2/h)
4.25	2.78–3.72
6.35	1.30–2.23
12.70	0.65–1.12
25.40	0.28–0.56

Scabblers are best suited for removing thin layers (up to 15 or 25 mm thick) of contaminated concrete (including concrete block) and cement. It is recommended for instances where:

- Airborne contamination should be limited or avoided
- The concrete surface is to be reused after decontamination
- Waste minimization is envisaged
- The demolished material is to be cleaned before disposal.

The scabbled surface is generally flat, although coarsely finished, depending on the cutting bit used. This technique is suitable for both large open areas and small areas.

The techniques can be applied to floors and walls, though the requirement to have a reaction force if the equipment is to be effectively used on walls often results in additional equipment requirements, e.g. hydraulic arms to hold the equipment in place.

Figure 7-7 shows a proprietary remotely operated floor scabbling device. This is typical of devices on the market. It can scabble between 25-40 m^2/h at a concrete removal depth of 1.6 mm (slower at increased removal depths, e.g. 12.1 m^2/h for 3.2 mm demonstrated at Argonne National Labs) and scabbles a 450 mm wide strip. It uses 7 tungsten carbide tipped 57 mm diameter scabbling heads, as shown in Figure 7-8.

As it can only reach to with 150 mm of walls other smaller devices are used to scabble areas that have not been cleaned by the larger machine. These smaller devices will typically be wheeled 3 head devices capable of scabbling a 150 mm wide strip at 1.8–2.8 m^2/h for a removal depth of 1.6 mm. Slightly wider 5 head machines are also available. For obstructions and other features that cannot be removed hand held, single head scabblers are available.

Similar machines are available for use on hydraulic arms or frames for scabbling walls.

Figure 7-7. *A Floor Scabbler.*

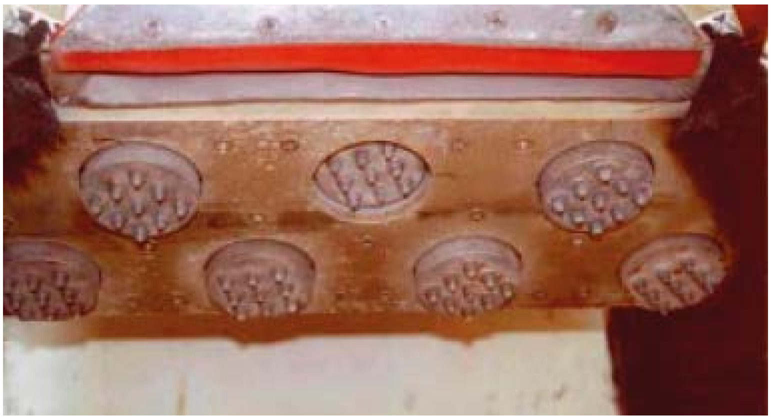

Figure 7-8. View of underside of the cutting head.

7.2.6.4 Needle scaling

Needle scalers are usually pneumatically driven and use uniform sets of 2, 3, or 4 mm needles to obtain a desired profile and performance. Needle sets use a reciprocating action to chip contamination from a surface. Most of the tools have specialized shrouding and vacuum attachments to collect removed dust and debris during needle scaling with the result of no detectable increase in airborne dust concentrations above normal levels.

Needle scalers are an excellent tool in tight, hard-to-access areas (e.g. pipe penetrations, corners etc), and may also be used for wall and ceiling surface decontamination. This technique is a dry decontamination process and does not introduce water, chemicals or abrasives into the waste stream. Only the removed debris is collected for treatment and disposal. Production rates vary depending on the desired surface profile to be achieved. Nominal production rates vary between 1.8–2.8 m^2/h for 1.6 mm removal depth using a 44.5 mm wide cutting head.

7.2.6.5 Concrete shaving

A Concrete Floor Shaver is similar in appearance to a wheeled Scabbler. It has a quick-change diamond-tipped rotary cutting head designed to give smoother surface finish than a scabbler, easier to measure and ready for painting. It is capable of cutting through bolts and metal objects, which would have damaged the cutting head of a traditional scabbler. Actual cutting performance results in:

- A higher mean working rate for floor decontamination compared to scabbling.
- Much less physical load on the operators due to the absence of machine vibration.

The Floor Shaver and the resulting floor surface are illustrated in Figure 7-9.

The concrete shaver consists of the following components:

- A 250 mm wide 127 mm diameter shaving drum into which diamond impregnated blades are fitted. The number of blades is dependent on the required surface finish.
- An extraction port for use with a vacuum extraction unit for dust-free operation.
- A manual rotary wheel depth control with electronic display.

The machine can also be fitted onto hydraulic arms for shaving walls (see Figure 7-10).

Based on the positive experience with the floor shaver a remote controlled diamond wall shaving system has been developed as a solution for concrete decontamination of larger surfaces. The system consists of:

- A remote-controlled hydro-electric power pack for the remote-controlled shaving unit.
- A vacuum system to fix temporarily vacuum pads holding the horizontal and vertical rails of the shaving head.
- A simple xy-frame system containing a guide rail, a vertical rail and a carriage for the shaving head.
- A quick-change diamond-tipped rotary shaving head with dust-control cover for connection to existing dust-extraction systems.

Figure 7-9. Floor Shaver and the resulting floor surface.

Figure 7-10. Floor Shaver mounted on a machine for wall decontamination.

The entire system is built up in sections, which are portable by one operator. It removes a concrete layer in a controlled and vibration-free manner with the removal depth being controllable between 1 and 15 mm per pass, producing a smooth-surface finish. The cutting head is designed to follow the contours of the surface being removed, and depth adjustments may be set manually in increments of 1 mm to minimize waste production. With 300 and 150 mm wide shaving heads available, both large areas and awkward corners may be accessed. When the vertical rail is fitted to the wall with the cutting head shaving, the horizontal rail may be disconnected and moved forward, thus ensuring continuous operation.

Production rates vary depending on the structure and the hardness of the concrete, the depth setting, the cutting speed and the type of diamond used. Heads can be used for shaving up to 2,000 m^2.

7.2.6.6 Summary

Table 7-4 provides summary data (where readily available) for the various techniques for surface concrete removal described above.

7.2.7 Bulk concrete removal

In cases where a significant depth of concrete has become activated or contamination has penetrated deep into the thickness of a concrete structure, e.g. a reactor biological shield, the entire concrete structure is removed. A number of techniques are available for this as described below.

7.2.7.1 Diamond Wire Saw

Diamond wire saw cutting is used to remove concrete, particularly reinforced concrete, as blocks, see Figure 7-11. This technique is particularly suitable if concrete needs to be removed cleanly, perhaps to generate access, or with minimal airborne contamination. A cart mounted unit drives a wire that carries diamond impregnated beads. Typically, three or four beads are held in place by springs mounted between smaller, fixed beads, see Figure 7-12. There are approximately forty 11 mm diameter beads per meter of wire. Wire saws are good at cutting through concrete with metal embedment, such as reinforcing bars, provided the material to be cut is solid (no voids or sections that can move during the cutting operation).

For cutting of large structures, the wire is threaded through holes drilled into the structure of approximately 50 mm diameter. For smaller structures the wire can be passed completely around the structure. There is no real limit to the depth of cut that can be achieved other than that determined by other practical factors such as the routing of the wire blade, the positioning of equipment or the ability to lift the removed pieces.

The cutting requires the introduction of water to act as both a dust suppressant and also as a lubricant for the blade. The resulting water/concrete dust mixture is a secondary waste that requires management. In the case of activated/contaminated concrete cutting, systems can be established to collect, filter and recycle the majority of the water used during the cutting.

Wire sawing techniques are also useful if removal of large components requires the removal of all or part of any surrounding concrete missile shields or bioshield walls.

Table 7-5 provides information regarding one Diamond Wire Saw Cutter.

Table 7-4. Summary data for surface concrete removal.

Technique	% Contamination Removed or Layer Thickness removed (mm)	Production Rate (m^2/h) (machine working time)	Operating Resources	Equipment Cost (2003)	Secondary Waste Produced
Manual Techniques	~20% Nil layer removed	2.8	2 laborers	~€21 /m^2	Cloths etc 0.005 m^3/h or 0.014 m^3/m^2
High Pressure Water washing	~25% for hard to remove contam. Higher for loose surface contam.	Up to 34	1 operator 2 laborers	~€8,000	Water 0.05 m^3/h or 0.0054 m^3/m^2
Floor/Wall Scabbler – Manually operated (1 head)	1.5 mm	1.13	1 operator	–	HEPA Filters for dust vacuum system, removed concrete dust
Floor Scabbler – Manually operated (5 Heads)	3 mm	2.5	1 operator	~€7,200 plus ~€500 for new heads every 113 m^2 or 45 h	HEPA Filters for dust vacuum system, removed concrete dust
Floor Scabbler – Remote Controlled (7 heads)	3.1 mm	12.1 (plus 2.5 h set time per location)	2 operators	~€170,000	HEPA Filters for dust vacuum system, removed concrete dust
Wall Scabbler (3 heads)	3 mm	4.6	–	–	HEPA Filters for dust vacuum system, removed concrete dust
Needle Scaler	1.6 mm	1.8–2.8	1 operator	~€1,300 plus ~€180 for new blades every 45 m^2 or 40 h	HEPA Filters for dust vacuum system, removed concrete dust
Floor/Wall Shaver	3 mm	11.9	1 operator	~€12,000 plus ~€7,900 for new blades every 1,860 m^2 or 156 h	HEPA Filters for dust vacuum system, removed concrete dust

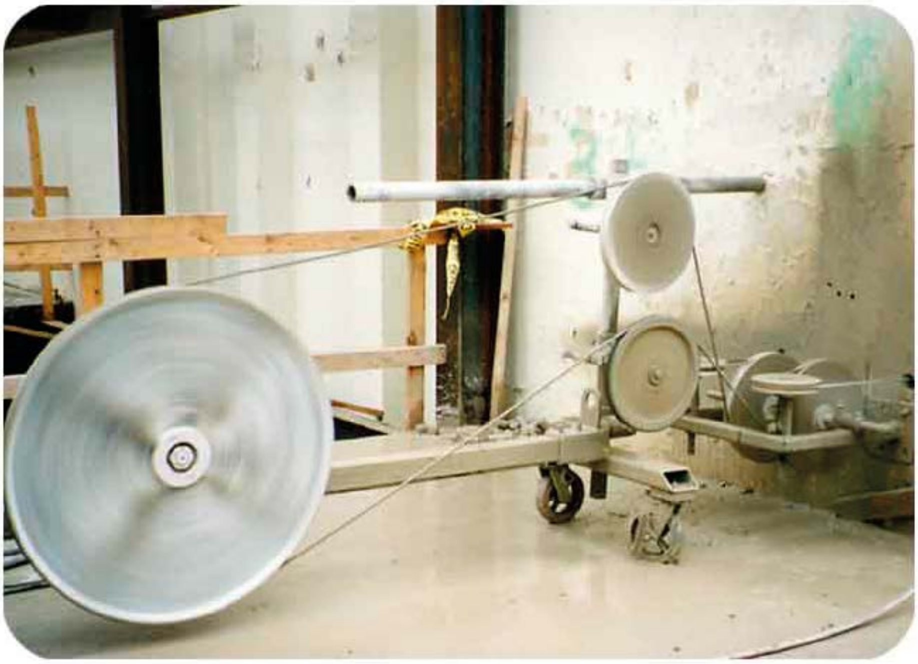

Figure 7-11. Typical Wire Saw drive in action cutting a section of wall.

Figure 7-12. Close up of diamond wire saw blade.

Table 7-5. Information regarding the Diamond Wire Saw Cutter.

Item	Diamond Wire Saw Cutter	Notes
Manpower Requirements	– 2 Equipment operators	Plus labor as required to handle waste material
Cost	– €5,000/week hire of 2 man team & equipment including power supply – €200/m wire	2003 values, UK rates
Capacity/ performance	– No real limit other than that set by the practicality of equipment positioning, wire routing etc – Drilling of 50 mm diameter holes for wire saw blade access = up to 1.0 m per hour per unit – Approx 2 hours to set up wire saw equipment for each cut – Wire sawing up to 1.0 m^2 per hour	
Utility Requirements	– 3-phase 440V AC / 60 Amps	Required to power the hydraulic power unit
Weight	– 545 kg for the saw drive/tensioning gear plus 635 kg hydraulic power pack	
Secondary Wastes	– Slurry consisting of cooling/lubricating water and concrete debris – Water flow rate for wire sawing = 10–15 liter/min – Spent saw blade consumed at approx 1 m wire per 0.5 m^2 of cut	

As an alternative to water as a blade coolant, liquid gases have been used in trials. However, these techniques are not as widely available and are not effective at suppression of dusts, which is expected to be an important issue in a nuclear facility decommissioning project.

7.2.7.2 Impact/crushing techniques

For situations where the care and precision of diamond wire sawing is not required, conventional demolition techniques can be used, such as impact and crushing techniques. These techniques use a combination of impact hammers (jackhammers or pneumatic drills) and concrete breaking jaws, typically mounted on small excavator demolition machines, see Figure 7-13, Figure 7-14 and Figure 7-15.

The impact hammer usually has a chisel point and impacts the surface to be removed at rates of up to 600 blows per minute delivering up to 2,700 Nm (~2,000 ft.lb) force per blow. The technique has been used extensively on many decommissioning applications largely because of its versatility and low cost.

Figure 7-13. *Demolition machine equipped for concrete breaking.*

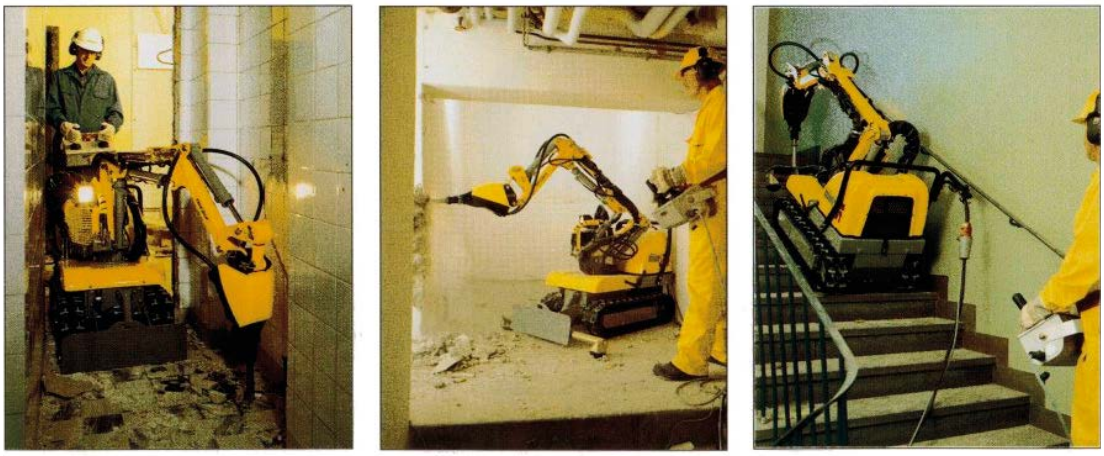

Figure 7-14. *Demolition machine equipped for remote control impact demolition.*

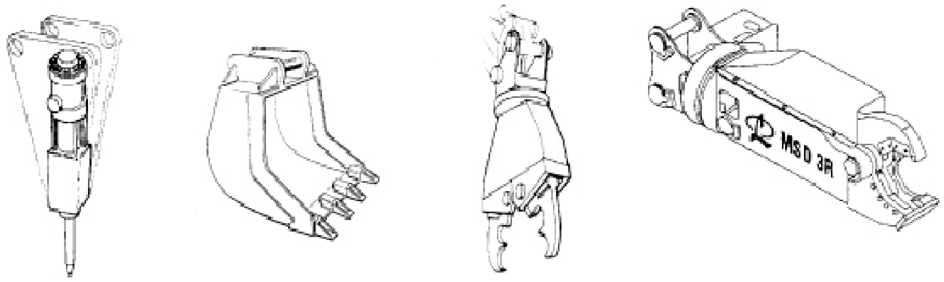

Figure 7-15. *Examples of tools for use with demolition machines.*

Concrete breaking jaws can also be used where there is suitable access to the edge of a wall to allow the jaws to work.

There are issues of noise pollution and dust generation, which can lead to airborne contamination, to be considered when using these techniques. The impact on personnel can be mitigated through the use of suitable personnel protective equipment and the use of water mist/sprays to reduce dust.

The production rates achievable using concrete breaking hammers and jaws are highly variable depending on issues such as accessibility and radiological conditions.

Table 7-6 provides information regarding the remote controlled demolition machine.

Table 7-6. Information regarding the remote controlled demolition machine.

Item	Remote controlled demolition machine	Notes
Manpower Requirements	1 Equipment operator	Plus labor as required to handle waste material
Cost	Variable depending on the model purchased and the precise application specific requirements	
Capacity/performance	Able to remove walls up to 0.9 m thick (3 feet). Larger scale equipment can handle greater thicknesses. Production rate is highly variable but during monitored trials an average rate of 4.5 m^3 per day was achieved and removing a reinforced concrete structure up to 3 feet thick.	
Utility Requirements	Power supplies to suit model and location. Alternatively a diesel version of the largest model is available.	
Weight	40–380 kg, plus max attachment weight 60 kg 90–980 kg, plus max attachment weight 140 kg 180–1,900 kg, plus max attachment weight 230 kg 330–4,400 kg, plus max attachment weight 550 kg	
Secondary Wastes	Misc. operating wastes such as hydraulic hose, wipes etc.	

7.2.8 Demolition

It is intended that all buildings, both contaminated and clean, are demolished using similar techniques. Contaminated buildings will be cleaned and surveyed as such and then demolished using conventional techniques appropriate to the building size and construction method.

Buildings will be stripped out of easily removed recyclable material. High level glass will also be removed as a safety measure. Concrete and brick buildings will be demolished using machine (excavator) mounted concrete crushers, breakers and grabs, with water spray applied where necessary to reduce creation of dust; which in this case would only be a conventional rather than a radiological hazard. The resulting debris will be crushed and metals separated out at this point. Concrete waste will be used to backfill ground voids up to one meter below ground level or transported off site as required.

Steel frame buildings represent an opportunity for relatively easy metals recycling and these will be demolished using mobile cranes, machine excavators and thermal/mechanical cutting tools.

Explosive demolition techniques may offer a safer demolition option on some taller structures, but may not be acceptable due to the presence of other nearby facilities.

7.3 Assumptions

7.3.1 Fuel management

It is assumed that, for safety reasons, no dismantling work is carried out while fuel remains on-site, e.g. in the storage pools. This is to ensure that there are no inadvertent modifications or system shutdowns that adversely affect the safe storage and management of the fuel. This is possibly a conservative approach, but more investigation work would need to be carried out before it is dismissed.

7.3.2 Installed lifting equipment

It is assumed that existing installed lifting equipment will be properly maintained and remain serviceable and available for use to support decommissioning.

There are an additional 33 overhead cranes in the Clink plant.

7.3.3 Waste containers

It is assumed that the following waste containers are available for the project and that site infrastructure exists that will allow these containers to be used safely.

1. ISO freight container (20 tonne)

These are standard 20ft long ISO Freight ("Sealand") shipping containers for lightly contaminated wastes. In this study half height containers are assumed to be used. The maximum total weight of the container is 20 tonnes and the maximum loading is 18 tonnes.

2. Steel box (5 tonne)

This is a relatively small steel container with 1.2×1.2×1.2 external dimensions and a 5 mm wall thickness. The maximum total weight of the container with intermediate and/or low level waste material is 5 tonnes and the maximum loading is 4.6 tonnes. The containers are transported in a shielded transport container (ATB 12K).

3. Future Developments

There is also the possibility that a larger Steel Box may be made available in advance of the Clink decommissioning project.

This container would be a large version of the 5 tonne Steel Box above, and would be 5 mm thick, 2.4 m long×2.4 m wide×1.2 m high with a maximum total weight of 20 tonnes and maximum loading of 19 tonnes. This waste container would be transported in a shielded transport container (ATB 8K).

In this study it is assumed that the large steel box will be ready in time for the decommissioning. The large steel box is used for the calculations of the intermediate level waste.

7.3.4 Waste disposal

It is assumed that all radiological wastes will be packaged for the purpose of disposal off-site in a dedicated repository. On this basis, the option of disposal of very low level wastes in on site voids/building basements has not been considered.

7.4 Dismantling sequences

The reduction in site radiological inventory offered by removal of the fuel significantly reduces the total radiological hazard present on site. Depending on the regulatory regime in operation at the time, this may allow a reduction in the nuclear safety measures that must be maintained, e.g. standing emergency teams, emergency arrangements and arrangements for independent review of modification (decommissioning) proposals etc, with resulting cost savings.

7.4.1 Planning and preliminary activities

In an ideal situation, the last 3 years of the plant operating life will be used to ensure that the period up to end of operation is carefully planned and managed, and to make suitable preparations for the decommissioning work that will follow. Some of these planning and preparatory activities will be required by regulations in force; others will be required only to ensure that resources are used efficiently during this period.

Some of the tasks to be completed during this period are as follows:

- Preparation of an Environmental Impact Assessment for Decommissioning – The requirement for this assessment stems from EU Directive 97/11/EC (itself an amendment of 85/337/EEC) which requires that an “assessment of the effects of certain public and private projects on the environment” is made with the aim of “providing the competent authorities with relevant information to enable them to take a decision on a specific project in full knowledge of the project’s likely significant impact on the environment”; the competent authorities being national regulators. The stated list of “certain projects” includes “nuclear power stations and other nuclear reactors including the dismantling and decommissioning of such power stations or reactors” so an assessment specific to the Clink decommissioning project is assumed to be required in this study. The assessment cover such environmental impacts such as pollution, noise, changes in traffic movements, effect on local flora and fauna etc.
- Preparation of Licensing Documents as required by the Swedish regulatory system (regulation for EIA, 1998:905), e.g. (a) submission of the general report to SSM explaining the objectives, measures and time schedule for decommissioning and (b) the facility’s plan, its incorporation into the facility safety report and its submission, with the completed EIAD (Environmental Impact Assessment for Decommissioning) attached, for the Swedish Environmental Court and SSM review and approval (as required by the Swedish Environmental Code “miljöbalken”).
- Preparation of any local/regional permissions required for demolition and other modifications to the appearance of the site.
- Site Characterization – preparation of comprehensive site radiological characterization data for plant and ground conditions, if insufficient data exists during the planning period.

- Review of Essential Services and other relationships between systems and structures – this is to enable predecessor/successor activities to be correctly logic-linked in the preparation of the decommissioning plan. It also identifies relationships between buildings and systems that might require modification to allow decommissioning, or activities that assist decommissioning, to proceed at the earliest opportunity. For example, power cables for a system that would be required for some time during the decommissioning programme might be routed through or attached to a redundant building. The power supply can be diverted to allow the redundant building to be demolished. There is often work of this type which can be identified, and sometimes completed, before end of generation, thereby helping to reduce the decommissioning period. This activity typically leads to the development and installation of an alternative Decommissioning Power Supply for the site which feeds only those systems required beyond the end of generation and avoids buildings which will be demolished early. As a safety measure this power supply is installed using cables of a color not otherwise used at the site (bright yellow or orange are typically used) which enables the original power distribution to be isolated when redundant and makes it easy for decommissioning workers to identify those power cables which are still live.
- Production of detailed decommissioning programme and cost estimate, with supporting analysis of cost and programme risks.
- Identification of major work packages and contract strategies – this identifies which packages of work will be carried out by site staff and which will require bought in specialist contractors or labor. This then enables the required staff levels to be determined and a staff run-down/retention strategy to be developed. It also allows technical specifications and contracts to be prepared early.
- Development of a modified site organization to suit the roles and responsibilities needed for the decommissioning phase and identification of the personnel to populate the organization. Alongside this would be the development of processes and plans for management of staff no longer required or those wishing to leave/change roles at the end of generation. This might include retraining opportunities, redeployment at other sites or staff redundancy arrangements.
- Development of a plan to manage the inventory of high cost items – thereby making sure that the site does not purchase items during the final period of generation that will not be used.
- Preparation of plans and contracts for disposal of non-radiological hazardous wastes (bulk chemicals, asbestos etc) and non-hazardous wastes (e.g. bulk concrete/brick rubble).
- Design and licensing of any non-standard waste packages identified as being necessary for the decommissioning of the site (e.g. bespoke containers for intact shipment of large components).
- Preparing and approving (in advance) revisions as required to the following plans/procedures or their local equivalents:
  - Site Emergency Plan
  - Radiation Protection Plan
  - Environmental Health and Safety Management Plan
  - Waste Management Plan.
- Place orders for any additional waste containers expected to be needed during the early phases of decommissioning.

7.4.2 On-site preparatory activities

As well as the planning activities above, the following activities will be required. In general they can be carried out during the normal operation and the preparation for dismantling.

1. Review access/egress routes for personnel and equipment to ensure that they provide efficient movement of personnel to and from work areas and allow efficient movement of wastes from workface to the Waste Management and Monitor Release Facilities. Ideally movements of personnel and waste materials should be kept separate to reduce worker dose and improve general safety. Modify routes in line with any suitable improvements identified.
2. Design and construct a Waste Management Facility appropriate to the types, volume and rate of waste arising to be expected during the decommissioning programme.

Typically this will be a refitting of a suitably sized existing facility, for example, an existing active workshop facility such as that found in the Clink workshops. Other suitably areas are the departure and arrival area. Ideally an existing facility would have:

- Good connections to the various workfaces that will be producing radiological waste
- Sufficient space to allow the various processes of additional size reduction, and packing to be laid out efficiently
- A suitably rated active extract system (or good opportunities to allow an extension to the HVA system to service the area)
- Easy access to the outside for dispatch of loaded waste containers
- A suitably rated overhead crane.

3. Design and equip a monitor/release facility appropriate to the types, volume and rate of non-radiological waste arising to be expected during the decommissioning programme. The aim of this facility is to efficiently monitor the materials produced by the dismantling programme that are expected to be suitable for unrestricted release. This facility would be equipped with automated scanning/monitor equipment and would be located in an area of low background radiation. The facility would not be required if applicable regulations prevented free release or if the radiological condition of the waste arising makes them unsuitable for release.

4. Establish a temporary contractor office/storage accommodation area if none already exists at the site. Typically, this will be a hardstanding area for contractors to bring temporary cabins to site. The area will be equipped with power, water and telephone lines as required. Alternatively make such accommodation available within existing buildings if space allows.

It may also be necessary to relocate staff and offices from areas to be decommissioned early in the programme to other areas of the site, possibly in temporary accommodation. Establish IT and service connections to temporary accommodation.

5. Develop a programme of training for the plant operations workforce in the new duties/skills required during the decommissioning period. Complete the training required by the initial decommissioning activities.

6. Carry out a Post Operational Clean Out of the site. This will involve such works as:
   - Draining and disposal of operational fluids
   - Disposal of operational wastes
   - Disposal of any remaining stored chemicals
   - Disposal of redundant spare components
   - Carrying out a general house-keeping exercise on the plant to remove any redundant materials, spares etc that may be stored within the various plant buildings.

7. Carry out a radiological housekeeping of the plant, where possible, to reduce worker dose rates.

8. Install new independent decommissioning power supplies to Clink using non-standard cable color (orange/yellow) to replace operational power supplies. Identify essential installed power supplies, which cannot readily be replaced and should not be removed at this stage, with spray paint of the same color. This will allow the existing system to be de-energized and removed while the Decommissioning Power Supply continues to power items that need to remain in service.

9. Design and install a new independent ventilation system when the demolition project makes the ordinary ventilations system obsolescent.

7.4.3 Buildings and systems dismantling and demolition

Buildings will be addressed on an "as-redundant" basis with buildings and rooms only being emptied of their contents when all systems within that area have become redundant, thereby avoiding the need to work in an area more than once.

Techniques to be used will generally be as above though there may be more scope for metals and material recycling from other areas of the plant. In this case it may be acceptable to remove systems in larger sections knowing that they do not need to be packaged in the various disposal boxes available.

The sequence for dismantling of systems from these other buildings will follow the same basic pattern. Firstly, any surveys necessary to ensure a good understanding of the radiological condition of the systems and work area will be carried out. Surveys will also be required for asbestos and other hazardous materials where there is any uncertainty regarding whether such materials will be found during dismantling.

Next, all redundant loose items will be removed, e.g. tools and other stored equipment, spares etc. Hazardous materials such as asbestos, oil and chemicals will then be removed. This will lead into the "clean strip out" or removal of items known to be radiologically clean that can be removed without disturbing any contamination that might be found inside systems. This will include removal of electrical equipment and cabinets etc only connected to contaminated systems by cabling. This might also include removal of non-structural building features such as partition walled office enclosures.

Redundant systems will be removed in a manner that opens up access to the work area, generally working away from the waste route if space is limited. For larger work areas, the area will be broken down into smaller workfaces which can be scaffolded or prepared as required, equipment removed and then move on to the next area. Useful operational systems such as overhead cranes will be left operational until the end of equipment removal.

Where practical, equipment will be removed in pieces which will allow for packaging the selected disposal container without further segmentation. However, this may only be possible for dismantling when personnel are working comfortably on the local operational floor level. Where personnel will be required to work at height, in conditions of elevated temperature or other non-ideal working conditions, equipment will be removed in the largest pieces possible so that more comfortable, reduced risk working conditions can quickly be re-established. Removed items can then be size reduced locally or in the Waste Management Facility as appropriate.

With all redundant equipment removed, decontamination of any high level areas can proceed, i.e. those areas which may need existing cranes or overhead platforms to provide access. Any in-service cranes etc can be removed next along with any stairs/platforms and other remaining items. Building walls and floors can now be decontaminated using appropriate techniques. A final survey will be carried out to ensure the building is clean of radiological and other material hazards.

8 Management of residual materials

8.1 Introduction

This chapter of the report describes the option for the decommissioning of areas of the Clink plant and for the management of the associated wastes. But at a conceptual level and the recommendations should therefore be considered as being indicative. Further engineering studies would be required to refine the evaluation and to develop definitive recommendations.

The main option has been considered with respect to waste management:

- A fit-for-purpose, modular waste screening facility constructed within one of the bigger rooms inside Clink or a similarly sized building, that makes use of re-usable modular containment and shielding, combined with the use of existing waste treatment buildings and their waste screening, size reduction, packaging and shipping systems.

This chapter evaluates the above option in the context of the anticipated waste arisings, waste monitoring and packaging requirements and relevant legal and regulatory considerations. Another option is described in Appendix A3.3 which is a fully engineered waste management facility contained within a purpose-built, dedicated structure.

An overview of potentially applicable size reduction equipments and methods are contained in Appendix A3.1 – Size reduction on site. An overview of potential monitoring solutions is provided in Appendix A3.2 – Waste monitoring.

Today all waste is treated at the waste treatment facilities at the OKG. These facilities will be decommissioned around year 2050. In this study it is assumed that the waste facilities at OKG will be replaced by new facilities on or off Clink site. The new facilities should handle both operational and decommissioning waste. It is assumed that the waste treatment facilities will be available at the time for decommissioning of Clink.

8.1.1 Decontamination

Consideration was given to the provision of decontamination facilities within the waste management system. The intention of these facilities would be to reduce levels of contamination to the next lower category. Therefore, LLW (Low Level Waste) items could potentially be disposed of as FRW (Free Release Waste) and ILW (Intermediate Level Waste) may attain LLW classification.

Given that it is assumed that decontamination will have been carried out on concrete surfaces, pipework interiors, etc, prior to dismantling, an effective process would have already been applied to those items of waste most likely to be of benefit from such a process.

8.1.2 Compaction facilities

Low level waste management facilities are often suited to the application of compaction or super-compaction in order to reduce waste volumes. Consideration was given to the provision of such facilities at Clink with the intention of significantly reducing packaged low level waste volumes.

If the new waste management system were to be designed to accept wastes from all three of the Oskarshamn units (O1, O2 and O3) and Clink, the cost benefits of including a large industrial compactor unit may be met. Even thought it will be a 25 year difference between the decommission of Oskarshamn NPP:s and Clink it is assumed that the same management system can be used if maintained. However, due to the space requirements and secondary waste volumes from the compactor itself, the cost benefit of including such a unit are diminished. (Even if all the secondary wastes were rerouted through the compactor, the total throughput may be insufficient to justify a large compactor on economic grounds alone.) As such, it has been decided that a large industrial compactor unit should not be included in the design concept for the waste management system. However, the use of a small-scale compactor may be appropriate for soft wastes arising from the plant dismantling operations, as well as the wastes from operating the facility itself, such as Personal Protective Equipment (PPE) and PVC sheeting.

8.1.3 Manual versus remote operation

A key question for the design of any waste management system relates to the source material that requires processing.

Consideration of the potential arisings of ILW across the site favors the use of manual dismantling methods for most, if not all, with dedicated temporary, shielded, remotely-operated facilities for the small quantities of ILW that are anticipated to arise.

8.2 Design assumptions and exclusions

For the purpose of this study, the following assumptions and exclusions have been agreed as the basis of design. Should any of these assumptions change during the course of the decommissioning planning, the concept design for the waste management system should be reviewed for validity.

- The waste management system will be designed to handle only wastes arising from the Clink plant.
- The design operating life of the waste management system will be 3–5 years.
- The system will have the capability to process up to 2,300 tonnes per year. Throughput may be as high as 50 tonnes per week (assuming a 46 week working year and 3 years nuclear dismantling). This is based on a working time of 8 hours per day.
- The waste categories will be short-lived LILW and FRW.
- Based on the data in Chapter 5 and Chapter 6, the predominant part of the waste is anticipated to be FRW on arising. A major portion of this waste is accounted for by concrete in building structures. The demolition of building structures is however outside the scope of this chapter. The remaining radioactive waste is assumed to be short-lived ILW and LLW, although some may be found to be suitable, either on arising or after minimal decontamination, for free release.
- The anticipated waste inventory requiring processing through the waste management system will be based on the data in Chapter 6.
- The waste will include concrete arisings from areas such as the fuel ponds (possibly contaminated following leaks).
- The wastes to be managed will be beta-gamma waste.
- All waste will be dry; therefore no liquid effluents will be present.
- Most of the waste will undergo some size reduction at the workface in order to facilitate retrieval and loading into a transfer container.
- Categories of waste will be initially determined at source and will be confirmed during sentencing.
- Some processing of mixed waste may be required.
- The FRW transport and LLW disposal containers are assumed to be 20 ft half-height ISO-type freight containers.

The short-lived ILW or mixed LILW final disposal package will be based on a 2.4×2.4×1.2 m, 5 mm thick steel container.

8.3 Generic sequence for dismantling and removal of decommissioning wastes

One of the key factors to success in the implementation of the physical decommissioning is to have a well thought-through, easy-to-use and accurate decommissioning database act as a management system for the documentation, planning and follow-up of the waste streams. The final design will be made at a later stage, but the idea is to have a database where every piece of the decommissioning waste is catalogued and marked for when it is supposed to be cleared out of the plant as well as its route in the waste management system and the final destination for disposal.

When the decommissioning commences, a worker gets a work order and goes to a pre-marked component. The component is removed, taken out of the plant and then scanned into the decommissioning database, thus marked as removed. The worker then gets instructions from the database about where the component is to be taken and what type of container to put it in.

Whatever approach is used for the processing and packaging of decommissioning wastes, broadly the same sequence will be used for dismantling and removal of waste materials. The sequence proposed is to deal as far as possible with the easier inactive wastes first, and steadily work through to the more difficult wastes higher up the ILW spectrum. This approach will allow operatives to learn from experience as they progress, and will also minimize any potential for active materials to cross-contaminate materials that might otherwise go for free release or LLW.

This sequence is based on actual experience in decommissioning operations in the UK[2], and follows the guidance of the relevant UK regulatory authority – the Health and Safety Executive Nuclear Installations Inspectorate (HSE-NII). The HSE-NII states in its guidance to inspectors on Decommissioning on Nuclear Licensed Sites:

"The processes associated with dismantling and decontamination will generally produce secondary radioactive waste, in the form of solid waste, or liquid and gaseous effluent. The strategy should avoid the unnecessary creation of radioactive waste and aim to minimize the quantities produced and discharged."

Similarly, in its guidance to inspectors on the Management of Radioactive Materials and Radioactive Waste on Nuclear Licensed Sites, the HSE-NII states:

"Radioactive waste is a product of many operations within the nuclear industry. Avoiding the creation of radioactive waste in the first instance and, secondly, minimizing the rate at which waste, which must be created, is produced is one of the foremost principles of good radioactive waste management which is embodied in international standards and Government Policy."

Number 7 of the principles of radioactive waste management set out by the IAEA (IAEA 1995) relates to waste minimization. It states:

"The generation of radioactive waste shall be kept to the minimum practicable, in terms of both its activity and volume, by appropriate design measures and operating and decommissioning practices. This includes the selection and control of materials, recycle and reuse of materials, and the implementation of appropriate operating procedures. Emphasis should be placed on the segregation of different types of waste and materials to reduce the volume of radioactive waste and facilitate its management."

In general, measures to reduce radioactive waste production at source are more effective than measures taken after the waste has been created. Waste minimization is fundamental good practice, reduces hazards on site, reduces the potential impact on the environment, and in many cases is cost effective. HSE-NII's expectations for the application of waste minimization include the following practices (in some cases the practices reduce the accumulation of waste rather than its creation):

- Avoidance of the production of secondary wastes
- Segregation of waste streams (by waste category, physical and chemical properties)
- Preventing spread of contamination
- Recycling and reusing material
- Waste clearance
- Decontamination
- Volume reduction
- Disposal.

The primary objectives of the proposed decommissioning sequence are therefore to minimize dose to personnel and to minimize the volume of materials that need to be disposed of as radioactive waste.

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[2] As demonstrated in the decommissioning of the 500 MW Hinkley Point A and 242 MW Bradwell reactors in the UK.

Such a generic dismantling sequence will proceed as follows:

1. Removal of uncontaminated (FRW) items, but with three exceptions:
   - Retention of plant and equipment[3] that can be employed in subsequent dismantling operations
   - Retention of plant and equipment where the removal task would subject operators to a dose (from adjacent radiation sources) which is not ALARA
   - Retention of concrete structures.
2. Removal of LLW, avoiding situations that would expose operators to an unacceptable dose uptake.
3. Removal of ILW.
4. Removal of uncontaminated plant and equipment that is either:
   - Inaccessible during stage 1
   - Retained to support stages 2 and 3.
5. Removal of activated and contaminated concrete e.g. LLW scabbling wastes.
6. Removal of bulk concrete (FRW).

It is recognized that it will not be possible to adhere rigidly to this sequence, but in broad terms dismantling should be programmed as described above. If, as the result of a building survey, radiation hotspots are detected that can be readily removed without giving rise to cross-contamination or significant additional worker dose, then this should be done before the removal of FRW and LLW. Reducing the risk of contamination spread in this way will minimize any subsequent problems in the management and disposal of those wastes. If, however, hotspots cannot be readily removed, then temporary modular shielding will be installed around the hotspots so as to allow removal of FRW and LLW in accordance with the above sequence.

8.4 Waste management system options

There are a number of approaches that could be employed in developing waste management systems for Clink. The option for this study consists of a modular fit-for-purpose screening facility built within an existing structure, split into segregated zones configured to meet the handling and screening requirements of different waste categories. This will be used in combination with the assumed available waste treatment facilities. Such a solution would place more emphasis on the logistics of the different waste streams, to avoid cross contamination and long and/or unnecessary transports between the different facilities.

8.4.1 Utilizing existing waste treatment facilities

8.4.1.1 Waste transfer logistics

The purpose of this approach is to maximize utilization of the future assumed available waste treatment structures at Clink or off site. This waste management system begins with an initial screening of the waste at an appropriate building inside Clink to roughly sort possible FRW, LLW and ILW already at an early stage. From the initial screening, the respective type of waste is transferred to the waste treatment facilities designated and redesigned where necessary, to manage that particular type of waste. A rough schematic of the different waste treatment facilities and waste routes as it is today is shown in Figure 8-1. The logistics of these waste transfers will be crucial to the success of the project.

8.4.1.2 Location of initial screening

One of the primary objectives of this option being to maximize waste sorting operations as close as practicable to source, there is one location in this case that is far better suited than any other. All of the major waste sorting activities are likely to take place within the receiving building, as it is one of the largest facilities being addressed in this chapter.

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[3] Equipment is here defined as that part of the installed plant that is relatively easy to install or remove (e.g. motors) as opposed to the major items of plant that are semi-permanently installed (e.g. vessels and pipework).

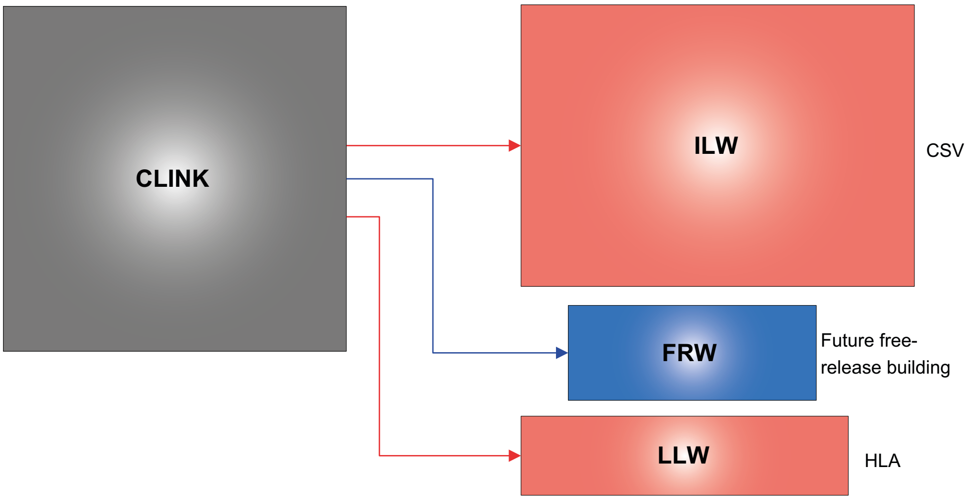

Figure 8-1. *Schematic of waste treatment facilities and waste transports from Clink to OKG as it is today.*

With regard to the decommissioning of structures, plant and equipment distant from the waste management facilities, while some initial in situ decontamination may be required, the bulk of the material is expected to be categorized at no more than LLW so it should present no difficulties in terms of its removal and on-site transport (local tenting-out, monitoring etc). Once removed, and if necessary given a preliminary size reduction, the wastes will then be passed on to the proper waste management facility, where the waste will be processed.

8.4.1.3 Utilizing existing facilities

The primary factor behind the suitability of this waste management solution stems from the fact that nearly all of the decommissioning waste arising from the Clink plant will be categorized as free release or LLW. An approach that is designed for handling high volumes of ILW will therefore be inappropriate.

The fit-for-purpose design concept for the initial waste screening comprises three main areas, all within the confines of an existing building, with the deployment where appropriate of re-usable modular containment and shielding. These three areas deal separately with FRW, LLW and ILW materials. A suitable enclosure might be in the form of a re-usable modular containment, (RMC) similar to that shown in Figure 8-2.

Figure 8-2. *Manual dismantling operations utilizing Re-usable Modular Containment (RMC).*

Free release material handling

As described in Section 8.4, free release materials will be dismantled and removed first. It will not be possible to remove all free release items during the first pass, but careful analysis of the location of various waste types, along with advanced sequence planning, will maximize the amount of FRW retrieved at this early stage.

The building for free release will be used for screening, processing and packaging of possible FRW. With free release materials having no potential to generate contamination, it will not be necessary to construct any type of enclosure for the breakdown and packaging of these wastes.

The building will be divided broadly into four areas, an area for screening of the incoming material, a buffer area for wastes waiting processing, the main size reduction and packaging area and finally an area set aside to store both empty skips and a small number of filled skips awaiting transfer from the free release facility.

Waste will be transferred to the size reduction/packaging area by a variety of means: by hand, on trolleys, or via one of the installed overhead cranes. Size reduction will be carried out using a mixture of hand-held power tools and floor mounted equipment (see Appendix A3.1 – Size reduction on site). As little size reduction as possible will be carried out on free release waste. Once size reduced, most waste will be loaded into transfer skips, if necessary by using one of the installed cranes.

Free release material export

With free release waste size reduced and ready to leave the free release building, the only operation remaining will be to transfer those wastes out of the facility for final export. Again this operation will be carried out using simple, fit for purpose means. Waste packages will be routed to an appropriate recycling or disposal facility. Metallic wastes could be dispatched to a metal recycling facility such as that currently operated by Studsvik (see Appendix A3.1 – Size reduction on site).

Waste loaded into skips will be moved on powered trolleys, whilst other ‘oversized’ but lightweight waste will be moved by hand. Waste will leave the building through a simple airlock facility. Waste will pass through the airlock with only one set of doors open at any time, thus minimizing any migration of possible airborne contamination between the building and adjacent area. Waste will be given a final monitoring whilst inside the closed airlock to ensure that it meets acceptance criteria for free release material.

The outer airlock doors will be opened and waste moved (either by trolley or by hand) onto a concrete hard-standing outside. Waste that can safely be man-handled will be loaded by hand into skips parked on hard standing immediately outside the building. Waste held in transfer skips will be lifted by a small crane which will provide coverage of the concrete hard-standing area and tipped into an ISO-type transport container for export off-site.

LLW material handling

As described earlier in this chapter, low level waste material (LLW) will generally be removed following the bulk removal of free release waste. It will of course not be possible to remove all low level waste in a single campaign, but careful analysis of the location of various waste types, along with advanced sequence planning, will maximize the amount of LLW retrieved during this first phase. Even though it is envisaged that LLW will be retrieved in several campaigns, it can be assumed that buffering of LLW adjacent to the processing area will allow LLW breakdown and packaging to continue without interruption. Some simpler methods for decontamination, such as high pressure water decontamination, is assumed to exist on site (Figure 8-3).

With low level waste having the potential to generate airborne contamination, it will be necessary to conduct processing operations using personal protective equipment (Figure 8-4 and Figure 8-5) and within a building which will provide radiological containment.

The building, will be divided broadly into three main areas: the waste buffer area, the main size reduction and packaging area and finally an area set aside to store a small number of empty transfer skips (with further buffer capacity available outside of the facility). Filled skips will be buffered outside of the building to await transfer from the waste treatment facility.

***Figure 8-3.** Example of high pressure water decontamination facility at Oskarshamn.*

***Figure 8-4.** Preparation work prior to plant dismantling operations.*

Waste will be transferred inside the facility by a variety of means: by hand, on trolleys, or via one of the existing overhead cranes. Size reduction will be carried out using a mixture of hand-held power tools and floor-mounted equipment (see Appendix A3.1 – Size reduction on site). Once size reduced, most waste will be loaded into transfer skips which will be lidded prior to exiting the building.

Figure 8-5. *Typical manual plant dismantling operations.*

LLW material export

With wastes size reduced and ready to leave the waste treatment facility, the only operation remaining will be to transfer those wastes out for final export. There are several ways in which waste can be transferred from inside the radiologically controlled confines of the facility to transport/disposal containers parked outside. The main problems associated with such export lie in ensuring that contamination does not migrate outside the facility and that operatives can load containers without risk of injury. Both problems are easily overcome using simple, fit for purpose means.

All packaged LLW, whether in lidded transfer skips or wrapped, will be swabbed and monitored before leaving the waste treatment facility. Waste loaded into skips will be moved on powered trolleys, whilst other 'oversized' but lightweight waste will be moved by hand.

If it is necessary to segregate the waste treatment facility's radiological zone from the adjacent waste transfer route, then a simple airlock will be constructed in the building perimeter wall. Waste will pass through the airlock with only one set of doors open at any one time, thus stopping any migration of airborne contamination between the waste treatment facility and the adjacent area. If necessary, waste packages will be monitored again for contamination whilst inside the closed airlock in order to confirm that they meet the necessary acceptance criteria for export from the facility. The outer airlock doors will be opened and the waste moved (either by trolley or by hand) onto a concrete hard-standing outside the facility.

Waste that can safely be man-handled will be loaded into ISO-type containers by hand, while waste in transfer skips will be lifted by a small crane that provides coverage of the concrete hard-standing area and tipped into the ISO container. (This assumes that the ISO containers are designed to be top opening. If the containers are side opening, then filling arrangements will be adjusted to suit.)

The ISO containers will then be exported off-site for either disposal in the SFR repository or further size reduction. Figure 8-6 shows different types of ISO containers.

ILW material handling

As mentioned previously, it is believed that a few percent of the waste arising from decommissioning activities will be categorized as ILW. Even though sequencing of waste removal dictates that (broadly speaking) these wastes should be removed last, there will be many instances where it will be prudent to remove ILW in tandem with free release and LLW materials such as where operators removing FRW and LLW will be subject to excessive radiation shine. Removing ILW in such a progressive manner will deliver benefits in terms of scheduling all waste processing and packaging activities, and also in throughput demands on the ILW processing area. ILW processing will thereby be phased over a longer period, and will not require ILW management solutions that are artificially compressed into a tight timescale.

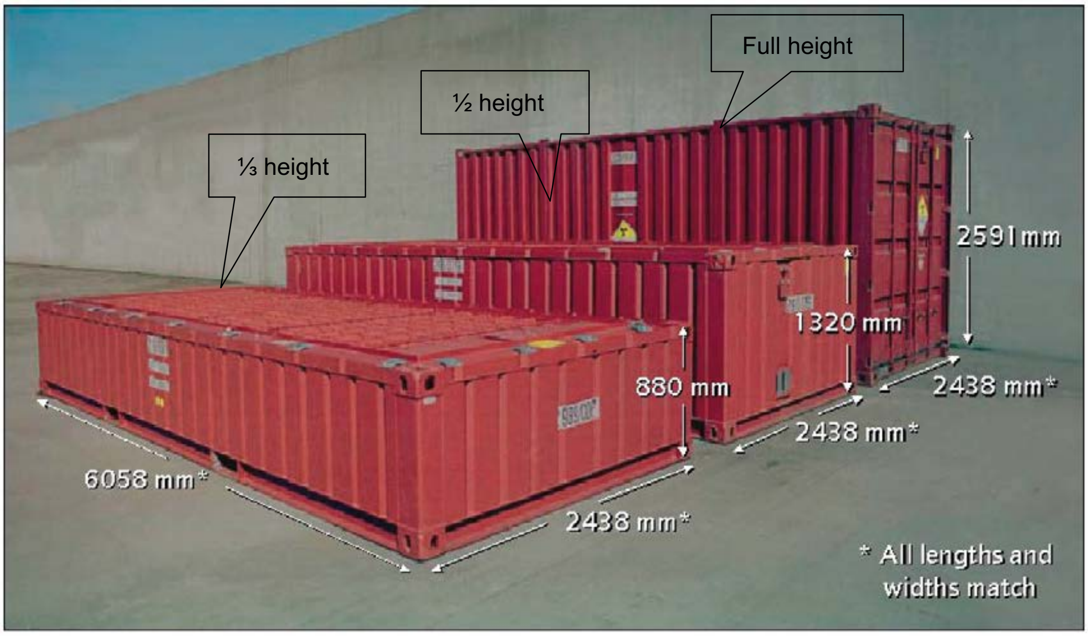

Figure 8-6. *ISO-type containers for LLW packaging.*

ILW will be removed using the most appropriate means for each situation which will be determined during the detail design stage. Although at this stage it is not possible to be prescriptive on how ILW will be removed and transferred to the appropriate waste treatment building the guiding principles are as follows:

- Local / temporary shielding will be erected to protect decommissioning operatives. Any dose to operatives will be ALARA.
- The area will be tented-out with a temporary enclosure which will mitigate any spread of contamination.
- As far as possible, dismantling and removal of ILW will be carried out manually, with recourse to remote techniques only when demanded by activity levels. Note: Much of the ILW will be at the low end of the ILW spectrum.
- ILW is assumed to be loaded into large steel boxes and transported in shielded transport containers such as one shown in Figure 8-7.
- Existing cranes will be utilized as far as is realistically possible for container loading and for moving containers in the ILW waste treatment building.

Figure 8-7. *Swedish shielded transport container (Photo: Bengt O Nordin, SKB).*

ILW material processing

ILW processing will be conducted in one of the waste treatment buildings within a shielded containment which will be developed in detail during later design development. However, guiding principles in designing the containment will be as follows:

- ILW processing and packaging activities will take place within a housing which is of a modular construction.
- The module will be fabricated, tested and taken through preliminary commissioning off site.
- The module will comprise of three main areas:
  - Waste container receipt and opening
  - Waste processing – assay, size reduction, decontamination (if required), etc
  - Waste loading into containers suitable for final disposal.
- In order to maintain containment, the atmosphere within the ILW waste processing module will be maintained at a depression. Ventilation will be provided by a mobile HEPA filtration unit which will be attached to the processing module and will vent to atmosphere via the existing ventilation of the building.
- Ideally all operator viewing requirements will be satisfied by use of cameras rather than shielded windows.
- The module will be as lightweight as possible. Therefore shielding will be provided around the perimeter of the module using materials such as pre-cast concrete panels or water-filled blocks. Existing cranes will be used to move and assemble shielding.
- The module will be deployed within the waste treatment building as fully assembled as possible to maximize the benefits of off-site fabrication and testing. If necessary, a pathway will be made by the demolition of peripheral structures and a new opening will be formed in the exterior wall of the building.

ILW material export

In this last stage of ILW processing, waste is loaded into its final disposal container, and dispatched for export to the SFR repository. The final disposal container is assumed to be an enlarged version (2.4×2.4×1.2 m) of the 1.2 m cubed 5 mm thick steel container shown in Figure 8-8. The container is 'docked' to the processing module and waste loaded remotely.

The operation of a shielded hatch within the floor of the loading area will be integrated with removal of the container lid. This will ensure that the outside of the container remains radiologically clean at all times and is therefore free to travel between the waste facility and the repository.

Prior to export, the disposal containers will be swabbed and monitored to ensure they meet acceptance criteria for off-site shipments. The containers will then be moved between the ILW processing building and the export bay by use of a bogie. At the export bay, a crane will be used to load the disposal containers into shielded transport containers (as shown in Figure 8-1) mounted on suitable transport equipment for transfer to the repository or further size reduction off-site.

Figure 8-8. *Swedish standard 1.2×1.2×1.2 m steel box for ILW disposal (Photo: Bengt O Nordin, SKB).*

9 Decommissioning programme

9.1 Introduction

This chapter presents a general decommissioning programme for Clink. The aim has been to cover all of the important phases of the decommissioning programme, from planning to site restoration. This has been done with input from Hallberg and Eriksson (2006). The entire nuclear site has been studied, but with a stronger emphasis on the structures on the site that contain radioactive parts.

The decommissioning programme has been developed in sufficient detail to give a good understanding of the varying activities that need to be performed and provides a good basis for a more detailed planning for an actual site-specific decommissioning project. Also, the level of detail has been set in order to give a sufficient basis for the cost estimation, presented in Chapter 10.

The programme will cover the whole decommissioning time span from shutdown of normal operation (including the initial planning that is done the last three years of normal operation) to hand-over of the cleared and decontaminated site for other industrial purposes. The programme will be limited to activities that the plant owner is responsible for and that are related to the decommissioning. Consequently, activities related to plant operation and maintenance before start of the dismantling (i.e. during the preparation for dismantling periods) are excluded. These activities are presented in detail in a separate study (Pålsson et al. 2003).

Activities after the radiological declassification of the plant, i.e. non-radioactive building demolition and restoration of the ground to a state adapted to the further use of the site, can be regarded as a sole interest of the site owner, not necessarily to be covered by mutual funds, and are therefore included but presented separately.

The programme starts with planning during the last three years of normal operation. For varying reasons the unit will not be dismantled immediately after shutdown of normal operation. Instead, a number of years of shutdown operation would be required when the plant is prepared for dismantling and the plant functions that need to be used during dismantling are maintained. A preparation for dismantling of two years has been assumed in this study as well as in reference Hallberg and Eriksson (2006). An overview of the decommissioning phases for Clink can be seen in Figure 9-2.

9.2 Conditions and assumptions

A number of conditions and assumptions have influence on the decommissioning programme. These are as follows:

- Based on the current reference scenario the decommissioning of Clink could commence in around 2076 (Hallberg and Eriksson 2006). Referred as year 0 in this report.
- The plant will be operated by the owner (licensee) with a staff adapted to the prevailing activities.
- All major decommissioning work will be executed as projects with separate project management and administration for each project.
- The plant owner has the overall responsibility for the relations with the authorities and the public.
- Planning, EIA work[4] etc for the decommissioning of the site commences three years before the planned shutdown date.
- The personnel building will be used for office spaces for the project as long as possible during the decommissioning period.
- An adaptation of the buildings will take place to prepare the different waste streams.
- All waste will be handled in the waste buildings available at the time of decommissioning, either on site or off site. See Chapter 8.
- The site shall be restored to a level suitable for other non-nuclear industrial enterprises i.e. the buildings shall be demolished to 1 meter below ground level and all buildings below ground shall be filled with crushed non-active concrete.
- Sufficient manpower, commercial equipment and materials are assumed to be available on demand.

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[4] Environmental Impact Assessment

9.3 General basis of the decommissioning programme

The construction of the decommissioning programme has been based on a high-level optimization of the time schedule. The objective of this optimization was to create a time schedule that is reasonably short without the need for extraordinary measures during the decommissioning work. The time schedule is based on the amount of work that has to be executed and the number of teams that can perform work in a building at the same time. The decommissioning sequences have been planned in a way that is logical.

With the above principle and the prerequisites according to Section 9.2, a high-level sequence has been structured for the decommissioning programme, see Figure 9-1 for a schematic outline. For the detailed planning of the decommissioning sequence, other factors like ALARA considerations, for example removal of the radioactive parts first in order to lower the dose or the opposite in order not to contaminate non-radioactive installations, will also matter.

The high-level sequence is defined by four time periods describing the plant's operational mode over time:

- Normal operation
  The normal operating cycle, interim storage and encapsulation of spent fuel, which continues until the final shutdown of the plant.
- Preparation for dismantling
  Preparation for dismantling begins when the last fuel has been removed from site and lasts until dismantling has started in a greater extent.
- Dismantling operation
  The period from when the dismantling has started in a greater extent until the site is "cleared". The following conditions would define the interface between the preparation for dismantling and dismantling operation periods:
  - The project organization for managing dismantling activities is established.
  - The most significant dismantling packages are purchased.
  - Investments in equipment for treatment and measuring of dismantling waste are prepared.
  - Necessary plant documentation is identified and arranged in a specific decommissioning archive.
  - A computer system that handles the outage labeling and flows of the decommissioning waste is put in place. This database reports directly to the time schedule.
  - The decommissioning plan and the environmental impact assessment are approved.
  - The radiological survey has been completed.
  - Decontamination of systems has been carried out and the decontamination waste has been taken care of.
  - Individual decontamination has been carried out for selected components.
  - The plant has been cleaned.
  - Systems not to be utilized during the dismantling phase are drained of its medium, if necessary dried, and the waste is taken care of.
  - Electrical equipment that is no longer needed is disconnected.
  - Equipment that are no longer needed and that can be sold are dismantled.
  - Existing systems, lifting devices etc that are needed during the dismantling phase are in proper condition and if needed rebuilt to suit the need from the dismantling operations.
  - Staffs with proper competence for operation and maintenance of the plant are available.
  - Necessary permissions and approvals from the authorities have been obtained.
  - Adaptation of buildings for waste handling and storage has been completed.
  - Adaptation of air, water and electrical systems has been carried out.
  - Adaptation of transport systems and communication facilities has been performed.
  - Other service facilities are installed on site.
- Building demolition and site remediation
  Demolition of non-contaminated buildings and site restoration.

In order to limit the total project time there has been an ambition to put several activities in parallel. An estimation of the number of dismantling teams is based on the maximum of people that can work in the same building at the same time. Based on number of teams and the amount of work hours that will be executed, the calendar time is calculated. This means that the numbers of dismantling teams will vary during the dismantling project.

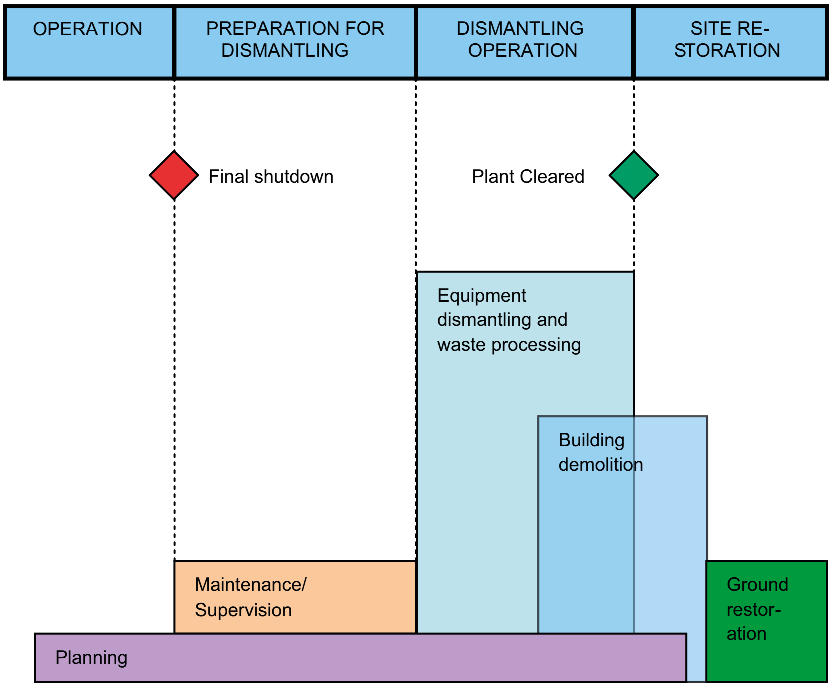

Figure 9-1. *Schematic outline of the decommissioning phases.*

The dismantling teams will move from one building to another and the same is valid for the demolition teams, so that dismantling and demolition sequences proceed in parallel in different buildings.

The milestones in the project plan presented in this chapter are mainly identified in Pålsson and Hedin (2005). However, information in plans presented in Ericsson (2005), Enekull (2000) and Hallberg and Eriksson (2006) has contributed to the specifics in the decommissioning time schedule.

9.4 Scope of decommissioning activities (WBS)

Many different criteria could be applied when establishing a Work Breakdown Structure (WBS) for a large project. The following have been considered here:

- The top level items are divided by time-depending milestones and this leads to the division into the main phases: normal operation, preparation for dismantling, nuclear dismantling and conventional demolition. For all phases only activities related to dismantling and demolition activities are included. This means that activities related to plant operation and maintenance before start of the dismantling (i.e. during the preparation for dismantling periods) are not included.
- The classification of activities that has been used in the study of dismantling operation (Pålsson and Hedin 2005) and information in the study of personnel during decommissioning operation (SKBdok 1359832) should also be used here, as far as reasonable. This implies that the classification of costs into own personnel, operational costs, fixed costs, organizational costs and project costs will be used.
- WBS items, whose size is dependent on time, are separated from items whose size are dependent on the actual work or activities that are carried out.
- WBS items related to so-called conventional dismantling and demolition are separated. With conventional dismantling is understood all dismantling/demolition that is executed after that the particular building has been classified as non-radioactive.
- A WBS item, after break-down to the most detailed level, should be able to be clearly linked to a single item in the ISDC structure (OECD/NEA 2012).

- Similar WBS structure as for earlier studies is a benefit as it enables comparisons. Hence, to facilitate comparisons with decommissioning studies for nuclear power plants, an extra WBS item is included between normal operation and preparation for dismantling. This compares to the power plants defueling period which is not applicable for Clink. By including the extra WBS item, the remaining phases are designated with the same WBS number as in the WBS structure for a nuclear power plant.
- Break-down should be done to a level that enables existing data in the form of inventory lists etc to be used with reasonable additional efforts for data separation in controlled areas and uncontrolled areas.
- The basis for each item should be traceable.

It is assumed that the plant owner has their own staff for operation of the site during the dismantling phase. The project organization is established early in the process. This organization will purchase all services needed, mainly through larger contractors.

Items connected to transport and disposal of radioactive waste, until the waste is packed and transported outside the waste facility, are included in the WBS. However, these WBS elements are covered by this study's time schedule on a very general level.

Based on the above mentioned criteria, a WBS has been established, see Appendix A4.1. The time schedule presented in Appendix A4.2 is structured according to this WBS.

9.5 Duration of the decommissioning activities

The WBS is presented in full detail in the programme attached in Appendix A4.2.

An important aspect of the time schedule preparation is to define a proper duration for each activity. For dismantling activities, like removal of process equipment (pumps, tanks, valves, pipes etc.), a specific model has been used. This model was established during the process system dismantling study (Lönnerberg 1994) and is mainly based on a combination of theoretical analysis and field experience, mostly from dismantling of equipment during repair work. The model relates the activity duration to a specific feature of the particular equipment, like length and diameter for pipe systems, number of units for small pumps etc. This is a fairly reliable and very practical way of dealing with the voluminous but less complex parts of the dismantling sequences. In addition, the model is used to calculate the corresponding work and, in that connection, the cost. More details about the model are given in Chapter 10.

An important factor is that only a certain number of people can work at the same time in a specific building and that more people means more administration and co-ordination effort in order to maintain the efficiency for the site work. Increased number of people working in the controlled area could also result in increased cross-contamination. Another factor to be considered is the limited capacity of lifts and overhead cranes which could result in increased waiting time.

The duration for demolition of the buildings is based on experiences from large scale demolition of conventional (non-nuclear) concrete buildings, e.g. a grain silo complex. This is described in Ericsson (2005).

A normal working time of 8 hours per day, 5 days a week, has been foreseen. In addition, four weeks in July and two weeks in connection with Christmas are designated as non-working time for most activities and resources.

9.6 Characteristics of the time schedule

The time schedule for the selected scenario is presented in Appendix A4.2. This section gives a broad description of its content, see Figure 9-2 for the decommissioning phases for Clink.

The first milestone in the time schedule is plant shutdown, which is planned to occur in year 0. The bars in the time schedule indicate the time period when the main parts of the activities, respectively, are carried out.

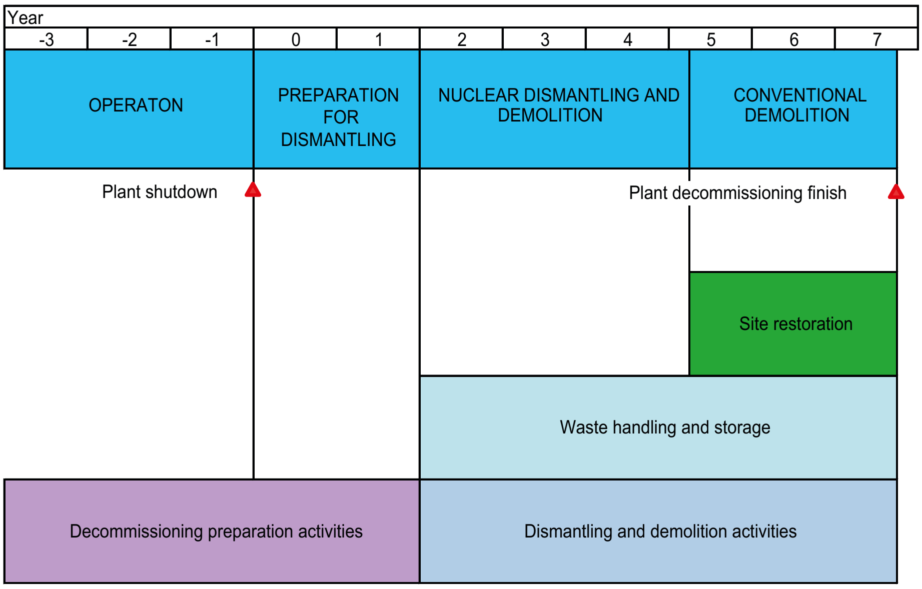

Figure 9-2. *The decommissioning phases for Clink.*

The main activities during the normal operation period are information gathering, planning, EIA work and formation of the decommissioning organization.

During the preparation for dismantling period the EIA and planning work continues. The period starts with a large-scale system decontamination and shortly after a radiological inventory characterization. This is followed by decontamination of selected equipments and plant systems adaptation to dismantling operation.

The main activities each year are summarized in Table 9-1.

The expected total duration of the decommissioning programme, from plant shutdown to finalized landscaping, is just over 7.5 years, while the actual dismantling and demolition period is about 5.5 years.

The workforce will amount to at the most around 200 staff members per year during the dismantling phase including contractor personnel, utility project management teams and utility operation personnel. More information about workforce and costs is given in Chapter 10.

9.7 Further optimization

The project plan presented here is an attempt to estimate the time required to perform a full-scale decommissioning project. In a second step the plan could be further optimized, either by shortening of the schedule and/or by optimizing the personnel utilizations.

Doing more activities in parallel than what has been proposed in this study could shorten the schedule. The size of the work force will then increase which could be done up to a level where it becomes impractical. Some aspects have been discussed in Section 9.5.

One possibility to shorten the schedule would be to start some of the insulation removal and system dismantling work during the preparation for dismantling period as soon as the necessary permits are obtained. An additional possibility is to start dismantling work in some parts of Clab before shutdown of Clink, e.g. in one part of the underground storage building if some the storage pools is empty. However, the benefit of shortening the schedule is affected by many factors.

Optimization efforts would need to focus primarily on activities on the critical path. Also, it would be necessary during more detailed planning to look at the personnel utilizations. Leveling out the work force requirements, so that the same staff could be used during longer periods of time, will increase the project efficiency.

Table 9-1. Main activities summary.

Year	Main activities
Year –3–0	(Normal operation)
	Information gathering and status review
	Preliminary EIA work
	Decommissioning planning work
Year 0	(Final shutdown)
	EIA work started
	System decontamination
	Radiological inventory characterization
	Selected object decontamination started
	Pre-decommissioning system adaptation started
Year 1	EIA work finalized
	Selected object decontamination finalized
	Pre-decommissioning system adaptation finalized
	General preparatory activities
	Adaptation of waste systems and building
Year 2	(Nuclear dismantling and demolition start)
	Dismantling work initiated
	Operation of waste systems started
Year 3	(Continued nuclear dismantling and demolition)
	Continued dismantling work in controlled area buildings
	Dismantling work in uncontrolled area buildings finalized
	Continued operation of waste systems
	Cleaning and clearance of controlled area buildings started
Year 4	(Continued nuclear dismantling and demolition)
	Dismantling work in controlled area buildings finalized
	Operation of waste systems finalized
	Removal of contaminated concrete
	Continued cleaning and clearance of controlled area buildings
	Decontamination and dismantling of the waste systems and buildings started
Year 5	(Continued nuclear dismantling and demolition)
	(Conventional demolition start)
	Cleaning and clearance of controlled area buildings finalized
	Decontamination and dismantling of the waste systems and buildings finalized
	Conventional demolition i.e. for free released buildings and non-active buildings initiated
Year 6	(Continued conventional demolition)
	Continued conventional demolition i.e. for free released buildings and non-active buildings
Year 7	(Continued conventional demolition)
	Conventional demolition i.e. for free released buildings and non-active buildings finalized
	Ground restoration started and finalized

10 Decommissioning cost estimate

10.1 Introduction

This chapter presents a cost estimate for the decommissioning of Clink. The cost estimate has been done for the decommissioning programme described in Chapter 9.

With the frame defined and all information generated previously in the study, the objective of this particular task is to estimate the total decommissioning costs, with the use of information from previous studies, Pålsson et al. (2003), Pålsson and Hedin (2005), SKBdoc 1359832, Ericsson (2005), OECD/NEA (2012), Gustafsson et al. (2006), Lönnerberg (1994) and Hallberg and Eriksson (2008), and the experience from both national and international decommissioning projects.

The cost estimate will cover the whole decommissioning phase from shutdown of operation (including the initial planning that starts approximately 3 years prior to shutdown) to hand-over of the cleared and decontaminated site for other industrial purposes. However, it is limited to activities that the site owner is responsible for and that are related to decommissioning. Consequently, activities during periods which are primarily aimed at keeping Clink in the intended state (i.e. activities not associated to the decommissioning) are excluded. The costs related to these activities are presented in detail in a separate study (Pålsson et al. 2003). The decommissioning of Clink can begin immediately after the last canister with spent fuel has left the site. Preparations at an early stage would be required that functions that are needed to be used during dismantling are maintained.

The costs of activities after the radiological declassification of the site, i.e. non-radioactive building demolition and restoration of the ground, can be regarded as a sole interest of the site owner, not necessarily to be covered by mutual funds, and are thus included but presented separately.

The cost estimates are presented both according to the WBS presented in Chapter 9, and according to the internationally accepted structure developed jointly between the OECD/NEA/EC/IAEA (OECD/NEA 2012).

10.2 Conditions and assumptions

A number of conditions have influence on the decommissioning costs. In addition, a number of assumptions have been made during the estimation of the costs. The conditions and assumptions are as follows:

- All conditions and assumptions in Chapter 7, 8 and 9 are also valid for the cost estimation.
- The cost estimates have been based on typical Swedish rates for different staff categories.
- All equipment costs are presented on the basis of the purchase price in the country of origin converted into SEK at the prevailing rate.
- Costs have been calculated as cash costs at the cost level of 2013. No discounting of costs of future work has been done.
- The programme of work and the resulting cash flows have been compiled on the basis that cash is available on demand. No attempt has been made to smooth cash flows throughout the project.
- The potential commercial or industrial benefits obtained by future use of the site, equipment or materials and the financial benefits of the decommissioning funds, are in general not considered.
- The costs associated with spent fuel management, transportation and final disposal of radioactive wastes from dismantling and demolition are not included.
- Costs for fees to authorities, SSM, are not part of the study, as these are not normally covered in SKB's annual Plan reports.
- No risk element has been added to any costs identified. Suitable contingencies are however suggested in Section 10.5.

10.3 Cost elements

10.3.1 General

The main cost elements in the WBS cost matrix (Appendix A5.1) are explained in more detail in the following subsections. A reference to the origin for each cost element is given in the column "Reference" if applicable. A "C" in this column implies that the cost is calculated from figures given in other places in this report.

The utility costs presented in Pålsson et al. (2003) and Pålsson and Hedin (2005) as well as the staff number in the project organization and the plant operation organization in SKBdoc 1359832 and the experience from previous decommission studies done by Westinghouse have been used that a relevant organization can be implemented in this study.

Cost figures calculated in this study are presented without associated contingency factors. Thus, in a further analysis it is possible to apply different contingencies depending on the particular case that is being studied. There is otherwise a risk that factors are applied on each other in several steps, reflecting an unjustified level of risk. Estimated (i.e. not calculated) cost figures, in particular figures based on experience, naturally include contingencies. Suitable contingencies are shown in Section 10.5.

10.3.2 Personnel rates

Each category of labour is classified, in the cost-index of 2013, according to Table 10-1. A typical Swedish rate for each category is used (Gustafsson et al. 2006). While the personnel in Category M, E and P are employed by the Utility (P as a consultant), the other categories (1–5) are employed by Contractors. The rates for category M and E correspond to wages including payroll tax only while the rate for the other categories should cover all costs, markups and profits associated to the work performed by the personnel employed by the Contractors.

The labour costs associated with the demolition of the buildings are based on special labour rates. This is described in more detail in Section 10.3.8 for labour costs associated with building demolition.

10.3.3 Utility personnel and project costs

The planning for decommissioning, including information gathering and EIA work, starts approximately 3 years before the shutdown of Clink. These cost elements comprise 10 positions; 2 planning engineers, 1 EIA engineer, 1 information engineer, 1 project manager, 0.5 documentalist, 0.5 IT engineer, 1 environmental engineer, 1 planner, 1 controller and 1 purchaser. These personnel are adapted to keep the site in a safe and good condition and to prepare the plant for the decommissioning. In addition to the utility site organization working with issues related to decommissioning, an ordinary operational organization is required during operation period. This organization works with regular maintenance of Clink, not related to decommissioning, and is thus not included in the cost estimate, and therefore these personnel is not presented here.

Table 10-1. Personnel rates.

Category	Typical kind of labour	Rate, SEK/hr
M	Utility Manager	700
E	Utility Engineer	350
P	Project Manager	1 400
1	Engineer	1 000
2	Foreman	800
3	HP Technician	650
4	Craftsman	650
5	Labourer	450

The utility site organization comprises the Lead Project Manager and his/her staff and below a subdivision in two main branches; one including the Project Managers and the other including the operation and executing personnel. The Project subdivision is fully concentrated on preparing the future decommissioning work while the other has a dual role, one to operate and perform maintenance to Clink and the other to assist the Project Managers with various technical services. The Plant Manager is responsible for the operating personnel and other personnel except the Project Managers, who reports directly to the Lead Project Manager. The organization is adapted according to the organization chart shown in Figure 10-1.

When the preparation for dismantling period begins after regular operation a larger organization is needed. The utility site organization then increases from 10 to 38 positions. The same number of positions is used during the second period, nuclear dismantling. The last period is conventional demolition and it requires a smaller organization than the previously two periods since all the active material has been removed. The amount of positions is therefore almost cut in half and decreases from 38 down to 20, 5. The number of positions in Table 10-2 and Table 10-3 are set after considering report SKBdoc 1359832 and discussions with SKB.

During the dismantling period and the conventional demolition period, all utility personnel costs are to be covered by the national decommissioning fund under the headline “Dismantling & Demolition Costs”. In the cost matrix (Appendix A5.1) the costs are separated in personnel costs (WBS 4.1.1 and 5.1.1) and purchaser´s project management costs (WBS 4.2 and 5.2).

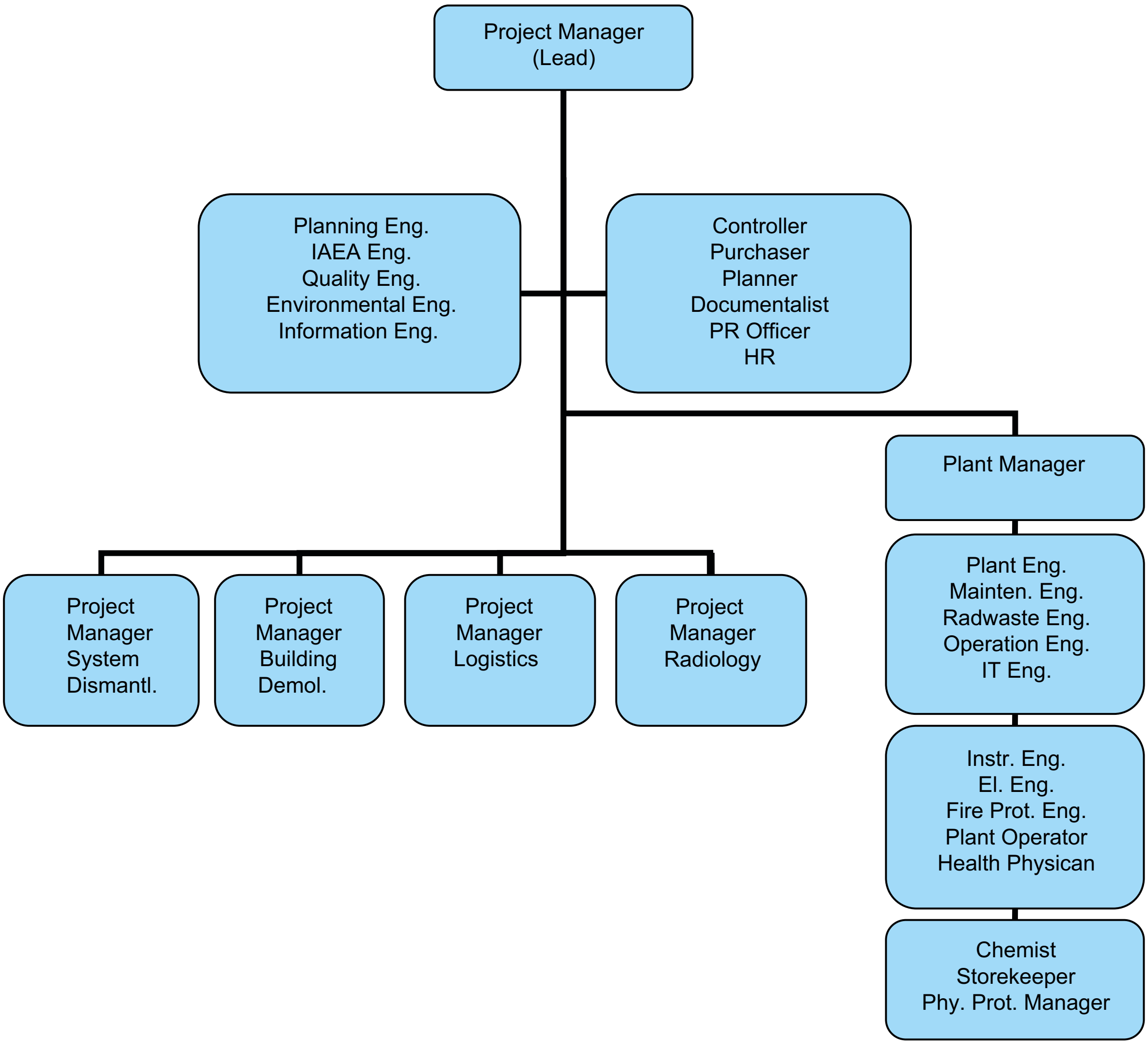

Figure 10-1. *Utility Organization for Normal Operation, Preparation for Dismantling, Nuclear Dismantling and Conventional Demolition.*

Table 10-2. Organizational utility personnel allocation.

Personnel Category	Time Period			
	Normal Operation	Preparation for Dismantling	Nuclear Dismantl.	Conv. Demol.
Plant Manager (M)	0	1	1	1
Plant Operator (E)	0	4	4	3
Plant Engineer EIA (E)	1	1	1	0
Plant Engineer Planning (E)	2	2	2	1
Plant Engineer Information (E)	1	1	1	0
Maintenance Engineer (E)	0	2	2	1
Radwaste Engineer (E)	0	2	2	1
Health Physics (E)	0	3	3	1
Chemist (E)	0	1	1	1
Storekeeper (E)	0	1	1	0
Physical Protection Manager (E)	0	1	1	0
Project Manager (P)	1	5	5	3
Instrument Engineer (E)	0	1	1	0,5
Electric Engineer (E)	0	1	1	0,5
Fire Protection (E)	0	2	2	1
Documentalist (E)	0,5	1	1	1
IT Engineer (E)	0,5	1	1	0,5
Environmental Engineer (E)	1	2	2	1
Planner (E)	1	1	1	1
Quality Engineer (E)	0	1	1	0
PR Officer (E)	0	1	1	1
Controller (E)	1	1	1	1
HR (E)	0	1	1	1
Purchaser (E)	1	1	1	0
Total	**10**	**38**	**38**	**20,5**

10.3.4 Operational costs

The operational costs for Clink during the Operation period (WBS 1.1.2) which are covered for in the present study are limited to the costs which in Pålsson et al. (2003) are classified as decommissioning costs, i.e. decommissioning preparation work. The costs are due to operational utility personnel costs and purchase of goods, services etc.

The operational costs for the dismantling and demolition periods (WBS 4.1.2 and 5.1.2) include utility personnel costs and all purchase of goods, services, energy etc necessary for the operation and maintenance of Clink (Pålsson and Hedin 2005, Hallberg and Eriksson 2008).

The utility personnel that is needed for the operation and maintenance, connected to the decommissioning of Clink is given in Table 10-3 (SKBdoc 1359832).

10.3.5 Fixed costs

The fixed costs for Clink (WBS 4.1.3 and 5.1.3) include fees, taxes and insurances. However, costs for fees to authorities are not part of the study, as these are not normally covered in the Plan reports. Other fees, inspection cost or taxes are not shown in Pålsson and Hedin (2005). It is presumed that these costs are included in plant operation costs.

Table 10-3. Operational utility personnel allocation.

	Time Period			
Personnel Category	**Normal Operation**	**Shutdown**	**Nuclear Dismantl.**	**Conv. Demol.**
HP Techicans (E)	0	3	3	0
Quality Engineer (E)	0	2	2	0
Chemist (E)	0	2	2	0
Environmental Engineer (E)	0	2	2	1
Physical Protection Guards (E)	0	6	6	2
Mechanic (E)	0	2	2	1
Electrician (E)	0	2	2	1
I&C Technician (E)	0	2	2	0
Cleaner (E)	0	2	2	2
Storage (E)	0	1	1	0
Controller (E)	0	2	2	1
Legal and Contracts (E)	0	1	1	1
Secretary (E)	0	2	2	2
Planning (E)	0	2	2	0
Total	**0**	**31**	**31**	**11**

10.3.6 Organizational costs

Organizational costs (WBS 1.1.3, 4.1.4 and 5.1.4) include costs for administration (personnel administration, legal and contracts, office equipment and supplies) and data processing hardware and software (Pålsson et al. 2003, Pålsson and Hedin 2005).

10.3.6.1 Process equipment

The amount of work ("man-hours") associated with the dismantling and the following treatment of the waste arising is calculated by means of a number of work procedures. For a certain equipment type, a number of procedures are generally used. For each procedure a "work team" is defined and in addition one or several formulas are developed to calculate the duration necessary for the work team to carry out dismantling, transport etc. The formulas are based on various parameters like number, length, weight or thickness.

The calculated duration is valid (with some exceptions) if the conditions were perfect, i.e. if the amount of work is carried out in workshop environment or similar, with no radioactivity and with ideal temperature, lighting, position etc. In order to take the real working conditions into consideration a factor, denominated Site Factor (SF), is used. The Site Factor is included in the calculation of the duration.

In order to obtain the amount of work, the resulting duration is multiplied with the number of individuals of the work team.

To use the formulas it is necessary to have very detailed information about all components and piping. From the inventory presented in Chapter 5, so-called macro-components have been defined according to Gustafsson et al. (2006). This implies that components, piping etc have been subdivided into intervals with respect to size and for each interval a characteristic quantity like length or weight is calculated. This way of dealing with data facilitates future revisions.

The work procedures, WP, used in the present study are presented in Table 10-4 and, including the composition of the corresponding work teams, in Appendix A5.3. The subdivision into macro-components and the corresponding productivity rates[5] are shown in Appendix A5.4.

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[5] A productivity rate defines the number of hours a work team needs for dismantling etc one unit of equipment, piping etc. The unit could be meter, kg, number etc.

Table 10-4. Work procedures.

WP No	WP Description
1a	Preparations of work area - radiological areas
1b	Preparations of work area – non-radiological areas
2	Removal of insulation from pipes and components
3a	Dismantling of intermediate level active pipes > DN50
3b	Dismantling of low level active pipes > DN50
3c	Dismantling of pipes up to and including DN50
3d	Dismantling of valves and actuators
4	Internal transports of waste
7	Dismantling and internal transportation of large components and tanks
8	Dismantling of steel (pipe supports, gratings, ladders, beams etc)
10	Dismantling of cables and cable trays etc
11a	Dismantling of HVAC ducts
11b	Dismantling of HVAC components
13a	Pool Liner - preparations, scaffolding and lifting preparations
13b	Pool Liner - decontamination by HP-cleaning
13c	Pool Liner - cutting, dismantling and removal
14	Dismantling and transportation of cranes
15a	Dismantling and transportation of cabinets
15b	Dismantling and transportation of electrical components

The Site Factor is in the present study generally set to 2.61 for Clink, i.e. the duration for a certain work in Clink is 2.61 times longer than if it is carried out under ideal conditions. It is an obvious fact that the Site Factor cannot be 2.61 in all areas of Clink, hence different Site Factors have been calculated for each area (K and OK as defined in Chapter 5). Also within a single area the Site Factor might differ between different types of equipment. The Site Factors in this study have been differentiated based on engineering judgements made by individuals with extensive experiences from installation and dismantling work in nuclear power plants. In Gustafsson et al. (2006), a correction factor was introduced to make it possible to change the Site Factor. The Site Factors and the correction factors are presented in Appendix A5.4**.**

The calculation of the amount of work for Clink has been carried out separately for each area (K and OK). Quantity values are collected from Chapter 5. The work has been summarized for each area and linked to the cost matrix (WBS 4.3.2 to 4.3.5). With the amount of work and the labour cost per hour, see Table 10-1, the resulting costs are calculated. In addition the average number of workers in each personnel category during the corresponding duration, which is collected from the time schedule in Chapter 9, is calculated. The resulting amount of work for various kinds of equipment is illustrated in Figure 10-2.

The project management and administration work within the process dismantling contractor's organization has been collected from Lönnerberg (1994).

The contractor's costs for the procurement and consumption of tools are based on an analysis made in Lönnerberg (1994). In the present study the tools are conservatively assumed to have no surplus value.

10.3.6.2 Cleaning and clearance of controlled area buildings

An estimation of the work associated to the clearance survey of the buildings is made in Ericsson (2005). The estimate is based on the total internal surface area given in Section 5.4.1 and with the following assumptions:

- Controlled area K, 100% survey for β/γ-nuclides and random check for α-nuclides. Duration 20 min/m^2.
- Uncontrolled area, equipment rooms: random (appr. 20%) survey for β/γ-nuclides. Duration 15 min/m^2.
- Uncontrolled area, offices etc.: no survey.

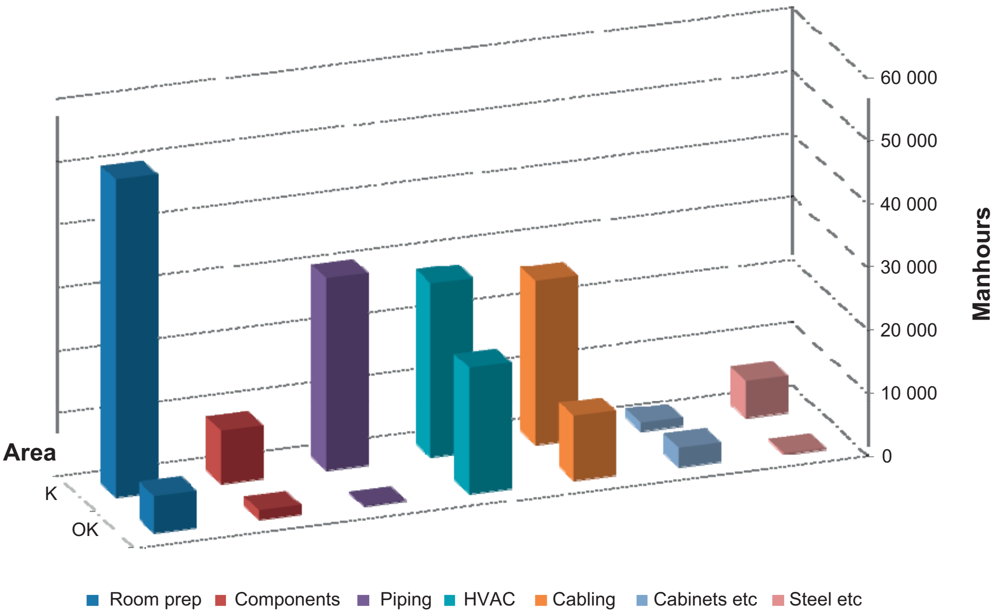

***Figure 10-2.** Dismantling Work Clink.*

The duration figures include wipe tests and documentation of the results and with the assumptions given above the total work will be 113,400 man-hours during approximately 1.8 years, WBS 4.3.3.2.

It is estimated in Ericsson (2005) that ten persons will be needed for other measurement and radiation protection activities during the active building demolition, WBS 4.3.2.2. In Clink this takes in the region of 60 days. In addition, five persons will be needed for further 1.9 years mainly for random check of the building rubble, WBS 5.3.5.

As it is not separated in Ericsson (2005), the costs for the cleaning of building surfaces are included in Demolition of radioactive concrete WBS 4.3.2.

10.3.7 Waste handling and storage

The waste handling and storage costs include the following:

- Waste Management System, as described in Section 8.1.4 (WBS 4.4.1)
- Disposal containers suitable for SFR (WBS 4.4.2)
- Transport to landfill (WBS 4.4.3.2 and 5.4.1.1)
- Landfill fees (WBS 4.4.4.1 and 5.4.1.2).

Neither the transports to SFR, nor disposal fees for radioactive waste are part of this study, as they are presented in another position in the SKB Funding, and the corresponding costs have been set to zero.

10.3.7.1 Waste management system

It is assumed that the waste management system will not be a purpose-built building or a purpose built facility in an existing building (that means that it will not be a room or building cleared out and specifically re-equipped for waste processing before waste production starts). Instead the waste management system will make use of the assumed future available existing waste treatment facilities on site.

The waste management system will not be required to manage the most active/contaminated wastes. Neither will it be required to survey large quantities of wastes for free release (the idea being that buildings and rooms are deplanted and decontaminated of all contaminated wastes so the remaining structural material of a building plus possibly some equipment will be surveyed as clean in situ and never need to go to the facility). The waste management system might be required to grout waste material into containers, but this is not considered in this study.

All of these factors tend to work towards making the waste management system relatively cheap, and in some ways more flexible as it will consist of individual facilities working together as a complement to the existing equipment being permanently linked together as an integrated process line. According to US experience at places such as Oak Ridge, this is the best way to manage the processing of wastes that may be highly variable in size and type of material.

Based on these assumptions, the costs for purchased equipment are estimated to 19,300 kSEK and the corresponding erection costs 2,150 kSEK. The facility is conservatively assumed to have no surplus value.

As for labour requirements, it is estimated each shift will require:

- 1 × Shift Supervisor/Waste Engineer (to look after QA records, package consignment paperwork etc)
- 1–2 × Health Physics Monitor (may vary with workload)
- 2 × Technicians (operate equipment and general maintenance)
- 3–6 × General Labourers (to move raw and processed material, operate equipment as required – may vary with workload)
- 0.1 × Electrical and Mechanical Technicians for maintenance.

In earlier studies (Gustafsson et al. 2006) it has been assumed that the average capacity for the waste management system is about 10 tonnes per 8 hour shift, based on experience, and that two shifts per day are handling the waste. However, for Clink the time for operation of the waste systems (WBS 4.4.1.1) is fixed and set to 650 days and the amount of waste is 4,300 tonnes. This makes it possible to have a workload of 6.6 tonnes per 8 hour shift. These assumptions result in a total work of approximately 31,700 man-hours during operation of the waste systems for Clink.

10.3.7.2 Waste containers

The costs for the waste containers are calculated from the number of containers of each category with radioactive waste, given in Section 8.2, and the unit costs as specified in Table 10-5. The costs are acquired from SKB and Forsmark.

10.3.7.3 Transport to landfill and landfill fees

The costs for the transport to landfills for non-radioactive waste and the corresponding landfill fees are calculated from the amount of waste in the blue and white activity category, given in Section 8.2, and the unit costs as specified in Table 10-6.

The unit costs used in Ericsson (2005) are also used in the present study, presented in the cost-index of 2013, as the actual amount of waste is dominated by the building rubbles.

Table 10-5. Cost for waste containers.

Cost per Waste Container	Value	Unit
ISO-type container (6×2,5×1,3)	30	kSEK
Cubical steel box (1,2×1,2×1,2)	30	kSEK
Large steel box (2,4×2,4×1,2)	150	kSEK

Table 10-6. Cost for landfill.

Cost for Landfill	Value	Unit
Landfill cost	0,75	kSEK/tonne
Transport to landfill	0,16	kSEK/tonne

10.3.7.4 Off-site processing and recycling

Instead of sending all the process components and pipes to SFR, 10 ISO-containers with waste can be sent to a plant for size-reduction (melting), see Section 8.1 and 8.2. Melting is not taken into account in the waste volume estimation for SFR.

After melting a total of 2 instead of 10 ISO-containers are going to SFR and for that reason the cost is negative for the waste containers.

The free-released components will be sent off-site for recycling. There are no additional costs for treatment or disposal of non-radioactive hazardous waste included. It is estimated that the costs, if any, would be covered by the value of the metal scrap.

The unit costs are specified in Table 10-7.

Table 10-7. Cost for off-site processing and recycling.

Off-site Processing and Recycling	Value	Unit
Recycling cost	0	kSEK/tonne
Melting cost	30	kSEK/tonne

10.3.8 Building demolition

The costs for building demolition have been investigated and reported in Ericsson (2005).

The cost calculation method is based on using simple measuring criteria, construction types and choice of demolition method with respect to, among other thing, concrete thickness, reinforcement, embedded steel and contamination penetration to calculate the demolition cost for various building elements. The calculation method is determined by the complexity of the building object. In case of thick contaminated concrete elements with strong reinforcement, the surface method[6] is used. For conventional building objects the building volume[7] is used as base for the calculation.

For buildings where both methods are used the building volume of the parts calculated with the surface method has to be subtracted from the building volume obtained from the volume method.

The costs for the building demolition are (as well as in Ericsson 2005) made up from the following components:

A. Basic costs.

B. Treatment, transport and final disposal of radioactive waste. Called "Waste handling and storage" (WBS 4.4) in the cost matrix in Appendix A5.1.

C. Treatment, transport and final disposal of non-radioactive waste. Called "Waste handling and storage" (WBS 5.4) in the cost matrix in Appendix A5.1.

D. General site expenses, contractor fees.

E. Proprietor costs.

The basic costs (A) have been derived by means of a so called production cost estimate, which implies that the costs are determined at activity level. The need for material, work and equipment is assessed for each activity and then the cost is estimated. However, relevant experience values from a project of this nature are not available. Instead, information from large conventional (non-nuclear) demolition projects has been used after appropriate adaptation. Finally, the costs related to the waste management, site expenses and customer costs have been added.

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[6] Can also be expressed as cost per compact concrete volume.

[7] According to SS 02 10 53, based on outer building volumes.

The “basic costs” (A) include costs for the resources necessary for the primary demolition work such as:

- Equipment, such as breaking jaws, floor shavers, impact hammers and diamond wire saws. The costs include depreciation, fuel, consumables, maintenance and repairs.
- Personnel resources for operation of the demolition equipment and other work directly related to the demolition.
- Equipment for handling and transport of radioactive building rubbles to containers. The container cost is included in the category “Treatment, transport and final disposal of radioactive waste”.
- Equipment for separation and decontamination of embedded steel such as cutters and high pressure cleaners.
- Equipment for handling and transport of non-radioactive building rubbles to transport vehicles. The vehicle cost is included in the category “Treatment, transport and final disposal of non-radioactive waste”.

The cost category (D), “General site expenses, contractor fees”, includes costs for the resources necessary for the general work and facilities necessary for the primary demolition work such as:

- Establishing on site.
- Machinery such as mobile cranes, lifts and general tools.
- Weather related costs.
- General operation and maintenance.
- Supervision and administration.
- Investigations, working preparations.
- Training.
- Adaptation of equipment and methods.
- Special auxiliary arrangements.
- Central administration, risks and profit.

The cost category E, “Proprietor costs”, includes costs for the resources necessary to realize the project but not included in the contractors undertaking. This cost category will not be discussed further here as the corresponding costs are covered by WBS 4.1 and 5.1, Plant operating costs, and WBS 4.2 and 5.2, Purchasers project management costs.

The cost figures used to calculate the basic costs (A) for the site buildings are presented in Table 10-8.

Table 10-8. Specific costs for demolition of the site buildings.

Element	Specific cost	Unit
Demolition of concrete estimated according to SS 10 02 53	100–200	SEK/m^3
Demolition contaminated concrete	39,000	SEK/m^3
Demolition non-radioactive concrete	6,500	SEK/m^3
Internal handling of building rubbles	200–300	SEK/m^3

The cost figures used to calculate the basic costs (A) for ground restoration work are presented in Table 10-9.

Table 10-9. Specific Costs for Ground Restoration.

Element	Specific cost	Unit
Demolition remaining building parts	3,300	SEK/m^2
Ground restoration, building with deep foundations	320	SEK/m^2
Ground restoration, buildings with surface foundations	230	SEK/m^2
Ground restoration, hard surfaces	270	SEK/m^2
Ground restoration, remaining areas	170	SEK/m^2

The costs in the category D, “General site expenses, contractor fees”, were in Ericsson (2005) calculated as a percentage of the basic cost varying from 30 to 45% depending on the complexity of the building. The same figures are used in this study.

The resulting demolition costs are, as well as the WBS elements to which the costs are assigned, summarized in Table 10-10.

10.4 Cost estimation results

10.4.1 WBS structure

The costs for each WBS element are presented in Appendix A5.1. The total cost amounts to 856 MSEK for Clink. The costs on a higher level of the WBS structure are shown in Table 10-11. For total costs with contingencies included see Table 11-4 and Table 11-5.

10.4.2 ISDC structure

The difficulty in comparing various decommissioning cost estimates between different countries is generally recognized. A comparison of individual cost estimates for specific facilities may show relatively large variations and several studies have attempted to identify the reasons for these variations. As the different kinds of costing methods define their cost items differently, values taken from one particular cost analysis, without regard to its context, is easily misunderstood and misinterpreted. One reason is that there has not been any standardized listing of cost items established, specific to decommissioning projects.

Table 10-10. Resulting building demolition costs.

WBS	Object	Basic cost (A) kSEK	Gen. Site Expenses (D) kSEK
4.3.2.1	Contaminated concrete	1,200	600
5.3.1	Receiving- auxiliary- and electrical building	7,500	2,600
5.3.2	Encapsulation building	5,900	2,100
5.3.3	Underground building	4,400	1,400
5.3.4	Other buildings	800	400
5.5.2	Ground restoration	16,900	6,800
Total		36,700	13,900

Table 10-11. Total costs (WBS structure, contingencies excluded).

WBS		Cost kSEK	%
1	**Normal operation**	**13,524**	**2%**
2	**Defueling**	**0**	**0%**
3	**Preparation for Dismantling**	**180,745**	**21%**
4	**Nuclear dismantling and demolition**	**536,504**	**63%**
4.1	Plant operationduring decommissioning	118,416	
4.2	Purchaser’s project management, admin. and technical supp.	85,337	
4.3	Dismantling and demolition activities	308,195	
4.4	Waste handling and storage	24,556	
5	**Conventional demolition**	**125,192**	**15%**
5.1	Plant operation during decommissioning	31,493	
5.2	Purchaser’s project management, admin. and technical supp.	36,979	
5.3	Dismantling and demolition activities	33,020	
5.4	Waste handling and storage	0	
5.5	Site restoration	23,700	
Total		**855,965**	**100%**

Based on similarly focused on-going activities with comparable objectives, the European Commission (EC), the International Atomic Energy Agency (IAEA) and the OECD/Nuclear Energy Agency (NEA) decided jointly to develop a common standardized list of decommissioning cost items. The objectives were to facilitate communication, promote uniformity and avoid inconsistency or contradiction of results or conclusions of cost calculations carried out by different organizations. The conclusion was that this would be a common interest for all the world's organizations involved in decommissioning activities, and thus it would be useful to encourage a common usage of the developed cost list.

The development work started in 1997 with a joint task force with representatives from the three organizations. In 1999 an interim report, "A Proposed Standardized List of Items for Costing Purposes", was published. The organizations behind this initiative hope that the list will be widely accepted and used for many cost calculation projects, thus creating a wider base for cost comparisons and bench-marking. Since then some organizations have adopted the format and made adjustments to their existing cost models.

An updated version has been made of the cost list in 2012, "International Structure for decommissioning Costing (ISDC) of Nuclear installations" (OECD/NEA 2012). The latter version has been used for the present study of Clink.

The standardized cost list groups the cost items into eleven main sections:

01. Pre-decommissioning Actions
02. Facility Shutdown Activities
03. Additional Activities for Safe Enclosure
04. Dismantling Activities within the Controlled Area
05. Waste Processing, Storage and Disposal
06. Site Infrastructure and Operation
07. Conventional Dismantling, Demolition and Site Restoration
08. Project Management, Engineering and Site Support
09. Research and Development
10. Fuel and Nuclear Material
11. Miscellaneous Expenditures.

The sections above are related to a specific cost type, regardless of the phases and activities of the project during which the cost is expected to appear. Thus, the structure is not so useful for project planning, only for cost comparisons. For example some preparatory activities from the Defueling Operation period of the WBS are sorted under the ISDC cost item Dismantling Activities within Controlled Area. For these reasons the present study has initially identified the cost items in the work breakdown structure (WBS) format. However, each WBS element is given a label which enables it to be transferred into the ISDC structure.

The costs, sorted according to the ISDC structure, are presented in Appendix A5.2. A summary is given in Table 10-12.

The main part of the equipment costs is included in contractors' fees and will thus be presented as part of the dismantling costs (04). No research and development costs (09) are foreseen as the decommissioning project will be carried out as a fully commercial project, using experienced sub-suppliers with fully developed technologies. By definition, no fuel costs (10) are presented as decommissioning costs in this study, neither costs which will be covered by the national decommissioning fund under the headline "Operation of Nuclear Power Plant Units after Final Shutdown". The conditions listed in Section 10.2 should also be noted, e.g, that the scope of the study excludes costs associated with final disposal of radioactive wastes.

All costs, sorted according to the ISDC structure, have also been attributed to one of the cost variables, EEF-codes, which have been defined by Professor Ulf Jakobsson together with SKB. These EEFs (external economic factors) have been defined in a method for handling and analyzing future real price changes for the goods and services included in the system for management of the waste products of nuclear power. Each EEF-code is linked to historical data of real prices, and with this data future real prices can be calculated.

Table 10-12. Total costs in ISDC format (contingencies excluded).

ISDC Matrix Elements			**Cost**	
			kSEK	**%**
01		**Pre-decommissioning Actions**	**14 812**	**1,7%**
	0100	Decommisioning Planning	4 347	29%
	0200	Facility Characterisation	2 174	15%
	0300	Safety, Security and Environmental Studies	3 381	23%
	0400	Waste Mamagement Planning	0	0%
	0500	Authorisation	0	0%
	0600	Preparing Management Group and Contracting	4 911	33%
02		**Facility Shutdown Activites**	**35 290**	**4,1%**
	0300	Decontamination of Closed Systems for Dose Reduction	34 120	97%
	0400	Radiological Inventory Characterisation to Support Detailed Planning	1 170	3%
03		**Additional Activities for Safe Enclosure**		
04		**Dismantling Activities within the Controlled Area**	**242 947**	**28,4%**
	0200	Preparation and Support for Dismantling	12 300	5%
	0600	Dismantling of Other Systems and Components	175 657	72%
	0700	Removal of Contamination from Building Structures	1 800	1%
	0900	Final Radioactivity Survay for Release of Buildings	53 190	22%
05		**Waste Processing, Storage and Disposal**	**58 123**	**6,8%**
	0100	Waste management system	54 066	93%
	0900	Management of Decommissioning Low-level Waste	1 170	2%
	1 200	Management of Decommissioning Exempt Waste and Materials	2 887	5%
	1 300	Management of Decomissioning Waste and Materials Generated Outside Controlled Areas	0	0%
06		**Site Infrastructure and Operation**	**154 632**	**18,1%**
	0100	Site Security and Surveillance	12 726	8%
	0200	Site Operation and Maintenance	58 468	38%
	0300	Operation of Support Systems	50 095	32%
	0400	Radiation and Environamental Safety Monitoring	33 344	22%
07		**Conventional Dismantling, Demolition and Site Restoration**	**70 532**	**8,2%**
	0100	Procurment of Equipment for Conventional Dismantling and Demolition	5 036	7%
	0200	Dismantling of Systems and Building Components Outside the Controlled Area	16 578	24%
	0300	Demolition of Buildings and Structures	25 217	36%
	0400	Final Cleanup, Landscaping and Refurbishment	23 700	34%
08		**Project Management, Engineering and Site Support**	**273 366**	**31,9%**
	0100	Mobilisation and Prepartory work	0	0%
	0200	Project Management	147 014	54%
	0300	Support Services	70 536	26%
	1000	Demobilisation by contractors	55 816	20%
09		**Reasearch and Development**		
10		**Fuel and Nuclear Material**		
11		**Miscellaneous Expenditures**	**6 264**	**0,7%**
	0100	Owner Costs	0	0%
	0200	Taxes	0	0%
	0300	Insurances	6 264	100%
Total			**855 965**	**100%**

The variables which have been defined are:

- Real payroll costs per unit produced in the service sector (code 0)
- Real payroll costs per unit produced in the construction industry (code 1)
- Real price trend for machinery (code 2)
- Real price trend for building materials (code 3)
- Real price trend for consumable supplies (code 4)
- Real price trend for crude copper (code 5)
- Real price trend for bentonite and similar materials (code 6)
- Real price trend for energy (code 7)
- SEK/USD exchange rate (code 8).

Table 10-13 shows the costs divided into the EFF-codes, as percentage of the total costs, for Clink.

Table 10-13. Total costs divided into EEF-codes.

ISDC Matrix Elements			Code 0, %	Code 1, %	Code 2, %	Code 3, %	Code 4, %	Code 5, %	Code 6, %	Code 7, %	Code 8, %
01		**Pre-decommissioning Actions**	**1,7**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
	0100	Decommisioning Planning	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0200	Facility Characterisation	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0300	Safety, Security and Environmental Studies	0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0400	Waste Mamagement Planning	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0500	Authorisation	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0600	Preparing Management Group and Contracting	0,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
02		**Facility Shutdown Activites**	**1,0**	**0,6**	**2,6**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
	0300	Decontamination of Closed Systems for Dose Reduction	0,8	0,6	2,6	0,0	0,0	0,0	0,0	0,0	0,0
	0400	Radiological Inventory Characterisation to Support Detailed Planning	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
03		**Additional Activities for Safe Enclosure**									
04		**Area**	**4,9**	**23,5**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
	0200	Preparation and Support for Dismantling	0,4	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0600	Dismantling of Other Systems and Components	4,4	16,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0700	Removal of Contamination from Building Structures	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0900	Final Radioactivity Survay for Release of Buildings	0,0	6,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0
05		**Waste Processing, Storage and Disposal**	**2,3**	**1,8**	**2,4**	**0,0**	**0,0**	**0,0**	**0,0**	**0,3**	**0,0**
	0100	Waste management system	2,3	1,8	2,3	0,0	0,0	0,0	0,0	0,0	0,0
	0900	Management of Decommissioning Low-level Waste	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0
	1 200	Management of Decommissioning Exempt Waste and Materials	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0
	1 300	Management of Decomissioning Waste and Materials Generated Outside Controlled Areas	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
06		**Site Infrastructure and Operation**	**13,5**	**0,9**	**0,0**	**0,0**	**1,1**	**0,0**	**0,0**	**2,5**	**0,0**
	0100	Site Security and Surveillance	1,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0200	Site Operation and Maintenance	6,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0300	Operation of Support Systems	2,2	0,0	0,0	0,0	1,1	0,0	0,0	2,5	0,0
	0400	Radiation and Environamental Safety Monitoring	3,0	0,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0
07		**Restoration**	**0,4**	**7,8**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
	0100	Procurment of Equipment for Conventional Dismantling and Demolition	0,1	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0200	Dismantling of Systems and Building Components Outside the Controlled Area	0,3	1,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0300	Demolition of Buildings and Structures	0,0	2,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0400	Final Cleanup, Landscaping and Refurbishment	0,0	2,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0
08		**Support**	**30,5**	**0,0**	**1,5**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
	0100	Mobilisation and Prepartory work	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0200	Project Management	17,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0300	Support Services	8,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	1000	Demobilisation by contractors	5,0	0,0	1,5	0,0	0,0	0,0	0,0	0,0	0,0
9		**Reasearch and Development**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
10		**Fuel and Nuclear Material**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
11		**Miscellaneous Expenditures**	**0,7**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
	0100	Owner Costs	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0200	Taxes	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	0300	Insurances	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Total			**54,9**	**34,6**	**6,5**	**0,0**	**1,1**	**0,0**	**0,0**	**2,9**	**0**

11.4.3 Annual costs and work

The cost and resource information given in Appendix A5.1 has been added to the MS Project time schedule, presented in Chapter 9.

If only cost information is available this has been inserted as fixed prorated cost.

The annual total cost is shown in Figure 10-3. The annual work for the main personnel categories is shown in Table 10-14.

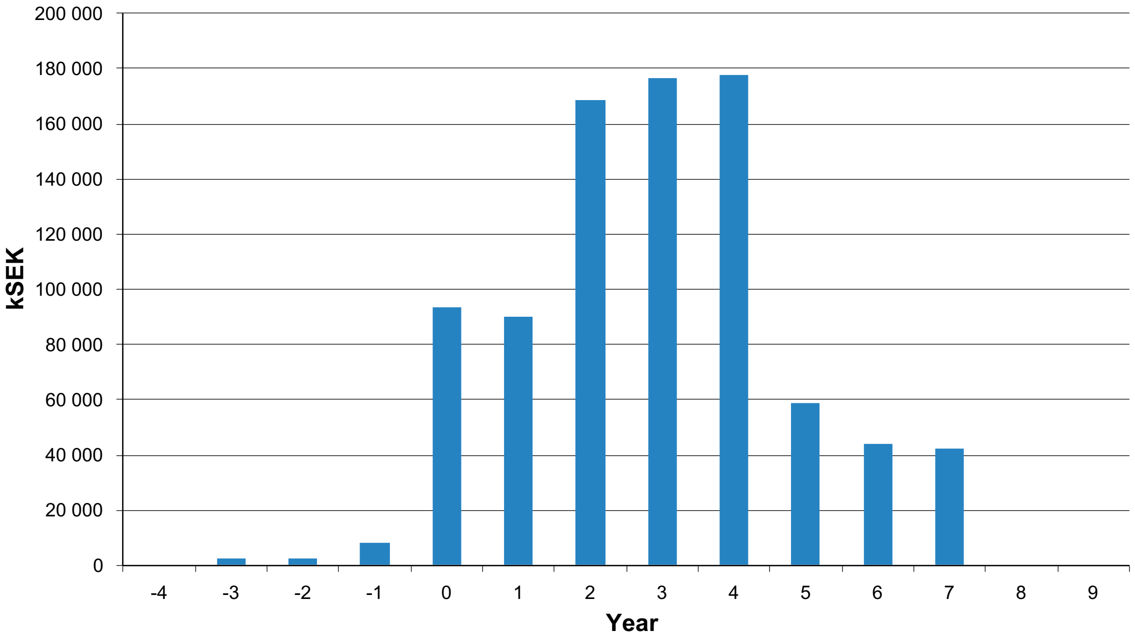

Figure 10-3. *Annual Cost.*

Table 10-14. Annual work.

	-4	**-3**	**-2**	**-1**	**0**	**1**	**2**
Utility Manager (cat.M)	0	0	0	0	2	2	2
Utility Engineer (cat.E)	0	4	4	8	63	63	63
Project Manager (cat. P)	0	0	0	1	6	5	6
Engineer (cat.1)	0	0	0	0	2	1	4
Foreman (cat. 2)	0	0	0	0	1	1	13
HP technician (cat.3)	0	0	0	0	2	0	4
Craftsmen (cat. 4)	0	0	0	0	2	3	11
Laborer (cat. 5)	0	0	0	0	3	1	63
Total	**0**	**4**	**4**	**9**	**81**	**76**	**165**

	3	**4**	**5**	**6**	**7**	**8**	
Utility Manager (cat.M)	2	2	2	2	1	0	15
Utility Engineer (cat.E)	63	64	32	26	16	0	406
Project Manager (cat. P)	6	6	3	3	2	0	38
Engineer (cat.1)	3	3	0	0	0	0	13
Foreman (cat. 2)	12	11	1	0	0	0	38
HP technician (cat.3)	3	2	0	0	0	0	10
Craftsmen (cat. 4)	11	9	0	0	0	0	37
Laborer (cat. 5)	76	80	8	5	1	0	238
Total	**176**	**178**	**47**	**36**	**19**	**0**	**795**

It is possible in MS Project to choose if the work volume for a specific activity should be proportional to the length of the activity (such as for security surveillance of the plant) or independent (such as a dismantling activity). This makes it feasible to investigate how the work volume, and the corresponding cost, is affected by altered length of the time schedule.

10.5 Contingency

This section contains an estimate of the project contingency. Contingency costs are for unforeseen, uncertain and unpredictable conditions typically encountered in decommissioning (known unknowns). In general, all contingency costs are spent as the project progresses, as these unforeseen events occur throughout the project.

The contingencies are of two basic types:

- contingencies related to material and equipment inventory
- contingencies related to the specific activities (resources, technique etc).

In Appendix A5.5, the contingencies and the reasons for them are specified. The reasons for the contingencies include the fact that some organizational costs are based on Barsebäck experience so some contingency is included in the cost, but by experience organizational costs tend to increase so some extra contingency is added. For the dismantling activities the contingencies are estimated on the basis of the accuracy in the inventory and the fact that the duration/work is increased due to difficulty in activity sequencing, tool troubles, not specified equipment etc. The contingencies for the room preparation costs are based on the fact that the costs are derived from the number of rooms in the building, not the size of the rooms. The contingencies have been estimated, in percent values, for individual cost items on a lower level in the ISDC structure. Then, the resulting contingency costs are summarized up to the higher level. The percentage is then recalculated considering the cost contribution of each contingency. In Table 10-15 the contingencies are shown for a higher level of the WBS-structure. A version showing the higher ISDC level is presented in Table 10-16.

The total contingency for Clink, according to Table 10-15 and Table 10-16, is approximately 148 MSEK, which results in a global contingency factor for the overall project of approximately 17%.

Table 10-15. Contingencies (WBS based).

WBS		Contingency	
		kSEK	%
1	**Normal operation**	**1,314**	**10%**
2	**Defueling**	**0**	**–**
3	**Preparation for Dismantling**	**31,373**	**17%**
4	**Nuclear dismantling and demolition**	**97,276**	**18%**
4.1	Plant operation during decommissioning	17,304	15%
4.2	Purchaser's project management, admin. and technical supp.	12,801	15%
4.3	Dismantling and demolition activities	63,490	21%
4.4	Waste handling and storage	3,682	15%
5	**Conventional demolition**	**17,929**	**14%**
5.1	Plant operation during decommissioning	3,662	12%
5.2	Purchaser's project management, admin. and technical supp.	4,345	12%
5.3	Dismantling and demolition activities	6,604	20%
5.4	Waste handling and storage	0	–
5.5	Site restoration	3,318	14%
Total		**147,893**	**17%**

Table 10-16. Contingencies (ISDC based).

ISDC Matrix Elements			Contingency	
			kSEK	%
01		**Pre-decommissioning Actions**	**1 507**	**10%**
	0100	Decommisioning Planning	435	10%
	0200	Facility Characterisation	169	8%
	0300	Safety, Security and Environmental Studies	405	12%
	0400	Waste Mamagement Planning	0	–
	0500	Authorisation	0	–
	0600	Preparing Management Group and Contracting	499	10%
02		**Facility Shutdown Activites**	**10 455**	**30%**
	0300	Decontamination of Closed Systems for Dose Reduction	10 236	30%
	0400	Radiological Inventory Characterisation to Support Detailed Planning	219	19%
03		**Additional Activities for Safe Enclosure**	**0**	**–**
04		**Dismantling Activities within the Controlled Area**	**48 321**	**20%**
	0200	Preparation and Support for Dismantling	3 530	29%
	0600	Dismantling of Other Systems and Components	40 875	23%
	0700	Removal of Contamination from Building Structures	360	20%
	0900	Final Radioactivity Survay for Release of Buildings	3 556	7%
05		**Waste Processing, Storage and Disposal**	**11 601**	**20%**
	0100	Waste management system	10 587	20%
	0900	Management of Decommissioning Low-level Waste	293	25%
	1 200	Management of Decommissioning Exempt Waste and Materials	722	25%
	1 300	Management of Decomissioning Waste and Materials Generated Outside Controlled Areas	0	–
06		**Site Infrastructure and Operation**	**19 348**	**13%**
	0100	Site Security and Surveillance	1 315	10%
	0200	Site Operation and Maintenance	6 598	11%
	0300	Operation of Support Systems	6 660	13%
	0400	Radiation and Environamental Safety Monitoring	4 775	14%
07		**Conventional Dismantling, Demolition and Site Restoration**	**14 100**	**20%**
	0100	Procurment of Equipment for Conventional Dismantling and Demolition	1 101	22%
	0200	Dismantling of Systems and Building Components Outside the Controlled Area	4 626	28%
	0300	Demolition of Buildings and Structures	5 055	20%
	0400	Final Cleanup, Landscaping and Refurbishment	3 318	14%
08		**Project Management, Engineering and Site Support**	**40 759**	**15%**
	0100	Mobilisation and Prepartory work	0	–
	0200	Project Management	18 832	13%
	0300	Support Services	8 990	13%
	1000	Demobilisation by contractors	12 937	23%
9		**Reasearch and Development**	**0**	**–**
10		**Fuel and Nuclear Material**	**0**	**–**
11		**Miscellaneous Expenditures**	**1 801**	**29%**
	0100	Owner Costs	0	–
	0200	Taxes	0	–
	0300	Insurances	1 801	29%
Total			**147 893**	**17%**

11 Summary results and conclusions

11.1 Introduction

The purpose of this chapter is to summarize the main results and conclusions of the decommissioning study of Clink. The impacts of alternative strategies are discussed. Finally, a discussion of interaction measures between earlier studies is given.

11.2 Summary results

11.2.1 General

The aim of this study is to provide a fully covering basis with the actual system inventory assessment, radiological inventory, time schedule, costs, waste production and waste types for the decommissioning of Clink. The waste amount estimations from the decommissioning study of Clink will be an input to SKB for the extension of SFR.

The same methodology has been used as for the "Swedish BWR Reference Plant Decommissioning Study" made for Oskarshamn 3 in 2006 (Gustafsson et al. 2006). The decommissioning study should be continually updated since new decommissioning techniques are developed and plant modernizations are conducted.

There is now considerable experience available in Light Water Reactor (LWR) decommissioning generally, though limited experience exists in the area of decommissioning of facilities such as Clink.

11.2.2 Site inventory

A site inventory has been conducted in Chapter 5 and Chapter 6 to determine the quantities of material of different types, both radiological waste and clean materials, which will need to be managed during the decommissioning activity. This information has been based on specific databases and other data, such as e.g. drawings. Where necessary, walk-downs and engineering judgments have been applied.

11.2.3 Waste quantities and classification

The decommissioning waste generated has been categorized in activity categories. Based on the activity, type and quantity of the waste, the number of appropriate waste containers has been estimated. The waste categorization has been based on the site specific materials inventory data, described in Section 11.2.2, in combination with nuclide specific data. The basis for the activity data are a computer simulation of the levels that are expected one year after final shutdown.

The resulting number of waste containers and their net disposal volume at the repository for Clink are shown in Table 11-1, Table 11-2 and Table 11-3. The free release waste in the Blue & White category in Table 11-1 can be used to fill cavities during the site restoration. Tunnels, shafts and the foundation will be backfilled up to one meter below ground level. The possibility of purchasing extra material to fill cavities has not been quantified or cost estimated.

Table 11-1. Waste container data: Process equipment waste for Clink.

Suggested Disposal Facility	Net disposal Volume (m^3)	Number of Waste Containers	Container	Waste Category	Outside measurements (m)
SFR	21	3	Large steel box	Red	2.40×2.40×1.20
SFR	177	9	ISO-type Container	Yellow & Green	6.06×2.50×1.30
Recycling	21,523	1,093	ISO-type Container	Blue & White	6.06×2.50×1.30

Table 11-2. Waste container data: Concrete waste for Clink.

Suggested Disposal Facility	Net disposal Volume (m^3)	Number of Waste Containers	Container	Waste Category	Outside measurements (m)
SFR	138	7	ISO-type Container	Yellow & Green	6.06×2.50×1.30
SFR	0	0	ISO-type Container	Blue & White	6.06×2.50×1.30

Table 11-3. Waste container data: Decontamination waste for Clink.

Suggested Disposal Facility	Net disposal Volume (m^3)	Number of Waste Containers	Container	Waste Category	Outside measurements (m)
SFR	12	7	Steel box	Red	1.20×1.20×1.20

11.2.4 Decommissioning programme

A decommissioning programme for Clink has been developed. It shows the sequence and timing of the major activities to be carried out during planning and execution of the decommissioning of the site.

In order to limit the total project time there has been an ambition to run several activities in parallel. The dismantling teams will move from one building to another and the same is valid for the demolition teams, so that dismantling and demolition sequences proceed in parallel in different buildings. The total reliance on proven tools and techniques that have been used on progressing or completed decommissioning projects in the USA and Europe is a key element in all sequences. In doing so, project programs have been developed that do not include any research or development of techniques that could lead to delays or cost escalations.

The programme for Clink covers the whole decommissioning time span from preparation for dismantling (including the initial planning that is done during the last 3 years of operation) to hand-over of the cleared and decontaminated site for other industrial purposes.

The first milestone in the time schedule is plant shutdown, which is planned to occur in year 0. The main activities during the normal operation period are information gathering, planning, EIA work and formation of the decommissioning organization.

During the preparation for dismantling period the EIA and planning work continues. The period starts with a large-scale system decontamination and shortly after a radiological inventory characterization. This is followed by decontamination of selected equipments and plant systems adaptation to dismantling operation. The decommissioning phases for Clink are presented in Figure 11-1.

The expected total duration of the decommissioning programme, from plant shutdown to finalized landscaping, is just over 7.5 years, while the actual dismantling and demolition period is about 5, 5 years.

11.2.5 Organization

The utility site organization responsible for the decommissioning is established early in the process, approximately three years before shutdown of Clink. This organization will purchase all services needed, mainly through larger contractors. The organization comprises the Lead Project Manager and his/her staff and below a subdivision in two main branches; one including the project managers and the other including the operation and executing personnel. The project subdivision is fully concentrated on preparing the future decommissioning work while the other has a dual role, one to operate and perform maintenance to the plant and the other to assist the project managers with various technical services. All major decommissioning work will be executed as projects with separate project management and administration for each project. The plant owner has the overall responsibility for the relations with the authorities and the public.

The workforce at Clink will amount to at the most around 200 staff members per year including contractor personnel, utility project management teams and utility operation personnel. This will occur during the dismantling phase.

11.2.6 Cost estimate

The cost estimate for Clink covers the whole decommissioning phase from preparation for dismantling (including the initial planning that starts 3 years prior to preparation for dismantling) to hand-over of the cleared and decontaminated site for other industrial purposes. However, it is limited to activities that the plant owner is responsible for and that are to be covered by the national decommissioning fund under the headline “Dismantling & Demolition Costs”.

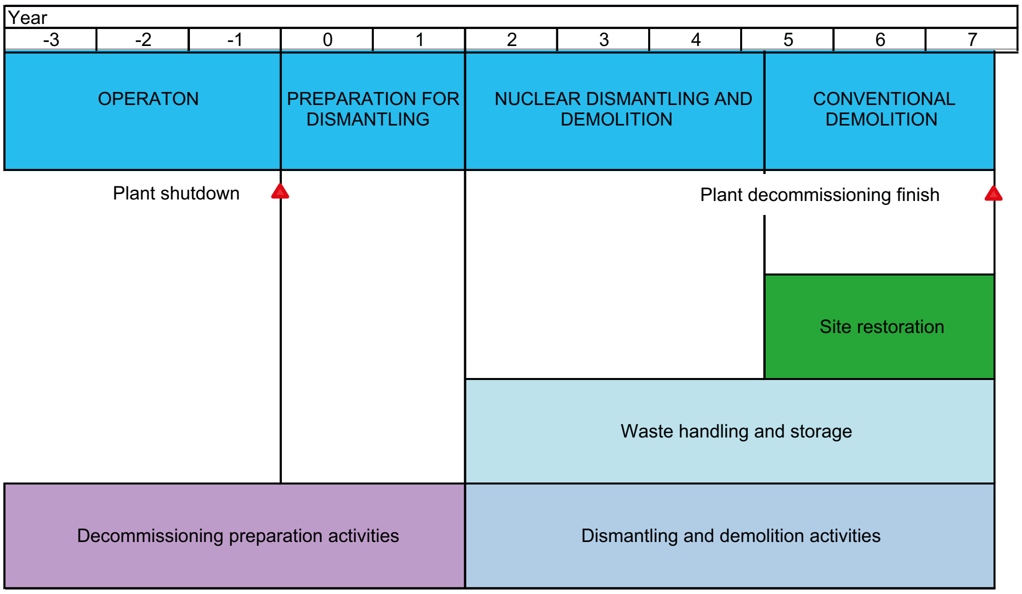

***Figure 11-1.** Decommissioning phases for Clink.*

11.2.6.1 Total cost estimation results

The total cost for the whole decommissioning of Clink will be about 1,004 MSEK. The total costs sorted according to the higher level of the WBS established in Chapter 9, are shown in Table 11-4.

As it is difficult to compare various decommissioning cost estimates between different countries, the cost estimation result has also been sorted according to OECD/NEA (2012) as can be seen in Table 11-5.

11.3 Techniques and strategies

11.3.1 Process equipment size reduction off-site

11.3.1.1 General

As described in Appendix A3.1, process equipment waste may be size reduced off-site through e.g. melting. The alternative of size reduction off-site is throughout the study taken as an example of an alternative treatment of some of the process waste.

Studsvik is used as an example of a licensed company that performs melting of radioactive waste. For Studsvik to be able to handle scrap or components for direct treatment there is a surface dose rate limit of < 0.2 mSv/h and a specific activity limit of $< 5\times10^5$ Bq/kg.

Table 11-4. Total cost sorted according to the WBS for Clink.

WBS		Cost		Contingency	
		kSEK	%	kSEK	%
1	**Normal operation**	**13,524**	**2%**	**1,314**	**10%**
2	**Defueling**	**0**	**0%**	**0**	**–**
3	**Preparation for Dismantling**	**180,745**	**21%**	**31,373**	**17%**
4	**Nuclear dismantling and demolition**	**536,504**	**63%**	**97,276**	**18%**
4.1	Plant operation during decommissioning	118,416	14%	17,304	15%
4.2	Purchaser’s project management, admin. and technical supp.	85,337	10%	12,801	15%
4.3	Dismantling and demolition activities	308,195	36%	63,490	21%
4.4	Waste handling and storage	24,556	3%	3,682	15%
5	**Conventional demolition**	**125,192**	**15%**	**17,929**	**14%**
5.1	Plant operation during decommissioning	31,493	4%	3,662	12%
5.2	Purchaser’s project management, admin. and technical supp.	36,979	4%	4,345	12%
5.3	Dismantling and demolition activities	33,020	4%	6,604	20%
5.4	Waste handling and storage	0	0%	0	–
5.5	Site restoration	23,700	3%	3,318	14%
Total		**855,965**	**100%**	**147,893**	**17%**

Table 11-5. Total cost sorted according to the ISDC structure for Clink.

ISDC Matrix Elements			Cost		Contingency		Cost + Cont.
			kSEK	%	kSEK	%	kSEK
01		**Pre-decommissioning Actions**	**14 812**	**2%**	**1 507**	**10%**	**16 319**
	0100	Decommisioning Planning	4 347	29%	435	10%	4 782
	0200	Facility Characterisation	2 174	15%	169	8%	2 343
	0300	Safety, Security and Environmental Studies	3 381	23%	405	12%	3 786
	0400	Waste Management Planning	0	0%	0	–	0
	0500	Authorisation	0	0%	0	–	0
	0600	Preparing Management Group and Contracting	4 911	33%	499	10%	5 410
02		**Facility Shutdown Activites**	**35 290**	**4%**	**10 455**	**30%**	**45 745**
	0300	Decontamination of Closed Systems for Dose Reduction	34 120	97%	10 236	30%	44 356
	0400	Radiological Inventory Characterisation to Support Detailed Planning	1 170	3%	219	19%	1 389
03		**Additional Activities for Safe Enclosure**					**0**
04		**Dismantling Activities within the Controlled Area**	**242 947**	**28%**	**48 321**	**20%**	**291 268**
	0200	Preparation and Support for Dismantling	12 300	5%	3 530	29%	15 830
	0600	Dismantling of Other Systems and Components	175 657	72%	40 875	23%	216 532
	0700	Removal of Contamination from Building Structures	1 800	1%	360	20%	2 160
	0900	Final Radioactivity Survay for Release of Buildings	53 190	22%	3 556	7%	56 746
05		**Waste Processing, Storage and Disposal**	**58 123**	**7%**	**11 601**	**20%**	**69 724**
	0100	Waste management system	54 066	93%	10 587	20%	64 653
	0900	Management of Decommissioning Low-level Waste	1 170	2%	293	25%	1 463
	1 200	Management of Decommissioning Exempt Waste and Materials	2 887	5%	722	25%	3 609
	1 300	Management of Decomissioning Waste and Materials Generated Outside Controlled Areas	0	0%	0	–	0
06		**Site Infrastructure and Operation**	**154 632**	**18%**	**19 348**	**13%**	**173 980**
	0100	Site Security and Surveillance	12 726	8%	1 315	10%	14 041
	0200	Site Operation and Maintenance	58 468	38%	6 598	11%	65 065
	0300	Operation of Support Systems	50 095	32%	6 660	13%	56 755
	0400	Radiation and Environamental Safety Monitoring	33 344	22%	4 775	14%	38 119
07		**Restoration**	**70 532**	**8%**	**14 100**	**20%**	**84 633**
	0100	Procurment of Equipment for Conventional Dismantling and Demolition	5 036	7%	1 101	22%	6 138
	0200	Dismantling of Systems and Building Components Outside the Controlled Area	16 578	24%	4 626	28%	21 204
	0300	Demolition of Buildings and Structures	25 217	36%	5 055	20%	30 273
	0400	Final Cleanup, Landscaping and Refurbishment	23 700	34%	3 318	14%	27 018
08		**Project Management, Engineering and Site Support**	**273 366**	**32%**	**40 759**	**15%**	**314 124**
	0100	Mobilisation and Prepartory work	0	0%	0	–	0
	0200	Project Management	147 014	54%	18 832	13%	165 846
	0300	Support Services	70 536	26%	8 990	13%	79 526
	1000	Demobilisation by contractors	55 816	20%	12 937	23%	68 753
9		**Reasearch and Development**	**0**	**0%**	**0**	**–**	**0**
10		**Fuel and Nuclear Material**	**0**	**0%**	**0**	**–**	**0**
11		**Miscellaneous Expenditures**	**6 264**	**1%**	**1 801**	**29%**	**8 065**
	0100	Owner Costs	0	0%	0	–	0
	0200	Taxes	0	0%	0	–	0
	0300	Insurances	6 264	100%	1 801	29%	8 065
Total			**855 965**	**100%**	**147 893**	**17%**	**1 003 858**

11.3.1.2 Impact on the waste estimate

The process equipment waste from Clink that fulfills the criteria stated above weighs 144 tonnes and equals 10 ISO-type containers. The total activity in the waste is 2.3×10^{9} Bq.

Assuming a 75% weight reduction, 25% of the melt will contain all the activity and will need to be sent to SFR. The density of the melt metal is so high that it is assumed that the maximum weight capacity of the container, 18 ton, is reached. This equals 36 tonnes of waste, or 2 ISO-type containers, with a specific activity of 6.4×10^{4} Bq/kg. Hence, the size reduction off-site alternative reduces the number of ISO-type containers by 8.

11.3.1.3 Impact on the programme

The impact on the time schedule with melting off-site is not treated in this study.

11.3.1.4 Impact on the cost estimate

The reduction of the number of ISO-type containers sent to SFR, by melting, gives an increased cost of 4 MSEK. These figures include the cost for transporting and melting the waste at the Studsvik melting facility, which is 4.3 MSEK, and the decreased container cost of 0.3 MSEK. However, the figures do not include the reduced disposal cost in SFR.

References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.se/publications.
References to SKB's unpublished documents are listed separately at the end of the reference list.
Unpublished documents will be submitted upon request to document@skb.se.

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Unpublished documents

SKBdoc id, version	Title	Issuer, year
1359832 ver 1.0	Avveckling och rivning av kärnkraftblock. (In Swedish)	SKB, 2012

Appendix 1

Disposition and flowcharts for Clink and Ink

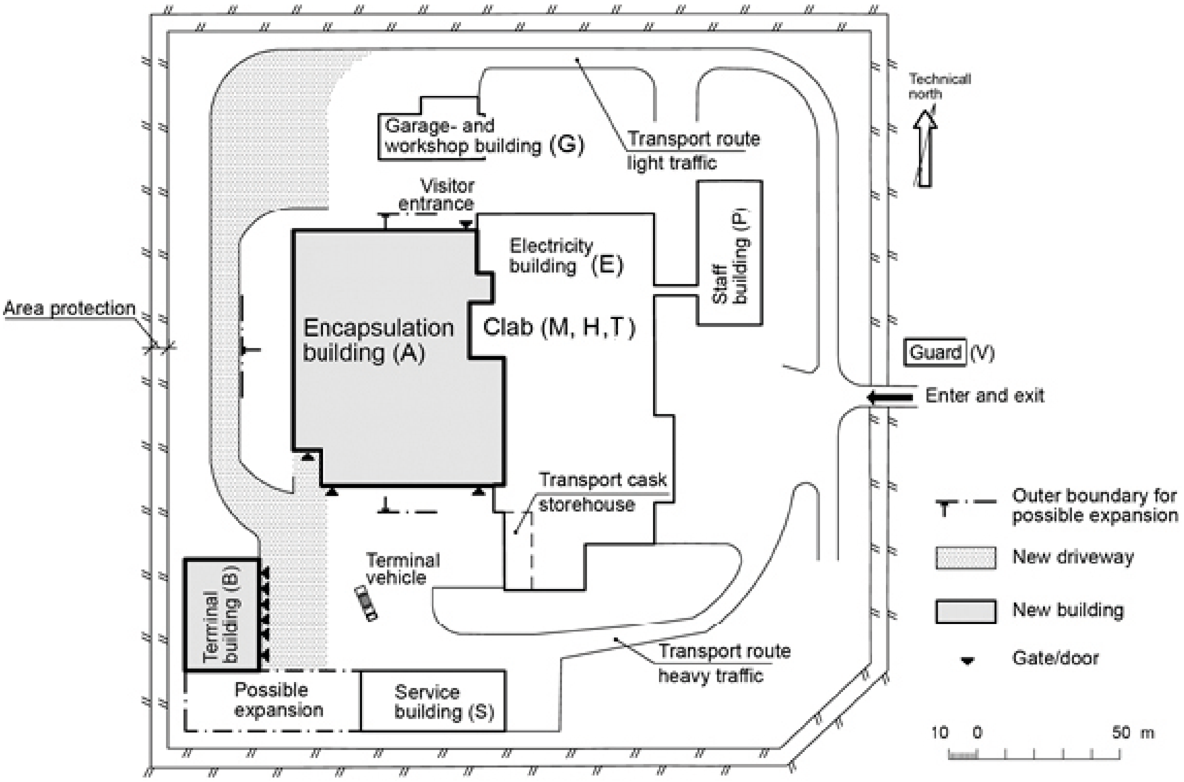

Figure A1-1. Disposition plan for Clink.

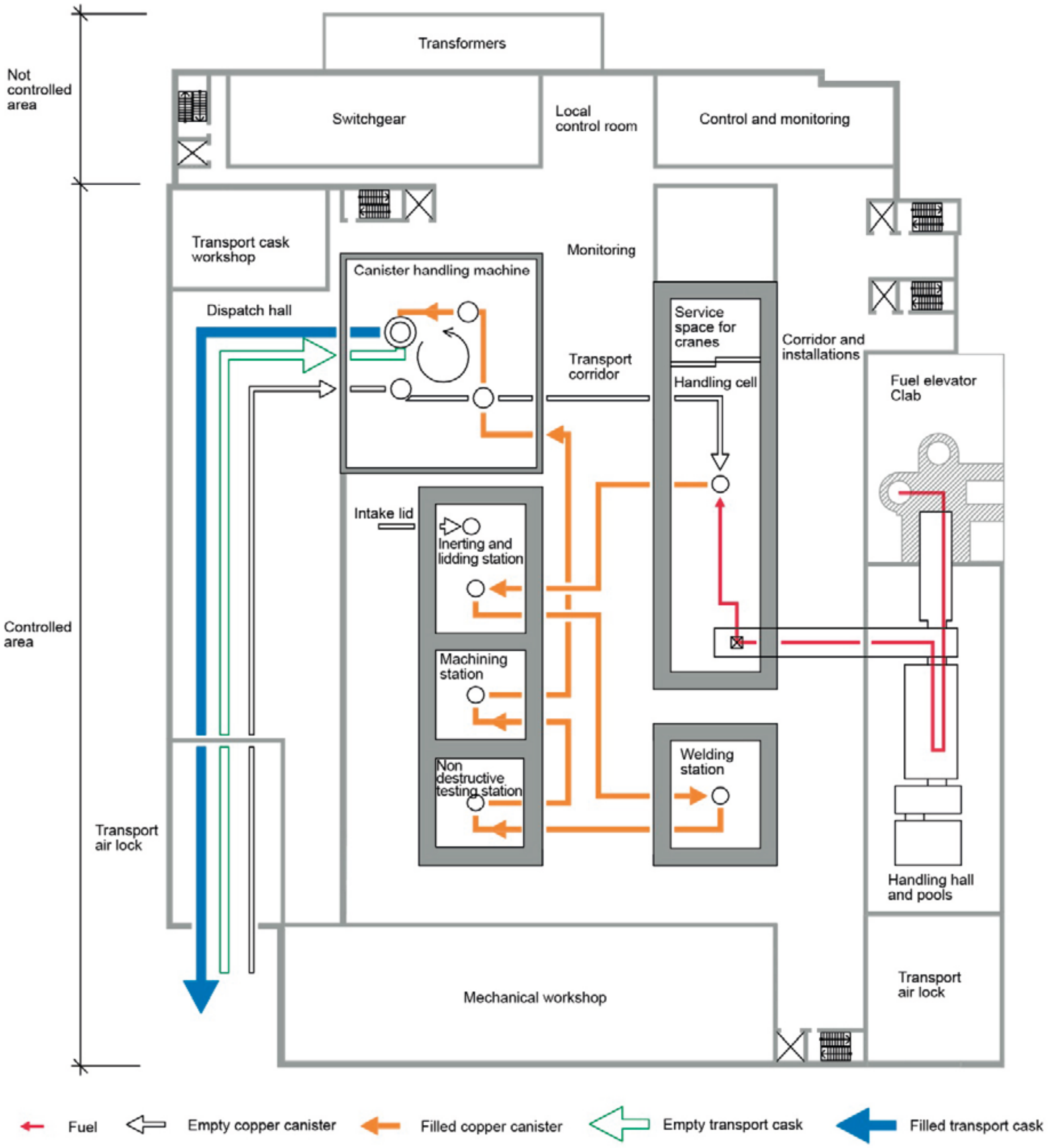

Figure A1-2. *Process flow through the encapsulation building.*

Appendix 2

Nuclide vector data for the Clink plant

Table A2-1. Nuclide vectors related to Co-60 after 30 years of decay in year 0.

Vector	1	2	3
Mn-54	9,4E-11	1,2E-16	1,9E-10
Fe-55	2,5E-02	2,0E-03	2,5E-02
Co-58	3,8E-47	5,6E-77	4,3E-47
Co-60	1,0E+00	1,0E+00	1,0E+00
Ni-59	1,7E-02	2,3E-01	1,7E-02
Ni-63	2,1E+00	2,5E+01	2,1E+00
Mo-93	1,0E-04	1,4E-03	1,0E-04
Nb-93m	2,4E-01	1,4E+00	2,4E-01
Nb-94	8,1E-04	1,1E-02	8,1E-04
Zr-93	7,1E-05	9,9E-04	7,1E-05
Tc-99	1,5E-05	2,1E-04	1,5E-05
Ag-108m	2,2E-03	2,9E-02	2,4E-03
Ag-110m	1,5E-14	3,9E-22	1,5E-14
Sb-125	1,4E-04	1,1E-05	1,5E-04
Ta-182	1,1E-29	9,9E-48	1,1E-29
Pu-238	1,5E-05	2,0E-04	1,5E-05
Pu-239	2,6E-06	3,6E-05	2,6E-06
Pu-240	3,6E-06	5,0E-05	4,5E-06
Pu-241	8,9E-05	4,7E-04	9,0E-05
Am-241	2,6E-06	3,5E-05	2,6E-06
Am-243	2,1E-07	2,8E-06	2,1E-07
Cm-242	5,3E-28	2,3E-40	5,1E-28
Cm-244	4,7E-06	3,0E-05	4,7E-06
Sr-90	0,0E+00	0,0E+00	1,7E-02
I-129	0,0E+00	0,0E+00	2,0E-06
Cs-134	0,0E+00	0,0E+00	3,5E-05
Cs-137	0,0E+00	0,0E+00	2,6E+00

Appendix 3

Size reduction

Appendix A3.1 – Size reduction on site

A range of different types of size reduction equipment is likely to be required for the decommissioning of the Clink complex.

The equipment is likely to include both conventional mechanical size reduction equipment and more advanced techniques. Conventional equipment includes:

- Hand held power tools e.g.:
  - hack saw
  - fret saw
  - band saw
  - bow saw
  - circular saw
- Shears
- Pipe cutters
- Diamond wire cutting rig
- Balers (Figure A3-1)
- Compactors
- Super Compactors.

The selection of the appropriate equipment will be largely driven by the nature of the object that is to be size reduced, although for some pieces of equipment, such as compactors, throughput economics will also be relevant. Many of the above techniques, particularly the saws, shears and pipe cutters, have the potential to be operated both manually and remotely.

Figure A3-1. *Compaction of soft LLW into square bales at Oskarshamn.*

More advanced techniques include the following[8]:

- Abrasive water jet cutting
  - Abrasive water injection jet (AWIJ).
  - Abrasive water suspension jet (AWSJ) – higher efficiency than AWIJ due to absence of air in system.
- Thermal cutting tools e.g.:
  - Flame cutting
    - For materials that react with oxygen in an exothermal combustion process and with an ignition temperature (~1,100°C) lower than the melting point, such as mild steel.
    - For materials with an ignition temperature higher than the melting point, such as stainless steel or non-ferrous metals, additional powder injection will be required.
  - Oxygen lance cutting, using pressurized oxygen burning at up to 2,500°C to cut high melting point metals and minerals such as concrete, often with the addition of an iron/aluminum powder mixture to further raise the cutting temperature to above 4,000°C.
  - Electrical (plasma arc) cutting
    - Transferred arc for electrically conductive materials, where the arc strikes between the electrode and the work piece.
    - Non-transferred arc for conductive and non-conductive materials, where the arc strikes between the electrode and the nozzle of the cutting torch. This type of torch transmits less energy to the work piece.

The ability to deploy these more advanced techniques remotely largely depends on the ability to achieve effective remote control of the devices. This ability will partially depend on the means by which the device is deployed, but will more heavily depend on the ability to develop appropriate control software. As a result, these techniques are more likely to be deployed manually with the operatives wearing PPE as appropriate.

Size reduction off site

There are a lot of materials that can be size reduced off site by e.g. incineration, melting or pyrolysis. These size reduction methods could be performed by Studsvik for the materials from Clink. Whether to use size reduction off site or not, and the method of size reduction, is determined by authority regulations for handling of this kind of waste material, profitability and the dose rate of the material. Studsvik cannot handle materials with dose rates higher than they are licensed to manage.

The incineration process takes place in the main incineration chamber where organic material is gasified into ash. The gas is led to an afterburning chamber containing oil burners where complete incineration takes place. The flue gas is led to the flue gas purification where lime and activated carbon is added to reduce the emissions. All emissions are continuously measured in the stack. The incineration is done in campaigns to avoid cross contamination between different plant's materials. The bottom ash and fly ash is collected and analyzed before further transportation and treatment.

Melting of metals is done in an induction oven. Prior to melting the metals must be sorted into each respective type of metal and if necessary decontaminated. After the melting, the slag is separated from the melt and then kept in containers modified for interim storage. Dust from filters and secondary process remnants are gathered and stored in containers modified for interim storage before they are analyzed and transported for further treatment. Metals are measured with regard to activity, and are free released if possible.

Pyrolysis is a method where the waste is packed in a container, suitable for incineration, which is connected to a ceramic filter. The container is heated to a maximum of 700°C. Overheated steam is added. Organic compounds will then be disintegrated and/or gasified. Out of the container come water steam and light carbon compounds. The light carbon compounds are incinerated in an afterburning chamber and become carbon dioxide. The gases thereafter pass through a dust filter, a wet scrubber and another filter with the adding of lime. Then the flue gases are led to the stack where continuous measurements are taking place.

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[8] Further information on some of these techniques can be found in Chapter 7 of this report.

Appendix A3.2 – Waste monitoring

A range of monitoring equipment is available for characterizing the ILW and LLW streams within the waste management facilities. These range from swab and probe measurements to more automated systems that measure the activity content of waste contained in a range of package sizes, including drums and boxes. The most appropriate monitors for this application use gamma spectroscopy.

Representative samples of waste expected from its location and history to be suitable for free release will be subjected to swab and probe monitoring. Suitable waste may then be loaded into containers for final compliance monitoring using, for example, a RADOS Clearance Measurement Station. Alternatively a conveyor system, such as the IonSens Conveyorised Survey Monitor, could be used to monitor loose or bagged material. Examples are shown in Figure A3-2, Figure A3-3 and Figure A3-4.

Figure A3-2. *Swab Counter.*

Figure A3-3. *RADOS Mobile Clearance Measurement Station.*

***Figure A3-4.** IonSens Conveyorised Survey Monitor.*

***Figure A3-5.** DrumScan HRGS Modular Segmented Gamma Scanner.*

Depending on the output required, use may be made of low or high resolution gamma spectroscopy (LRGS or HRGS). Examples include the DrumScan series of monitors shown in Figure A3-5 and Figure A3-6.

An alternative means of monitoring bulk waste in an ISO freight container is currently under development by BIL Solutions Ltd, a sister company of British Nuclear Group Project Services Ltd. This is illustrated in Figure A3-7. This monitor offers significant cost benefits compared to manual survey and also offers opportunities for much greater throughputs.

Figure A3-6. DrumScan LRGS Mk II Drum, Package and HEPA Filter Monitor.

Figure A3-7. ISO Container Monitor for Bulk LLW.

Monitoring techniques

In general it is not possible to prescribe that specific techniques should be used on certain wastes, as the choice of technique will be dependent on the nature of the suspected contamination or activation, the natural activity present in the materials concerned and whether the materials are potentially magnetic (non-shielded scintillators being susceptible to interference from magnetic fields). It is nonetheless possible to make broad recommendations as to the type of technique that may be suitable, and such guidance is given in Table A3-1 and Table A3-2 with examples of potentially suitable monitoring equipment.

In particular, equipment selection will depend upon a number of factors, including:

- The purpose of the monitoring[9]
- The physical form of the materials to be monitored
- The area and/or mass over which measurements are to be taken and averaged
- The natural background level of radiation prevailing in the materials
- The expected contamination fingerprint
- The environment within which monitoring will be carried out (e.g. ease of access, nearby operations involving sources of radioactivity that may interfere with radiometric measurements, etc.)
- Who will perform the measurements and the balance between manual and automatic monitoring.

Experience on UK Magnox power station sites has shown high resolution gamma spectroscopy (HRGS) to be suitable for the clearance monitoring of steel ductwork, fuel skips and transport containers and small shielded flasks. HRGS has been found in particular to offer considerable sensitivity and selectivity.

HRGS has also been found to be effective for the clearance monitoring of steel and concrete cooling water culverts and on concrete and steel plate breakwaters. Concrete assay can however pose some problems due to the absorption of contamination below the surface and the natural attenuation of gamma emissions through the concrete substrate. In such circumstances, coring may be needed to develop baseline fingerprints for the spectroscopic analysis.

Some further guidance is given in a UK National Physical Laboratory document (McClelland and Lewis 2003) which recommends the use of passive total neutron counting (TNC), passive neutron coincidence counting (PNCC), passive neutron multiplicity counting (PNMC) and gross gamma counting techniques for the assay of lower level wastes. The document also recommends the consideration of segmented and tomographic gamma scanning for the assay of LLW drummed wastes.

With respect to the physical form of the wastes requiring monitoring, the following points should be noted:

1. For intact solids such as steel and brick, surface contamination monitoring will be relatively easy. Sampling of bulk material from these solids will however tend to require aggressive intervention (e.g. coring).
2. The use of hand-held health physics probes is likely to be appropriate for the monitoring of large numbers of small items of waste.
3. Direct surface monitoring of wire and narrow bore pipework will be difficult without prior size reduction. Bulk activity assessment will however be relatively easy.
4. Surface monitoring will generally require clean, dry surfaces that are free from dust, grease, paint and condensation.

Generally the larger the detector surface on the monitor, the more efficient is the measurement in terms of the number of sample points covered and the speed of measurement. Effective measurement will also require prior identification and measurement of background sources of radiation to provide a baseline against which clearance monitoring can take place[10].

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[9] It is important to distinguish between sentencing for disposal and clearance. For example, drum monitors will be sensitive enough for sentencing ILW or LLW for disposal, but will not be sensitive enough for clearance purposes.

[10] The presence of high natural levels of certain beta and gamma emitters will require the use of energy selective detectors to screen these emitters out.

Table A3-1. Summary of monitoring techniques.

Technique	Preferred target/uses	Advantages	Limitations/Constraints	Comments
Bulk alpha monitoring	Confirmation of stability of waste fingerprint. Confirmation of homogeneity of materials that only contain alpha emitters.		Very short range of emitters requires thin samples. Thin samples may require long counting time to gather adequate data and may not be representative of inhomogeneous wastes. Often requires supporting radiochemistry **NOT** for materials with high natural alpha levels such as some soils and concrete.	Need prior calibration against a well mixed sample based on: • Determination of background count rate • Extraction and concentration of alpha emitters from sample to form a source which can then be counted to form a bench line for future monitoring
Bulk beta monitoring	High energy beta emitters (due to need to overcome count due to natural gamma emitters or to gamma emitters within the sample). Confirmation of stability of waste fingerprint. Confirmation of homogeneity of materials that only contain beta emitters.		For low energy beta emitters, similar limitations as for bulk alpha monitoring	Cannot be used for tritium
Bulk gamma monitoring	Homogeneous material	Relatively accurate	Potentially susceptible to missing hot spots or over-estimating bulk activity if activity is concentrated in discrete pieces such as fuel particles Difficult to effectively monitor material in centre of a load	
Small hand-held detector and gross gamma detection	Material with low and natural activity relative to the nuclides of interest Material without significant hot spots		Large area recommended for detector surface Detector must be held in virtual contact with surface Surface of interest must fill whole of detector window measurements cannot be made close to edges.	

Table A3-1 continued.

Technique	Preferred target/uses	Advantages	Limitations/Constraints	Comments
Small hand-held detector and a counting window		Similar to gross gamma monitoring but energy selectivity of counting window helps to reduce background count rate	Cannot be used where energy of contaminant is close to that of a naturally occurring gamma emitter.	No advantage over gross gamma counting where contaminant comprises the same nuclide(s) as is/are present in natural activity. For example, where the natural activity is mainly the U-238 chain, the major gamma emitters are below Ra-226. Therefore the technique cannot be used where the potential contaminant is Ra-226. (Consider using a hyper-pure germanium detector on a rotating load platform in such circumstances).
Small hand-held detector with spectrometry		Further advance on counting window. Produces a detailed energy spectrum that user can interpret and so can deal with more complicated situations. Can reduce missable activity in materials with variable or high natural activities. Will identify any significant gamma emitters including those that would not normally be anticipated.		No advantage over gross gamma counting where contaminant comprises the same nuclide(s) as is/are present in natural activity. (Consider using a hyper-pure germanium detector on a rotating load platform in such circumstances).
Small hand-held detector and rotating load platform		Reduces problem of manual monitoring in sufficient detail to identify hot spots. By keeping the detector stationary and moving the platform, the process can be largely automated increasing reliability and allowing the use of larger detectors. The use of a heavily shielded collimator can significantly reduce the background count. For materials with complicated artificial &/or natural activities, the use of a fixed monitor allows the use of hyper-pure germanium detectors, greatly improving spectral resolution. This is of value where the potential contaminant is part of the decay chain of a naturally occurring nuclide.		

Table A3-1 continued.

Technique	Preferred target/uses	Advantages	Limitations/Constraints	Comments
Conveyor belt monitoring	Demolition rubble, etc potentially containing high activity particles or objects	Overcomes weakness of bulk monitoring in that a hot spot buried in the centre of a waste mass may be difficult or impossible to detect. Material monitored is spread into a much thinner layer allowing for more even and consistent monitoring.	Additional handling stages. Conventional industrial safety (moving equipment). Cost, noise, dust, power requirements.	If excessive activity detected, belt stops automatically to enable either hand searching or automated segregation.
Box monitors	Materials with very low natural gamma activities such as stainless steel Bagged/containerized material that is difficult to monitor using other equipment (e.g. tools, cable, books and other documentary records)	By totally surrounding an object with detectors, a very large proportion of any radiation escaping from the object will be detected. External walls of box monitor may also provide efficient shielding from background radiation.	Size of monitor needs to be scaled to size of object being monitored Gamma emitters only. Low natural gamma count (equipment has no spectral resolution). Heavy and largely static equipment. Potential presence of hotspots will reduce the maximum mass of material that can be monitored as dimensions of object will be constrained by need to be able to monitor to centre of mass.	Care required in transport and assembly to maintain integrity of shielding
Vehicle monitors	Final check that previous monitoring and control procedures have been effective and that there is no unexpected activity. Suitable for materials of low natural activity (e.g. steel). Red brick, granite blocks, ceramics, etc may therefore not be suitable.		Not suitable for sentencing waste Monitors only have very simple energy analysis and so should only be used in areas of low background radiation. Equipment only detects gamma emitters. Works best where source is close to one side of the load. Of limited effect where there are voids in the material or where the activity source is buried within a dense load.	
Direct alpha surface monitoring	Not on objects with a significant magnetic field e.g. steel beam, tools, electrical equipment unless using shielded scintillators.		Requires thin window and large area (at least 100 cm^2 for clearance purposes). Equipment must have good beta and gamma rejection to avoid masking the alpha signal. Non-shielded scintillators susceptible to magnetic fields.	Based on standard radiation protection equipment

Table A3-1 continued.

Technique	Preferred target/uses	Advantages	Limitations/Constraints	Comments
Blown ion chamber alpha monitoring	Objects such as pipes above 25 mm in diameter through which the air can be blown and for complicated objects such as valve bodies with blind holes as long as the air stream blows directly over the end of the hole.		Alpha emitters must be on surface over which air is passed and must not be concealed by paint or rust. Object must also be dust free to avoid interference with ionization chamber. Of limited effectiveness for long thin pipes (below 10 mm diameter)	Based on placing object in a moving stream of air that then enters an ionization chamber.
Sorting table	Thin non-absorbent objects that cannot be placed in a blown ion chamber monitor	Overcomes ergonomic issues of hand-held counting	Difficult to use on absorbent materials as activity will have migrated to interior of material. Difficult to use for many-sided objects due to need to monitor each surface. Will not work on very thin samples (e.g. sheets of paper) as the conversion of the bulk activity level into a surface activity level would result in unattainable clearance levels.	Objects placed on sorting table for a specified period of time, then turned over to be counted from other side.
Direct surface beta monitoring	Not on objects with a significant magnetic field e.g. steel beam, tools, electrical equipment unless using shielded scintillators.		Requires large detector area (at least 100 cm^2 for clearance purposes) to achieve reasonably fast surface coverage. Thin detector window, as most beta emitters are likely to be of low energy. Good gamma rejection to avoid masking of beta emitters. Non-shielded scintillators susceptible to magnetic fields.	Based on standard radiation protection equipment. Can be hand-held or in the form of a sorting table or conveyor belt monitor as for alpha monitoring. Blown ion chambers of limited use due to low energy level of beta emitters and the long range (i.e. insufficient counts will be made within the chamber).
Direct surface X and low energy gamma monitoring	Not on objects with a significant magnetic field e.g. steel beam, tools, electrical equipment unless using shielded scintillators.		The longer range of X and gamma radiation means that monitoring does not have take place in contact with the surface (reducing the number of measurements) needed to cover a given area. However, the higher susceptibility to background count of these monitors (compared to beta monitors) requires the use of a reasonably large detector area.	Based on standard radiation protection equipment. Can be hand-held or in the form of a sorting table or conveyor belt monitor as for alpha monitoring. Non-shielded scintillators susceptible to magnetic fields.

Table A3-1 continued.

Technique	Preferred target/uses	Advantages	Limitations/Constraints	Comments
Assessment of tritium surface activity			Mobility of tritium means that any assessment of surface tritium activity will be almost meaningless.	Tritium must be treated as a bulk contaminant.
Surface monitoring by wipe	For waste fingerprinting and confirmation that removable activity is near zero		Surface must be accessible for wiping. Prior calibration against a "clean" sample is required. Uncertain process. Limited reliability particularly if carried out by hand.	Wipe becomes a contaminated waste that will itself require monitoring. May be possible to automate process as in WVP
Sampling with radiochemistry	In many cases, a full assessment of an activity profile will require radiochemical treatment and analysis.	An ability to utilize gamma spectrometry will reduce the need for sample preparation and the use of separation chemistry. Gamma spectrometry can detect a wide range of gamma emitting activation products, fission products and actinides.	Samples must be collected, preserved and stored so as to prevent any significant change in concentration or form due to: • loss of volatile nuclides, • biological degradation of organics, • changes in physical or chemical form, • adsorption into container walls. Alpha spectrometry due to the high attenuation rate of alpha emitters will require the separation of the alpha emitter of interest from the bulk material and its preparation into a thin source. The wide range of energies associated with the decay of beta emitters makes spectrometric analysis difficult without chemical separation and purification of the beta fraction.	Size of sample will depend on: • the analyses required • the limits of detection required • the heterogeneity of the material • requirements for sample archiving Gross alpha and beta measurement can be carried out as an initial screening procedure.

Table A3-2. Potential applicability of techniques for waste clearance.

Waste category	Type of monitoring required	Potentially applicable techniques	Potentially suitable equipment
Items and materials believed to be clean	Confirmation against fingerprint Mass must be known. Clearance decisions will be made on Bq/g measurement.	Bulk alpha, bulk beta, bulk gamma, surface wipes	RaDos RTM suite of instruments (gross gamma) MGPi CPO (gross gamma) Thermo Active Waste Monitor AWM1B (gross gamma) BIL Solutions IonSens® Pipe (airborne alpha ionization) BIL Solutions IonSens® Large Item Monitor (airborne alpha ionization) HP&S instruments for alpha/beta/gamma: Thermo AP5 (alpha) Thermo DP6 (alpha/beta) Thermo Mini Smart Ion (beta/gamma ion chamber)
Potentially surface contaminated items	100% surface monitoring. Surface area must be known. Clearance decisions will be made on Bq/cm^2 measurement.	Direct alpha surface, direct beta surface, direct low energy gamma For steel, gamma monitors that are not susceptible to magnetic fields are required (e.g. with shielded scintillators). Box monitors are also be suited for the clearance of steel as they are suitable for the assay of non-gamma emitters.	BIL Solutions IonSens® Pipe (airborne alpha ionization) BIL Solutions IonSens® Large Item Monitor (airborne alpha ionization) RaDos RTM suite of instruments (gross gamma) RaDos Scaffold Monitor RTM690 (gamma with optional beta) HP&S instruments for alpha/beta/gamma: Thermo AP5 (alpha) Thermo DP6 (alpha/beta) Thermo Mini Smart Ion (beta/gamma ion chamber)
High surface area to volume items, materials & clothing	Bulk monitoring	Box monitors For materials, gas flow proportional counters may be suitable	RaDos Laundry Monitor RTM740 (alpha/beta) MGPi Laundry Monitor LMGH (gross gamma) RaDos RTM suite of instruments (gross gamma) Thermo Active Waste Monitor AWM1B (gross gamma)
Potentially activated solids	Activation monitoring and surface monitoring Fe^{55} may pose a problem. HP&S probes should be used to measure soft betas from Fe^{55}	Gamma spectrometry or thin windowed gamma detectors for activation products Surface monitoring equipment as detailed above	RaDos RTM suite of instruments (gross gamma) Thermo Active Waste Monitor AWM1B (gross gamma) Thermo BP19 or SLR (Fe^{55}) Coring and radiochemical analysis Gamma spectrometry or thin windowed gamma detectors
Potentially tritiated solids	Bulk monitoring Surface monitoring is close to meaningless due to mobility of tritium	Sampling and radiochemical analysis including liquid scintillation counting Specialist monitors or calorimeters able to detect the low energy beta emissions associated with tritium. Shielding from background radiation may be needed e.g. by use of a box-based monitor Inductive Coupled Plasma Emission Spectroscopy may be suitable for wet activated steel and concrete.	

Table A3-2 continued.

Waste category	Type of monitoring required	Potentially applicable techniques	Potentially suitable equipment
Potentially contaminated loose solids	Hot spot detection	Sampling (alpha) Conveyor belt monitor (beta/gamma)	BIL Solutions IonSens® Conveyor Monitor (simultaneous alpha and beta)
Potentially contaminated porous solids	Surface and bulk monitoring	Surface measurement using HP&S survey probes to determine location for sampling Core sampling or crushing may be needed for bulk monitoring. Crushing may enable use of conveyor belt monitors for beta-gamma. **NB Bulk alpha monitoring of limited value for concrete due to high natural alpha level.**	BIL Solutions IonSens® Conveyor Monitor (simultaneous alpha and beta)
Potentially contaminated impervious objects with accessible surfaces	100% surface monitoring Bulk monitoring may be needed if diffusive nuclides suspected Sampling may be feasible.	Surface monitoring equipment as detailed above Bulk alpha, bulk beta, bulk gamma as appropriate	BIL Solutions IonSens® Pipe (airborne alpha ionization) BIL Solutions IonSens® Large Item Monitor (airborne alpha ionization) RaDos RTM suite of instruments (gross gamma) RaDos Scaffold Monitor RTM690 (gamma with optional beta) HP&S instruments for alpha/beta/gamma: Thermo AP5 (alpha) Thermo DP6 (alpha/beta) Thermo Mini Smart Ion (beta/gamma ion chamber)
Potentially contaminated impervious objects with inaccessible surfaces	100% surface monitoring of dismantled/size reduced material Bulk monitoring may be needed if diffusive nuclides suspected	Surface monitoring equipment as detailed above Bulk alpha, bulk beta, bulk gamma as appropriate	BIL Solutions IonSens® Pipe (airborne alpha ionization) BIL Solutions IonSens® Large Item Monitor (airborne alpha ionization) RaDos RTM suite of instruments (gross gamma) RaDos Scaffold Monitor RTM690 (gamma with optional beta) HP&S instruments for alpha/beta/gamma: Thermo AP5 (alpha) Thermo DP6 (alpha/beta) Thermo Mini Smart Ion (beta/gamma ion chamber)
All	Nuclide specific analysis	Subject to the ability to obtain suitable representative samples, radiochemical analysis may provide a full activity profile. Gamma spectrometry (HPGe) analysis may reduce the need for sample preparation.	

APPENDIX A3.3 – A fully engineered waste processing & packing facility

This option consists of a fully-engineered stand-alone facility that is capable of receiving, processing and packaging all decommissioning wastes, from free-release material and LLW, through to the full range of ILW arisings. A facility of this type could be furnished with a full array of equipment capable of carrying out operations such as remote size reduction and decontamination.

Location

The sheer size and throughput requirements of a facility of this type place limitations on its location. Ideally it should be located in a new building adjacent to the existing facility.

It might be possible to construct a fully engineered waste processing and packaging facility within another area of the Clink plant, such as the receiving building. But it is unlikely that sufficient unencumbered space would be available, or could easily be made available. The prospect of carrying out major construction works within a radiologically controlled area, with associated personnel dose, high costs and scheduling implications, makes the idea unappealing. The design, particularly the layout, would be constrained by limitations on modifying the existing structure, and there would be radiological issues to overcome (similar to those encountered in the receiving building).

Without prejudging a comprehensive optioneering study, it is likely that a new building would be erected. This would have several benefits, namely:

- Designing the waste processing and packaging plant from a ‘blank-sheet’ would deliver a fully optimized facility, in terms of operator ergonomics, waste throughput rates and logistics, etc.
- Construction and commissioning of the new facility could be carried out in conditions as close as possible to those of ‘greenfield’ e.g. free access, no restrictions due to building within an existing shell and little or no radiological constraints.

A major portion of the decommissioning wastes could be transferred directly from the source facility to the waste processing and packaging plant, without the need to be transferred across the site.

Fully-engineered facility overview

A fully engineered Waste Processing & Packaging Facility (WPPF) will be remotely operated and (in order to provide shielding) constructed from reinforced concrete. Detailed shielding calculations will determine the exact concrete thickness, but at this stage it can be assumed to be around 500 mm. Operator viewing may be achieved directly, via shielded windows, carried out exclusively by the use of in-cell cameras, or by a combination of both approaches. Later viewing studies will determine the optimum approach.

If adopting the fully engineered philosophy, there will be minimal segregation of wastes at the decommissioning workface. Instead, mixed waste will be transferred directly to the WPPF for all processing operations. The WPPF will therefore need to have the capability to receive, segregate and process all decommissioning wastes, from mixed ILW/LLW to wastes which are potentially acceptable as free release. Once processed, ILW and LLW will be loaded into approved waste packages and dispatched to either the SFR waste repository or further size reduction off-site, while free release waste will be routed through normal commercial channels. Some LLW may be disposed in a landfill, depending on authority regulations at that time.

Fully-engineered facility components

Figure A3-8 provides a schematic overview of a fully engineered WPPF. The various areas within the WPPF and its primary operations are described below.

Mixed solid waste receipt

Mixed dry waste will be transferred to the receipt area of the WPPF via a self-shielded transfer container that is docked to the underside of the receipt cell. The operation of a shielded hatch within the floor of the cell will be integrated with removal of the transfer container lid. This will ensure that the outside of the transfer container remains radiologically clean at all times and that the container is therefore free to

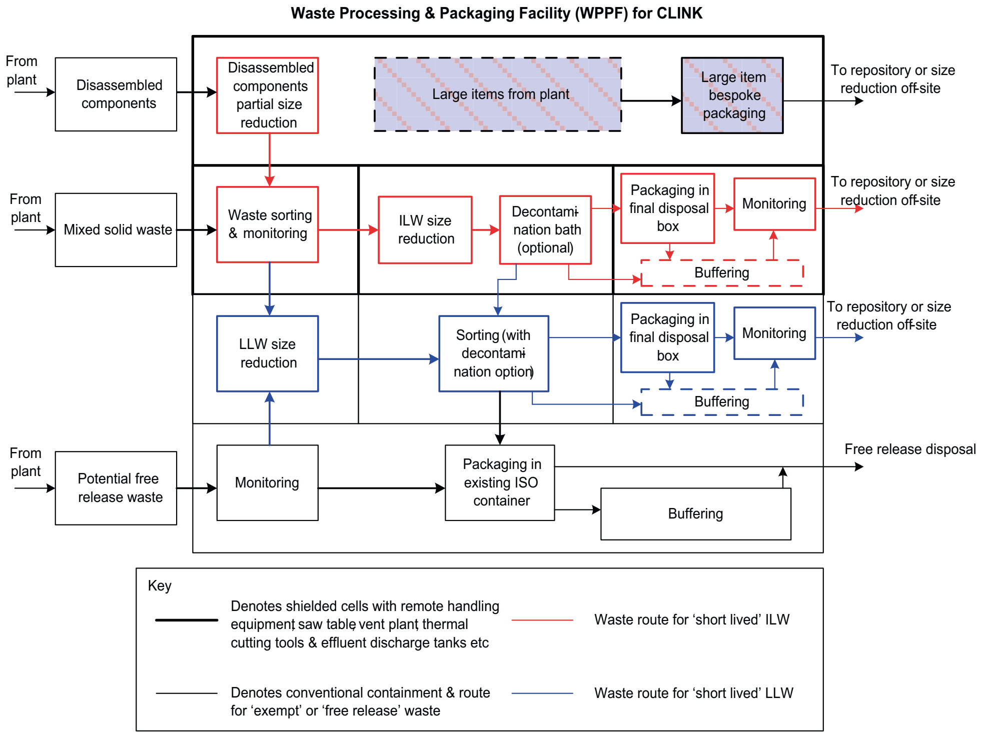


Figure A3-8. *Schematic of a fully engineered Waste Processing & Packaging Facility (WPPF).*

travel between the WPPF and the decommissioning workface. Similar arrangements will also be made at the workface to ensure that the transfer container remains clean during loading operations.

The self-shielded internal transfer container will be moved on a motorized trolley or other similar apparatus.

Waste sorting and monitoring

Waste will be removed from the transfer container and remotely sorted, then monitored to determine its next destination. ILW material will continue along the ILW processing line, whilst LLW and FRW will be transferred to an adjacent size reduction area.

Large item handling

In some instances it may not be productive, or even necessary, to break large items of plant or equipment into components small enough to fit within a standard disposal container. Large items may therefore bypass the main WPPF and instead be contained within bespoke packaging suitable for final disposal or size reduction of the category of waste concerned.

Free release waste monitoring

Material which is considered primarily suitable for free release may contain some lesser percentage of LLW. Potential free release waste will therefore be monitored prior to packaging. Any LLW identified will be isolated and transferred to the LLW size reduction area for further processing.

Free release waste packaging

Free release waste will be loaded into standard ISO-type freight containers for transport and disposal off site. Loading will be carried out by manually-controlled techniques, using local lifting gear as appropriate. No large efforts will be made on site for size reduction of free release waste.

Waste packages will be routed to an appropriate recycling or disposal facility. Metallic wastes could be dispatched to a metal recycling facility such as that currently operated by Studsvik (see Appendix A3.1 – Size reduction on site).

LLW size reduction

Low level waste will be transferred to the size reduction area from either the mixed waste sorting area or the potential free release monitoring area. Size reduction will be carried out within an enclosed re-usable modular containment primarily using hand-held tools (see Appendix A3.1).

LLW decontamination and sorting

Following size reduction and sorting, there is the potential to decontaminate LLW arisings down to free release levels, in order to further reduce the volume of LLW generated. Whether this is cost effective will need to be assessed in a similar way to that of potentially decontaminating ILW. Factors such as the practicalities of decontaminating in an area that may be subject to significant airborne contamination and the consequent disposal of decontamination wastes will need to be considered.

LLW packaging and monitoring

LLW will be loaded into ISO-type containers, similar to those shown in Figure 8-6. Loading will be carried out by primarily manually-controlled techniques, using local lifting gear as appropriate.

ILW size reduction and decontamination

Size reduction will be performed using conventional industrial robots, similar to those shown in Figure A3-9. Reducing the size of decommissioning wastes can improve the efficiency of subsequent processing and will achieve a greater packing factor in the final disposal container.

In this same area, there will be the potential to decontaminate wastes in order to further reduce the volume of ILW generated. Whether it is cost effective to decontaminate waste (by for example the use of a decontamination bath) will be determined by factors such as the practicalities of decontaminating in an area that may be subject to significant airborne contamination and the consequent disposal of decontamination wastes.

ILW packaging and monitoring

In this last stage of ILW processing, waste will be loaded into its final disposal container and dispatched for export to either the SFR waste repository or further size reduction off-site.

This final area and last stage in the process will complete the waste management process. The container will be docked to the facility and waste loaded. The operation of a shielded hatch within the floor of the loading area will be integrated with removal of the container lid. This will ensure that the outside of the container remains radiologically clean at all times and is therefore free to travel between the Clink site and the repository.

This area will also be equipped with monitoring and swabbing equipment to ensure that the package is clean and within the required radiological specification.

The waste container that will be used for ILW is likely to be an enlarged version of the standard 1.2×1.2×1.2 m, 5 mm thick steel container. This enlarged version of the steel box measures 2.4×2.4×1.2 m to fit the existing transport overpack system at SFR.

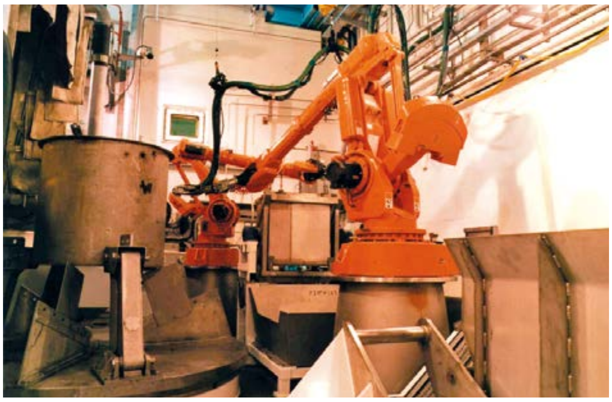


Figure A3-9. *Remote dismantling at a Sellafield Waste Management Facility.*

Appendix 4

WBS decommissioning programme

Appendix 4.1

ID	WBS	Main activities
1	**1**	**NORMAL OPERATION (related to decommissioning)**
2	**1.1**	**PLANT OPERATION COSTS**
3	**1.1.1**	**Personnel costs**
4	1.1.1.1	Management and administration
5	1.1.1.2	Information and public relations
6	1.1.1.3	Radiation and environment protection
7	1.1.1.4	Chemistry, waste
8	1.1.1.5	Surveillance, fire protection
9	1.1.1.6	Maintenance of buildings and equipment
10	1.1.1.7	Plant system operation
11	**1.1.2**	**Operational costs**
12	1.1.2.1	Radiation and environment protection
13	1.1.2.2	Chemistry, waste
14	1.1.2.3	Surveillance, fire protection
15	1.1.2.4	Maintenance
16	1.1.2.5	Energy and water
17	**1.1.3**	**Organizational costs**
18	1.1.3.1	Administration and information management
19	**1.2**	**PROJECT COSTS**
20	**1.2.1**	**Purchasers project management, administration and technical support**
21	1.2.1.1	Project management
22	1.2.1.2	Planning and controlling
23	1.2.1.3	Quality management and control
24	1.2.1.4	Technical support
25	1.2.1.5	Documentation
26	1.2.1.6	General and supplier administration
27	**1.2.2**	**Decomissioning preparation activities**
28	1.2.2.1	Preliminary EIA work
29	1.2.2.2	Decommissioning planning work
30	1.2.2.3	Information gathering
31	**2**	**EXTRA WBS ITEM**
32	**3**	**Preparation for dismantling**
33	**3.1**	**PLANT OPERATION COSTS**
34	**3.1.1**	**Personnel costs**
35	3.1.1.1	Management and administration
36	3.1.1.2	Information and public relations
37	3.1.1.3	Radiation and environment protection
38	3.1.1.4	Chemistry, waste
39	3.1.1.5	Surveillance, fire protection
40	3.1.1.6	Maintenance of buildings and equipment
41	3.1.1.7	Plant system operation
42	**3.1.2**	**Operational costs**
43	3.1.2.1	Radiation and environment protection
44	3.1.2.2	Chemistry, waste
45	3.1.2.3	Surveillance, fire protection
46	3.1.2.4	Maintenance
47	3.1.2.5	Energy and water
48	**3.1.3**	**Organizational costs**
49	3.1.3.1	Administration and information management
50	**3.2**	**PROJECT COSTS**
51	**3.2.1**	**Purchasers project management, administration and technical support**
52	3.2.1.1	Project management
53	3.2.1.2	Planning and controlling

ID	WBS	Main activities
54	3.2.1.3	Quality management and control
55	3.2.1.4	Technical support
56	3.2.1.5	Documentation
57	3.2.1.6	General and supplier administration
58	**3.2.2**	**Decommissioning preparation activities**
59	3.2.2.1	EIA work
60	3.2.2.2	Radiological inventory characterization
61	3.2.2.3	Object decontamination
62	3.2.2.4	System decontamination
63	3.2.2.5	Pre-decommissioning system adaption
64	3.2.2.6	General preparatory activities
65	3.2.2.7	Adaptation of waste systems and buildings
66	**4**	**NUCLEAR DISMANTLING AND DEMOLITION**
67	**4.1**	**PLANT OPERATION COSTS**
68	**4.1.1**	**Personnel costs**
69	4.1.1.1	Management and administration
70	4.1.1.2	Information and public relations
71	4.1.1.3	Radiation and environment protection
72	4.1.1.4	Chemistry, waste
73	4.1.1.5	Surveillance, fire protection
74	4.1.1.6	Maintenance of buildings and equipment
75	4.1.1.7	Plant system operation
76	**4.1.2**	**Operational costs**
77	4.1.2.1	Radiation and environment protection
78	4.1.2.2	Chemistry, waste
79	4.1.2.3	Surveillance, fire protection
80	4.1.2.4	Maintenance
81	4.1.2.5	Energy and water
82	**4.1.3**	**Fixed costs**
83	4.1.3.1	Other fees, inspection costs
84	4.1.3.2	Taxes
85	4.1.3.3	Insurances
86	**4.1.4**	**Organizational costs**
87	4.1.4.1	Administration and information management
88	**4.2**	**PURCHASER'S PROJECT MANAGEMENT, ADMINISTRATION AND TECHNICAL SUPPORT**
89	**4.2.1**	**Project management**
90	**4.2.2**	**Planning and controlling**
91	**4.2.3**	**Quality management and control**
92	**4.2.4**	**Technical support**
93	**4.2.5**	**Documentation**
94	**4.2.6**	**General and supplier administration**
95	**4.3**	**DISMANTLING AND DEMOLITION ACTIVITIES**
96	**4.3.1**	**Controlled area buildings**
97	4.3.1.1	Room preparations
98	4.3.1.2	Process piping and equipment
99	4.3.1.3	Structural and various steel
100	4.3.1.4	Air treatment systems
101	4.3.1.5	Electrical Equipment and Cabling
102	**4.3.2**	**Demolition of radioactive concrete**
103	4.3.2.1	Other contaminated concrete
104	4.3.2.2	Radiation protection and measurement
105	**4.3.3**	**Cleaning and clearance of controlled area buildings**
106	4.3.3.1	Building surface decontamination
107	4.3.3.2	Building clearance survey
108	**4.3.4**	**Process dismantling uncontrolled area buildings**
109	4.3.4.1	Room preparations
110	4.3.4.2	Process piping and equipment
111	4.3.4.3	Structural and various steel
112	4.3.4.4	Air treatment systems

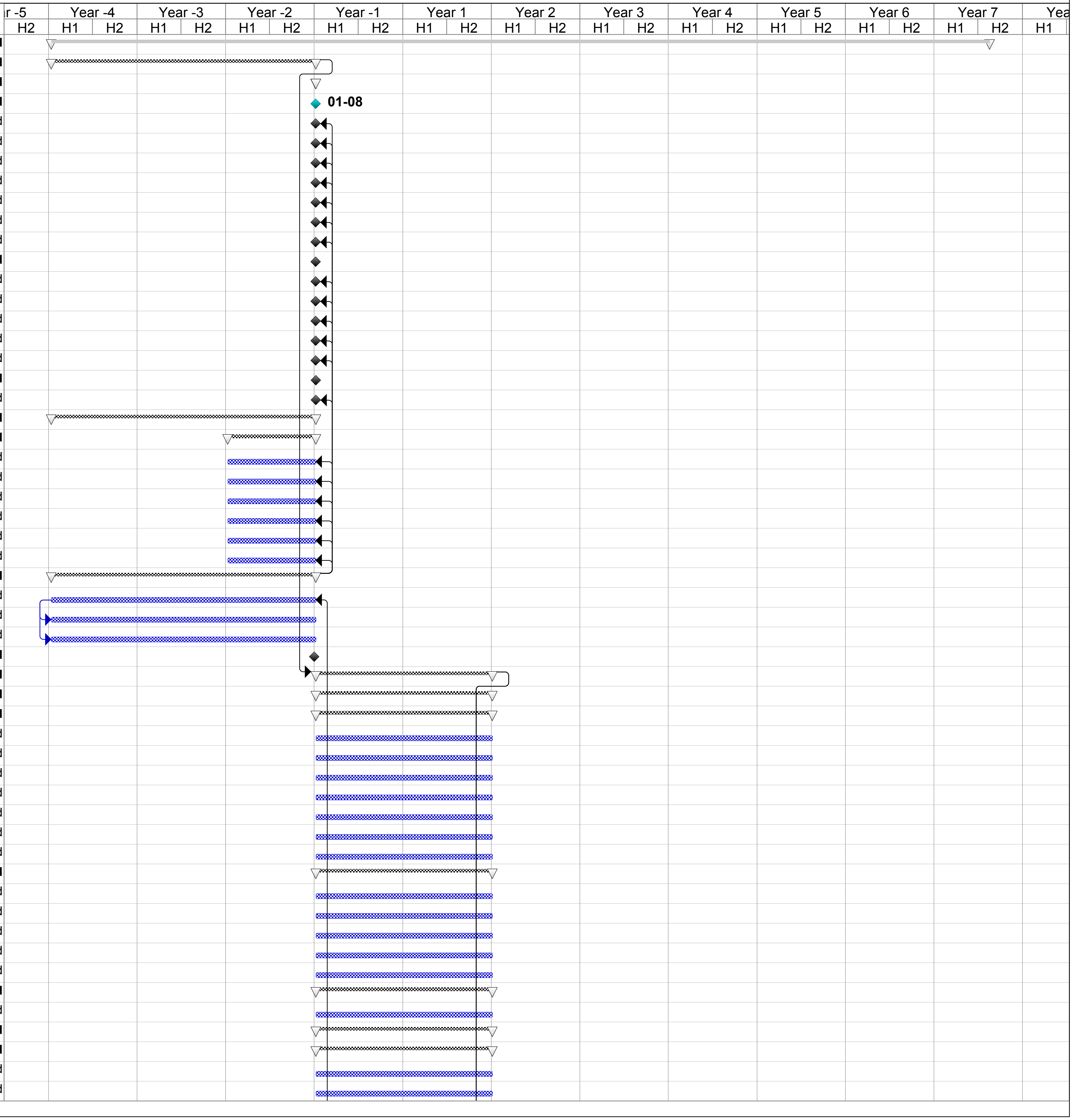
ID	WBS	Main activities
113	4.3.4.5	Electrical equipment and cabling
114	**4.3.5**	**Misc undistributed costs**
115	4.3.5.1	Process dismantling contractor project management and administration
116	4.3.5.2	Process dismantling contractor equipments and tools
117	4.3.5.3	Decommissioning system adaption
118	**4.4**	**WASTE HANDLING AND STORAGE**
119	**4.4.1**	**Waste management system**
120	4.4.1.2	Operation of the waste systems
121	4.4.1.3	Decontamination and dismantling of the waste systems and buildings
122	**4.4.2**	**Containers for transport and storage**
123	4.4.2.1	SFR containers
124	**4.4.3**	**Transports to repository and landfills**
125	4.4.3.1	Transport to SFR
126	4.4.3.2	Transport to landfills
127	**4.4.4**	**Repository and landfill storage fees**
128	4.4.4.1	Landfill fees
129	**4.4.5**	**Handling of non-radioactive hazardous waste**
130	**5**	**CONVENTIONAL DEMOLITION**
131	**5.1**	**PLANT OPERATION DURING DECOMMISSIONING**
132	**5.1.1**	**Personnel costs**
133	5.1.1.1	Management and administration
134	5.1.1.2	Surveillance and environment protection
135	5.1.1.3	Maintenance
136	**5.1.2**	**Operational costs**
137	5.1.2.1	Surveillance and environment protection
138	5.1.2.2	Maintenance
139	5.1.2.3	Energy and water
140	**5.1.3**	**Fixed costs**
141	5.1.3.1	Fees and inspection costs
142	5.1.3.2	Taxes
143	5.1.3.3	Insurances
144	**5.1.4**	**Organizational costs**
145	5.1.4.1	Administration and information management
146	**5.2**	**PURCHASER’S PROJECT MANAGEMENT, ADMINISTRATION AND TECHNICAL SUPPORT**
147	**5.2.1**	**Project management**
148	**5.2.2**	**Planning and controlling**
149	**5.2.3**	**Quality management and control**
150	**5.2.4**	**Technical support**
151	**5.2.5**	**Documentation**
152	**5.2.6**	**General and supplier administration**
153	**5.3**	**DISMANTLING AND DEMOLITION ACTIVITIES**
154	**5.3.1**	**Receiving building, auxiliary building and electrical building**
155	**5.3.2**	**Encapsulation building**
156	**5.3.3**	**Underground buildings**
157	**5.3.4**	**Other buildings**
158	**5.3.5**	**Building rubble random activity check**
159	**5.4**	**WASTE HANDLING AND DISPOSAL**
160	**5.4.1**	**Transports and repository**
161	5.4.1.1	Transports
162	5.4.1.2	Landfill fees
163	**5.4.2**	**Handling of non-radioactive hazardous waste**
164	**5.5**	**SITE RESTORATION**
165	**5.5.1**	**Independent radiological survey**
166	**5.5.2**	**Ground restoration**

Appendix 4.2

(The year 2076-01-01 is set as a reference year 0 throughout this study since the date of decommission of Clink is not certain. MS project can not display year 0. Therefore the starting point will be named year -1 in Appendix 9-2)

Clink Decommissioning Study
Decommissioning Programme

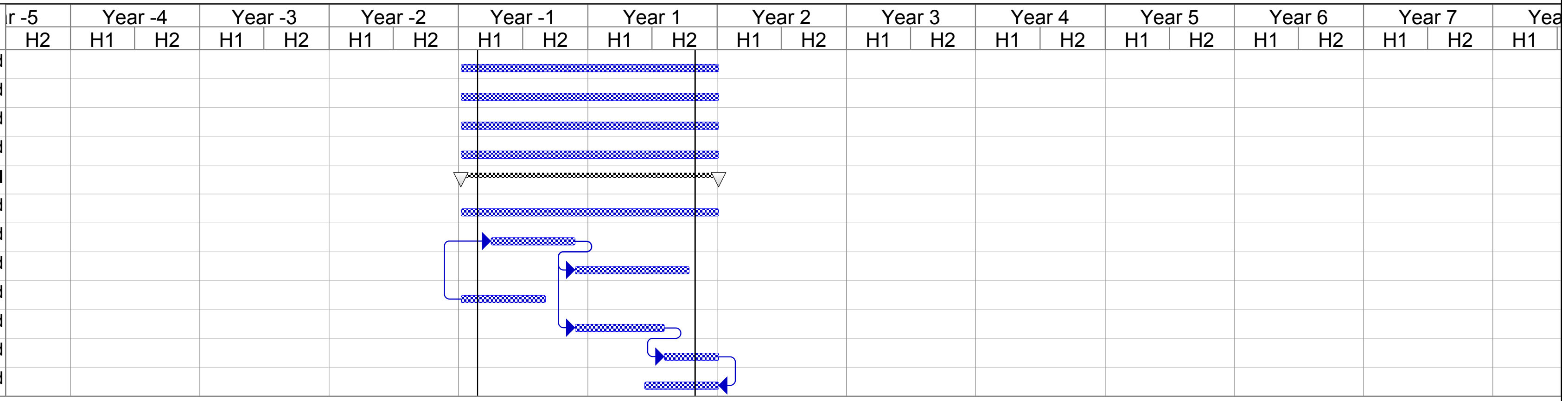
WBS	Task Name	Duration
0	**Clink Decommissioning**	**2445 d**
1	**NORMAL OPERATION (related to decommissioning)**	**690 d**
1.1	**PLANT OPERATION COSTS**	**1 d**
1.1.1	**Personnel costs**	**0 d**
1.1.1.1	Management and administration	0 d
1.1.1.2	Information and public relations	0 d
1.1.1.3	Radiation and environment protection	0 d
1.1.1.4	Chemistry, waste	0 d
1.1.1.5	Surveillance, fire protection	0 d
1.1.1.6	Maintenance of buildings and equipment	0 d
1.1.1.7	Plant system operation	0 d
1.1.2	**Operational costs**	**0 d**
1.1.2.1	Radiation and environment protection	0 d
1.1.2.2	Chemistry, waste	0 d
1.1.2.3	Surveillance, fire protection	0 d
1.1.2.4	Maintenance	0 d
1.1.2.5	Energy and water	0 d
1.1.3	**Organizational costs**	**0 d**
1.1.3.1	Administration and information management	0 d
1.2	**PROJECT COSTS**	**690 d**
1.2.1	**Purchasers project management, administration and technical support**	**230 d**
1.2.1.1	Project management	230 d
1.2.1.2	Planning and controlling	230 d
1.2.1.3	Quality management and control	230 d
1.2.1.4	Technical support	230 d
1.2.1.5	Documentation	230 d
1.2.1.6	General and supplier administration	230 d
1.2.2	**Decomissioning preparation activities**	**690 d**
1.2.2.1	Preliminary EIA work	690 d
1.2.2.2	Decommissioning planning work	690 d
1.2.2.3	Information gathering	690 d
2	**EXTRA WBS ITEM**	**0 d**
3	**PREPARATION FOR DISMANTLING**	**460 d**
3.1	**PLANT OPERATION COSTS**	**460 d**
3.1.1	**Personnel costs**	**460 d**
3.1.1.1	Management and administration	460 d
3.1.1.2	Information and public relations	460 d
3.1.1.3	Radiation and environment protection	460 d
3.1.1.4	Chemistry, waste	460 d
3.1.1.5	Surveillance, fire protection	460 d
3.1.1.6	Maintenance of buildings and equipment	460 d
3.1.1.7	Plant system operation	460 d
3.1.2	**Operational costs**	**460 d**
3.1.2.1	Radiation and environment protection	460 d
3.1.2.2	Chemistry, waste	460 d
3.1.2.3	Surveillance, fire protection	460 d
3.1.2.4	Maintenance	460 d
3.1.2.5	Energy and water	460 d
3.1.3	**Organizational costs**	**460 d**
3.1.3.1	Administration and information management	460 d
3.2	**PROJECT COSTS**	**460 d**
3.2.1	**Purchasers project management, administration and technical support**	**460 d**
3.2.1.1	Project management	460 d
3.2.1.2	Planning and controlling	460 d



(The year 2076-01-01 is set as a reference year 0 throughout this study since the date of decommission of Clink is not certain. MS project can not display year 0. Therefore the starting point will be named year -1 in Appendix 9-2)

Clink Decommissioning Study
Decommissioning Programme

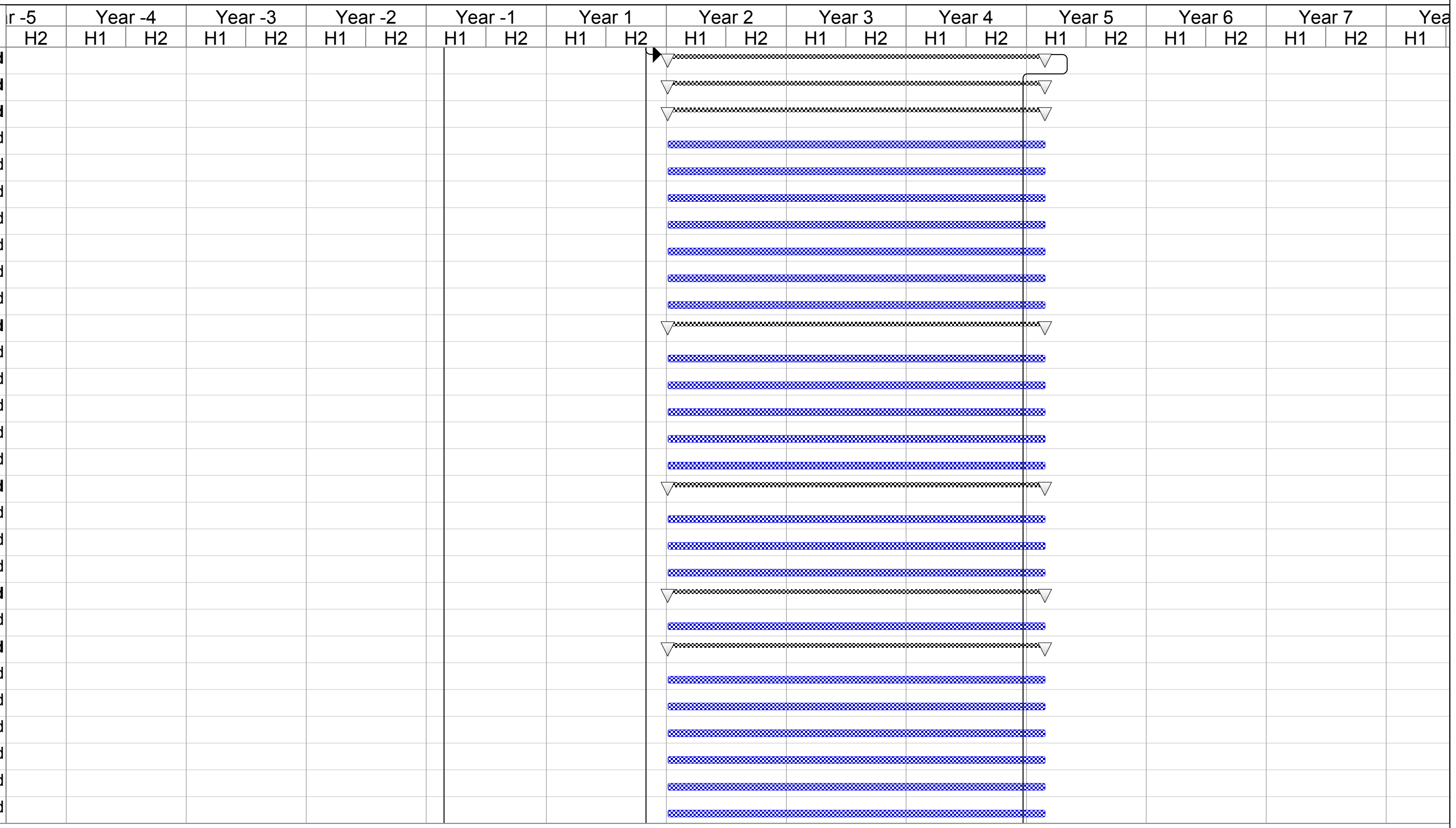
WBS	Task Name	Duration
3.2.1.3	Quality management and control	460 d
3.2.1.4	Technical support	460 d
3.2.1.5	Documentation	460 d
3.2.1.6	General and supplier administration	460 d
3.2.2	**Decommissioning preparation activities**	**460 d**
3.2.2.1	EIA work	460 d
3.2.2.2	Radiological inventory characterization	150 d
3.2.2.3	Object decontamination	200 d
3.2.2.4	System decontamination	150 d
3.2.2.5	Pre-decommissioning system adaption	150 d
3.2.2.6	General preparatory activities	100 d
3.2.2.7	Adaptation of waste systems and buildings	120 d



(The year 2076-01-01 is set as a reference year 0 throughout this study since the date
of decommission of Clink is not certain. MS project can not display year 0.
Therefore the starting point will be named year -1 in Appendix 9-2)

Clink Decommissioning Study
Decommissioning Programme

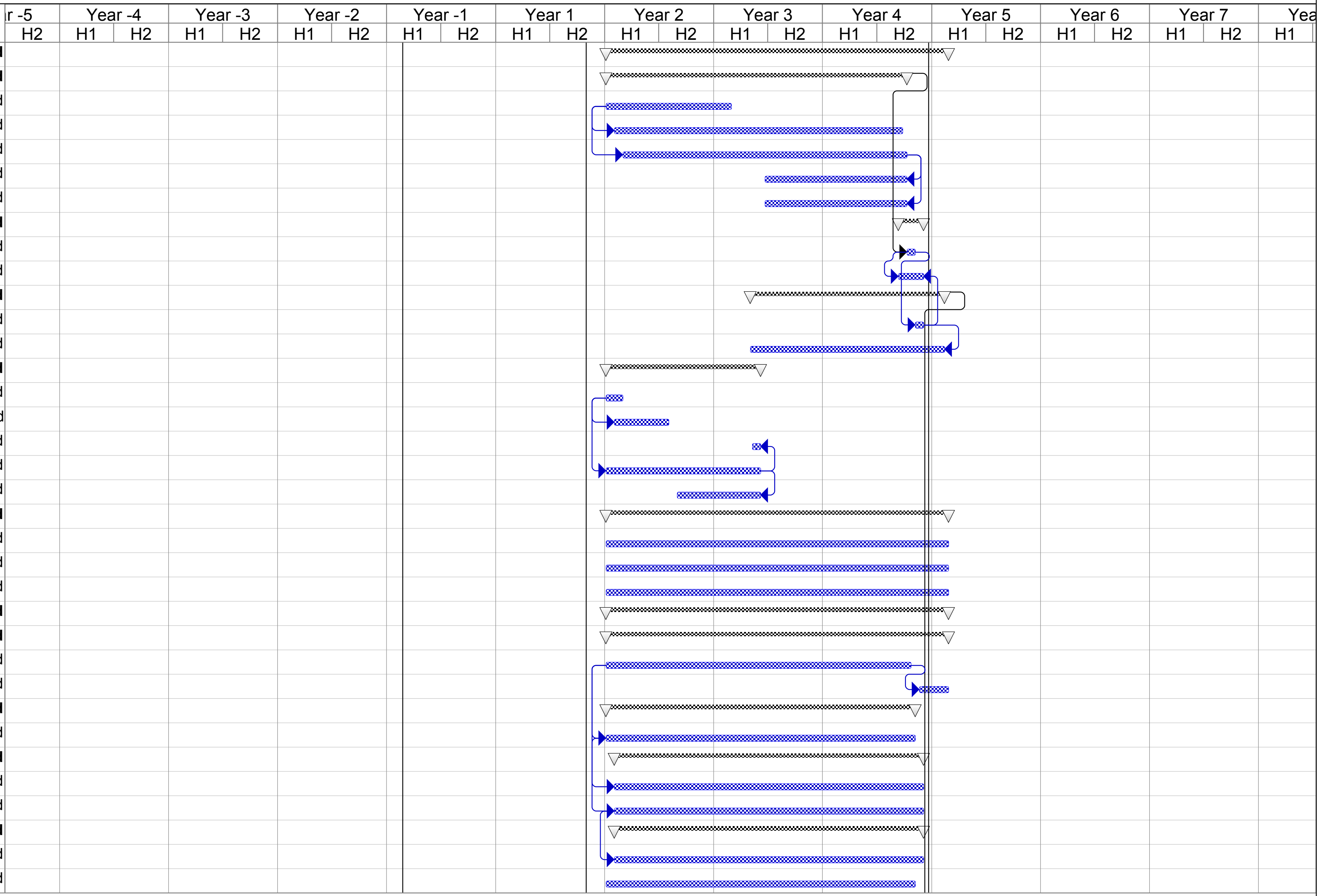
WBS	Task Name	Duration
4	**NUCLEAR DISMANTLING AND DEMOLITION**	**730 d**
4.1	**PLANT OPERATION COSTS**	**730 d**
4.1.1	**Personnel costs**	**730 d**
4.1.1.1	Management and administration	730 d
4.1.1.2	Information and public relations	730 d
4.1.1.3	Radiation and environment protection	730 d
4.1.1.4	Chemistry, waste	730 d
4.1.1.5	Surveillance, fire protection	730 d
4.1.1.6	Maintenance of buildings and equipment	730 d
4.1.1.7	Plant system operation	730 d
4.1.2	**Operational costs**	**730 d**
4.1.2.1	Radiation and environment protection	730 d
4.1.2.2	Chemistry, waste	730 d
4.1.2.3	Surveillance, fire protection	730 d
4.1.2.4	Maintenance	730 d
4.1.2.5	Energy and water	730 d
4.1.3	**Fixed costs**	**730 d**
4.1.3.1	Other fees, inspection costs	730 d
4.1.3.2	Taxes	730 d
4.1.3.3	Insurances	730 d
4.1.4	**Organizational costs**	**730 d**
4.1.4.1	Administration and information management	730 d
4.2	**PURCHASER'S PROJECT MANAGEMENT, ADMINISTRATION AND TECHNICAL SUP**	**730 d**
4.2.1	Project management	730 d
4.2.2	Planning and controlling	730 d
4.2.3	Quality management and control	730 d
4.2.4	Technical support	730 d
4.2.5	Documentation	730 d
4.2.6	General and supplier administration	730 d



(The year 2076-01-01 is set as a reference year 0 throughout this study since the date
of decommission of Clink is not certain. MS project can not display year 0.
Therefore the starting point will be named year -1 in Appendix 9-2)

Clink Decommissioning Study
Decommissioning Programme

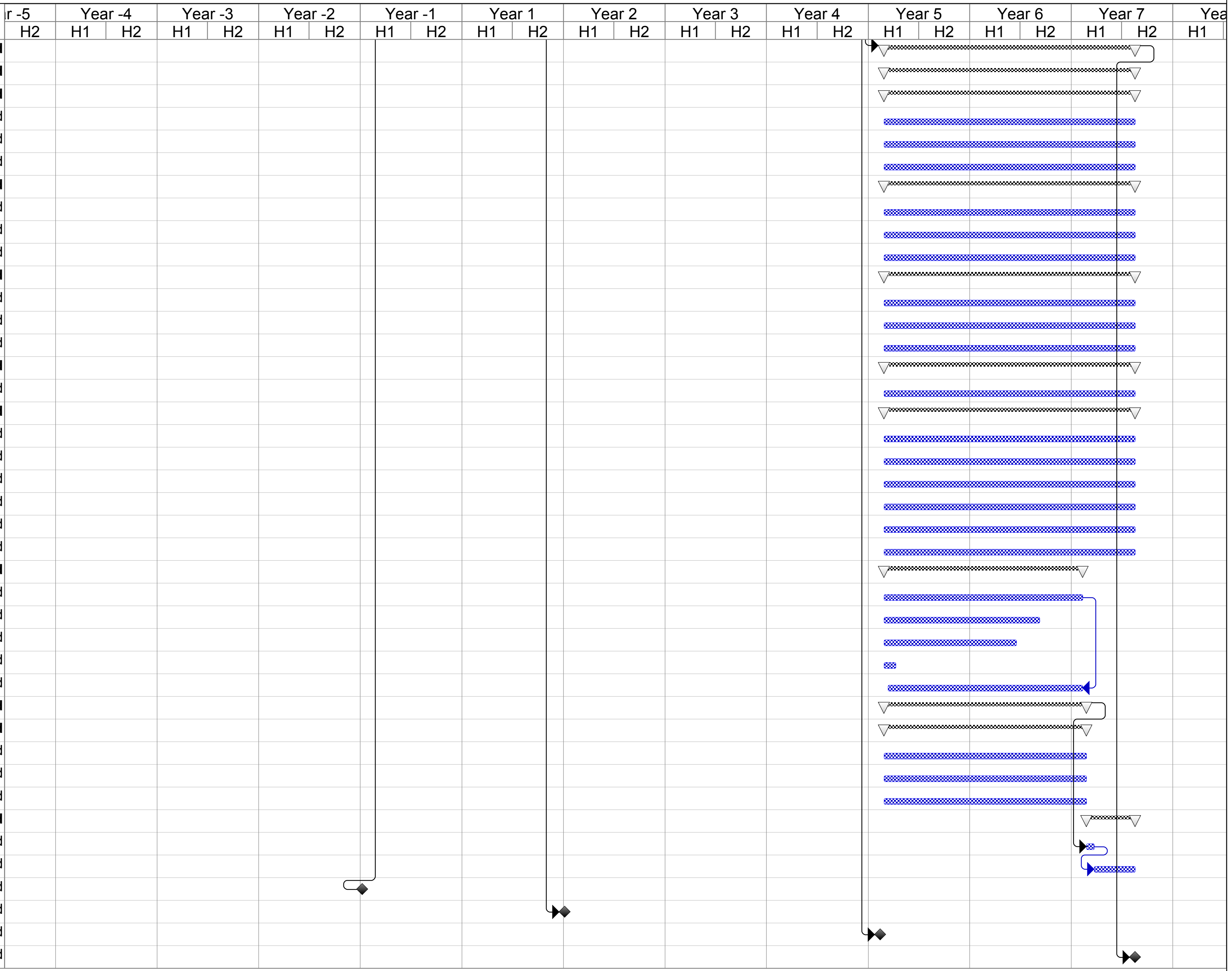
WBS	Task Name	Duration
4.3	**DISMANTLING AND DEMOLITION ACTIVITIES**	**730 d**
4.3.1	**Controlled area buildings**	**640 d**
4.3.1.1	Room preparations	270 d
4.3.1.2	Process piping and equipment	610 d
4.3.1.3	Structural and various steel	600 d
4.3.1.4	Air treatment systems	290 d
4.3.1.5	Electrical equipment and cabling	290 d
4.3.2	**Demolition of radioactive concrete**	**60 d**
4.3.2.1	Other contaminated concrete	20 d
4.3.2.2	Radiation protection and measurement	60 d
4.3.3	**Cleaning and clearance of controlled area buildings**	**405 d**
4.3.3.1	Building surface decontamination	20 d
4.3.3.2	Building clearance survey	405 d
4.3.4	**Process dismantling uncontrolled area buildings**	**340 d**
4.3.4.1	Room preparations	40 d
4.3.4.2	Process piping and equipment ok	110 d
4.3.4.3	Structural and various steel ok	20 d
4.3.4.4	Air treatment systems ok	340 d
4.3.4.5	Electrical equipment and cabling ok	190 d
4.3.5	**Misc undistributed costs**	**730 d**
4.3.5.1	Process dismantling contractor project management and administration	730 d
4.3.5.2	Process dismantling contractor equipments and tools	730 d
4.3.5.3	Decommissioning system adaption	730 d
4.4	**WASTE HANDLING AND STORAGE**	**730 d**
4.4.1	**Waste management system**	**730 d**
4.4.1.1	Operation of the waste systems	650 d
4.4.1.2	Decontamination and dismantling of the waste systems and buildings	60 d
4.4.2	**Containers for transport and storage**	**660 d**
4.4.2.1	SFR containers	660 d
4.4.3	**Transports to repository and landfills**	**660 d**
4.4.3.2	Transport to SFR	660 d
4.4.3.2	Transport to landfills	660 d
4.4.4	**Repository and landfill storage fees**	**660 d**
4.4.4.1	Landfill fees	660 d
4.4.5	Handling of non-radioactive hazardous waste	660 d



(The year 2076-01-01 is set as a reference year 0 throughout this study since the date of decommission of Clink is not certain. MS project can not display year 0. Therefore the starting point will be named year -1 in Appendix 9-2)

Clink Decommissioning Study
Decommissioning Programme

WBS	Task Name	Duration
5	**CONVENTIONAL DEMOLITION**	**565 d**
5.1	**PLANT OPERATION DURING DECOMMISSIONING**	**565 d**
5.1.1	**Personnel costs**	**565 d**
5.1.1.1	Management and administration	565 d
5.1.1.2	Surveillance and environment protection	565 d
5.1.1.3	Maintenance	565 d
5.1.2	**Operational costs**	**565 d**
5.1.2.1	Surveillance and environment protection	565 d
5.1.2.2	Maintenance	565 d
5.1.2.3	Energy and water	565 d
5.1.3	**Fixed costs**	**565 d**
5.1.3.1	Fees and inspection costs	565 d
5.1.3.2	Taxes	565 d
5.1.3.3	Insurances	565 d
5.1.4	**Organizational costs**	**565 d**
5.1.4.1	Administration and information management	565 d
5.2	**PURCHASER'S PROJECT MANAGEMENT, ADMINISTRATION AND TECHNICAL SUP**	**565 d**
5.2.1	Project management	565 d
5.2.2	Planning and controlling	565 d
5.2.3	Quality management and control	565 d
5.2.4	Technical support	565 d
5.2.5	Documentation	565 d
5.2.6	General and supplier administration	565 d
5.3	**DISMANTLING AND DEMOLITION ACTIVITIES**	**450 d**
5.3.1	Receiving building, auxiliary building and electrical building	450 d
5.3.2	Encapsulation building	350 d
5.3.3	Underground buildings	310 d
5.3.4	Other buildings	30 d
5.3.5	Building rubble random activity check	440 d
5.4	**WASTE HANDLING AND DISPOSAL**	**460 d**
5.4.1	**Transports and repository**	**460 d**
5.4.1.1	Transports	460 d
5.4.1.2	Landfill fees	460 d
5.4.2	Handling of non-radioactive hazardous waste	460 d
5.5	**SITE RESTORATION**	**105 d**
5.5.1	Independent radiological survey	20 d
5.5.2	Ground restoration	85 d
6	***Plant shutdown***	0 d
7	***Shutdown operation finish***	0 d
8	***Building clearance finish***	0 d
9	***Plant decommissioning finish***	0 d



Decommissioning cost estimate

A5.1 WBS cost matrix

Clink Decommissioning Study
WBS COST MATRIX

1 = **Summary** activity, level 1
2 = **Summary** activity, level 2
3 = **Summary** activity, level 3
4 = **Summary** activity, level 4

Working days/year: 230

Working hours/day: 8

				Average Number of People									Worked hours									Labor Cost (kSEK/hour)												
													Utility			Contractors						0,700	0,350	1,400	1,000	0,800	0,650	0,650	0,450					
Reference	ID	WBS no.	TASK / Component	Utility Manager (cat.M)	Utility Engineer (cat.E)	Project Manager (cat. P)	Engineer (cat.1)	Foreman (cat. 2)	HP technician (cat.3)	Craftsmen (cat. 4)	Laborer (cat. 5)	Duration	Utility Manager (cat.M)	Utility Engineer (cat.E)	Project Manager (cat. P)	Engineer (cat.1)	Foreman (cat. 2)	HP technician (cat.3)	Craftsmen (cat. 4)	Laborer (cat. 5)	Total Labor	Utility Manager (cat.M)	Utility Engineer (cat.E)	Project Manager (cat. P)	Engineer (cat.1)	Foreman (cat. 2)	HP technician (cat.3)	Craftsmen (cat. 4)	Laborer (cat. 5)	Total Utility Labour Cost	Contractor cost	Material Cost	Equipment Cost	Total Cost
				no.	no.	no.	no.	no.	no.	no.	no.	days	hours	hours	hours	hours	hours	hours	hours	hours	hours	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK
	1	1	NORMAL OPERATION	0	9	1	0	0	0	0	0	0	0	31 280	1 840	0	0	0	0	0	33 120	0	10 948	2 576	0	0	0	0	0	10 948	2 576	0	0	13 524
	2	1.1	PLANT OPERATING COSTS	0	1	0	0	0	0	0	0	0	0	2 300	0	0	0	0	0	0	2 300	0	805	0	0	0	0	0	0	805	0	0	0	805
	3	1.1.1	Personnel costs	0	1	0	0	0	0	0	0	0,0	0	2 300	0	0	0	0	0	0	2 300	0	805	0	0	0	0	0	0	805	0	0	0	805
1	4	1.1.1.1	Management and administration	0,0	1,0							230	0	1 840	0	0	0	0	0	0	1 840	0	644	0	0	0	0	0	0	644	0			644
1	5	1.1.1.2	Information and public relations		0,0							230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0
1	6	1.1.1.3	Radiation and environment protection		0,3							230	0	460	0	0	0	0	0	0	460	0	161	0	0	0	0	0	0	161	0			161
1	7	1.1.1.4	Chemistry, waste		0,0							230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0
1	8	1.1.1.5	Surveillance, fire protection		0,0							230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0
1	9	1.1.1.6	Maintenance of buildings and equipment		0,0							230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0
1	10	1.1.1.7	Plant system operation		0,0							230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0
	11	1.1.2	Operational costs	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	12	1.1.2.1	Radiation and environment protection		0,0							230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0
1	13	1.1.2.2	Chemistry, waste		0,0							230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0
1	14	1.1.2.3	Surveillance, fire protection		0,0							230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0
1	15	1.1.2.4	Maintenance		0,0							230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0
1	16	1.1.2.5	Energy and water									230	0		0	0	0	0	0	0		0		0	0	0	0	0	0		0			0
	17	1.1.3	Organizational costs	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	18	1.1.3.1	Administraton and information management		0							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0
	19	1.2	PROJECT COSTS	0	8	1	0	0	0	0	0		0	28 980	1 840	0	0	0	0	0	30 820	0	10 143	2 576	0	0	0	0	0	10 143	2 576	0	0	12 719
	20	1.2.1	Purchasers project management, administration and technical support	0	4	1	0	0	0	0	0		0	6 900	1 840	0	0	0	0	0	8 740	0	2 415	2 576	0	0	0	0	0	2 415	2 576	0	0	4 991
1	21	1.2.1.1	Project management			1,0						230	0	0	1 840	0	0	0	0	0	1 840	0	0	2 576	0	0	0	0	0	0	2 576			2 576
1	22	1.2.1.2	Planning and controlling		1,5							230	0	2 760	0	0	0	0	0	0	2 760	0	966	0	0	0	0	0	0	966	0			966
1	23	1.2.1.3	Quality management and control		0,0							230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0
1	24	1.2.1.4	Technical support		0,8							230	0	1 380	0	0	0	0	0	0	1 380	0	483	0	0	0	0	0	0	483	0			483
1	25	1.2.1.5	Documentation		0,4							230	0	690	0	0	0	0	0	0	690	0	242	0	0	0	0	0	0	242	0			242
1	26	1.2.1.6	General and supplier administration	0,0	1,1							230	0	2 070	0	0	0	0	0	0	2 070	0	725	0	0	0	0	0	0	725	0			725
	27	1.2.2	Decommissioning preparation activities	0	4	0	0	0	0	0	0		0	22 080	0	0	0	0	0	0	22 080	0	7 728	0	0	0	0	0	0	7 728	0	0	0	7 728
1	28	1.2.2.1	Preliminary EIA work		1,0							690	0	5 520	0	0	0	0	0	0	5 520	0	1 932	0	0	0	0	0	0	1 932	0			1 932
1	29	1.2.2.2	Decommissioning planning work		2,0							690	0	11 040	0	0	0	0	0	0	11 040	0	3 864	0	0	0	0	0	0	3 864	0			3 864
1	30	1.2.2.3	Information gathering		1,0							690	0	5 520	0	0	0	0	0	0	5 520	0	1 932	0	0	0	0	0	0	1 932	0			1 932
	31	2	EXTRA WBS ITEM	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	65	3	SHUTDOWN OPERATION	1	63	6	5	3	3	15	6		3 680	231 840	19 600	5 600	3 200	3 000	15 600	8 000	290 520	2 576	81 144	27 440	5 600	2 560	1 950	10 140	3 600	83 720	55 665	0	41 360	180 745
	66	3.1	PLANT OPERATING COSTS	1	42	0	0	0	0	0	0		1 840	152 720	0	0	0	0	0	0	154 560	1 288	53 452	0	0	0	0	0	0	54 740	2 225	0	0	56 965
	67	3.1.1	Personnel costs	1	11	0	0	0	0	0	0		1 840	38 640	0	0	0	0	0	0	40 480	1 288	13 524	0	0	0	0	0	0	14 812	0	0	0	14 812
1	68	3.1.1.1	Management and administration	1	2							460	1 840	5 520	0	0	0	0	0	0	7 360	1 288	1 932	0	0	0	0	0	0	3 220	0			3 220
1	69	3.1.1.2	Information and public relations		0							460	0	920	0	0	0	0	0	0	920	0	322	0	0	0	0	0	0	322	0			322
1	70	3.1.1.3	Radiation and environment protection		1							460	0	4 600	0	0	0	0	0	0	4 600	0	1 610	0	0	0	0	0	0	1 610	0			1 610
1	71	3.1.1.4	Chemistry, waste		2							460	0	8 280	0	0	0	0	0	0	8 280	0	2 898	0	0	0	0	0	0	2 898	0			2 898
1	72	3.1.1.5	Surveillance, fire protection		2							460	0	5 520	0	0	0	0	0	0	5 520	0	1 932	0	0	0	0	0	0	1 932	0			1 932
1	73	3.1.1.6	Maintenance of buildings and equipment		2							460	0	6 440	0	0	0	0	0	0	6 440	0	2 254	0	0	0	0	0	0	2 254	0			2 254
1	74	3.1.1.7	Plant system operation		2							460	0	7 360	0	0	0	0	0	0	7 360	0	2 576	0	0	0	0	0	0	2 576	0			2 576
	75	3.1.2	Operational costs	0	24	0	0	0	0	0	0		0	88 320	0	0	0	0	0	0	88 320	0	30 912	0	0	0	0	0	0	30 912	2 225	0	0	33 137
1	76	3.1.2.1	Radiation and environment protection		5							460	0	18 400	0	0	0	0	0	0	18 400	0	6 440	0	0	0	0	0	0	6 440	0			6 440
1	77	3.1.2.2	Chemistry, waste		2							460	0	7 360	0	0	0	0	0	0	7 360	0	2 576	0	0	0	0	0	0	2 576	0			2 576
1	78	3.1.2.3	Surveillance, fire protection		6							460	0	22 080	0	0	0	0	0	0	22 080	0	7 728	0	0	0	0	0	0	7 728	0			7 728
1	79	3.1.2.4	Maintenance		11							460	0	40 480	0	0	0	0	0	0	40 480	0	14 168	0	0	0	0	0	0	14 168	0			14 168
1	80	3.1.2.5	Energy and water									460	0	0	0	0	0	0	0	0	0	0	0		0					0	2 225			2 225
	81	3.1.3	Organizational costs	0	7	0	0	0	0	0	0		0	25 760	0	0	0	0	0	0	25 760	0	9 016	0	0	0	0	0	0	9 016	0	0	0	9 016
1	82	3.1.3.1	Administration and information management		7							460	0	25 760	0	0	0	0	0	0	25 760	0	9 016	0	0	0	0	0	0	9 016	0			9 016
	83	3.2	PROJECT COSTS	1	22	6	5	3	3	15	6		1 840	79 120	19 600	5 600	3 200	3 000	15 600	8 000	135 960	1 288	27 692	27 440	5 600	2 560	1 950	10 140	3 600	28 980	53 440	0	41 360	123 780
	84	3.2.1	Purchasers project management, administration and technical support	1	21	5	0	0	0	0	0		1 840	75 440	18 400	0	0	0	0	0	95 680	1 288	26 404	25 760	0	0	0	0	0	27 692	25 760	0	0	53 452
1	85	3.2.1.1	Project management			5						460	0	0	18 400	0	0	0	0	0	18 400	0	0	25 760	0	0	0	0	0	0	25 760			25 760
1	86	3.2.1.2	Planning and controlling		2							460	0	5 520	0	0	0	0	0	0	5 520	0	1 932	0	0	0	0	0	0	1 932	0			1 932
1	87	3.2.1.3	Quality management and control		1							460	0	1 840	0	0	0	0	0	0	1 840	0	644	0	0	0	0	0	0	644	0			644
1	88	3.2.1.4	Technical support		13							460	0	46 000	0	0	0	0	0	0	46 000	0	16 100	0	0	0	0	0	0	16 100	0			16 100
1	89	3.2.1.5	Documentation		1							460	0	2 760	0	0	0	0	0	0	2 760	0	966	0	0	0	0	0	0	966	0			966
1	90	3.2.1.6	General and supplier administration	1	5							460	1 840	19 320	0	0	0	0	0	0	21 160	1 288	6 762	0	0	0	0	0	0	8 050	0			8 050
	91	3.2.2	Decomissioning preparation activities	0	1	1	5	3	3	15	6		0	3 680	1 200	5 600	3 200	3 000	15 600	8 000	40 280	0	1 288	1 680	5 600	2 560	1 950	10 140	3 600	1 288	27 680	0	41 360	70 328
1	92	3.2.2.1	EIA work		1,0							460	0	3 680	0	0	0	0	0	0	3 680	0	1 288	0	0	0	0	0	0	1 288	0			1 288
1	93	3.2.2.2	Radiological inventory characterisation, Tank inventory						1,5			150	0	0	0	0	0	1 800	0	0	1 800	0	0	0	0	0	1 170	0	0	0	1 170			1 170
1	94	3.2.2.3	Object decontamination, conservation								1,3	200	0	0	0	0	0	0	0	2 000	2 000	0	0	0	0	0	0	0	900	0	900			900
1	95	3.2.2.4	System decontamination			1,0	3,0	1,0	1,0	3,0	5,0	150	0	0	1 200	3 600	1 200	1 200	3 600	6 000	16 800	0	0	1 680	3 600	960	780	2 340	2 700	0	12 060		22 060	34 120
1	96	3.2.2.5	Pre-decommissioning system adaption				1,0	1,0		6,0		150	0	0	0	1 200	1 200	0	7 200	0	9 600	0	0	0	1 200	960	0	4 680	0	0	6 840			6 840
1	97	3.2.2.6	General prepatory activities				1	1		6		100	0	0	0	800	800	0	4 800	0	6 400	0	0	0	800	640	0	3 120	0	0	4 560			4 560
	98	3.2.2.7	Adaption of waste systems and buildnings									120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2 150		19 300	21 450
	99	4	NUCLEAR DISMANTLING AND DEMOLITION	1	63	6	5	19	5	15	156		5 840	367 920	35 040	18 865	68 243	16 308	56 493	411 860	971 810	4 088	128 772	8 176	18 769	54 018	10 288	36 097	184 473	132 860	389 574	1 170	12 900	536 504
	100	4.1	PLANT OPERATING COSTS	1	42	0	0	0	0	0	0		2 920	246 740	0	0	0	0	0	0	249 660	2 044	86 359	0	0	0	0	0	0	88 403	30 013	0	0	118 416
	101	4.1.1	Personnel costs	1	11	0	0	0	0	0	0		2 920	65 700	0	0	0	0	0	0	68 620	2 044	22 995	0	0	0	0	0	0	25 039	0	0	0	25 039
2	102	4.1.1.1	Management and administration	0,5	1,5							730	2 920	8 760	0	0	0	0	0	0	11 680	2 044	3 066	0	0	0	0	0	0	5 110	0			5 110
2	103	4.1.1.2	Information and public relations		0,3							730	0	1 460	0	0	0	0	0	0	1 460	0	511	0	0	0	0	0	0	511	0			511
2	104	4.1.1.3	Radiation and environment protection		3,5							730	0	20 440	0	0	0	0	0	0	20 440	0	7 154	0	0	0	0	0	0	7 154	0			7 154
2	105	4.1.1.4	Chemistry, waste		1,3							730	0	7 300	0	0	0	0	0	0	7 300	0	2 555	0	0	0	0	0	0	2 555	0			2 555
2	106	4.1.1.5	Surveillance, fire protection		1,5							730	0	8 760	0	0	0	0	0	0	8 760	0	3 066	0	0	0	0	0	0	3 066	0			3 066
2	107	4.1.1.6	Maintenance of buildings and equipment		1,3							730	0	7 300	0	0	0	0	0	0	7 300	0	2 555	0	0	0	0	0	0	2 555	0			2 555
2	108	4.1.1.7	Plant system operation		2,0							730	0	11 680	0	0	0	0	0	0	11 680	0	4 088	0	0	0	0	0	0	4 088	0			4 088
	109	4.1.2	Operational costs	0	24	0	0	0	0	0	0		0	140 160	0	0	0	0	0	0	140 160	0	49 056	0	0	0	0	0	0	49 056	26 482	0	0	75 538
2	110	4.1.2.1	Radiation and environment protection		5,0							730	0	29 200	0	0	0	0	0	0	29 200	0	10 220	0	0					10 220	0			10 220
2	111	4.1.2.2	Chemistry, waste		2,0							730	0	11 680	0	0	0	0	0	0	11 680	0	4 088	0	0					4 088	0			4 088
2	112	4.1.2.3	Surveillance, fire protection		6,0							730	0	35 040	0	0	0	0	0	0	35 040	0	12 264	0	0					12 264	0			12 264
2	113	4.1.2.4	Maintenance		11,0							730	0	64 240	0	0	0	0	0	0	64 240	0	22 484	0	0					22 484	0			22 484
2	114	4.1.2.5	Energy and water									730	0		0	0	0	0	0	0		0		0	0						26 482			26 482

Clink Decommissioning Study

WBS COST MATRIX

Reference	ID	WBS no.	TASK / Component	Average Number of People								Duration	Worked hours								Total Labor	Labor Cost (kSEK/hour)								Total Utility Labour Cost	Contractor cost	Material Cost	Equipment Cost	Total Cost
													Utility			Contractors						0,700	0,350	1,400	1,000	0,800	0,650	0,650	0,450					
				Utility Manager (cat.M)	Utility Engineer (cat.E)	Project Manager (cat. P)	Engineer (cat.1)	Foreman (cat. 2)	HP technician (cat.3)	Craftsmen (cat. 4)	Laborer (cat. 5)		Utility Manager (cat.M)	Utility Engineer (cat.E)	Project Manager (cat. P)	Engineer (cat.1)	Foreman (cat. 2)	HP technician (cat.3)	Craftsmen (cat. 4)	Laborer (cat. 5)		Utility Manager (cat.M)	Utility Engineer (cat.E)	Project Manager (cat. P)	Engineer (cat.1)	Foreman (cat. 2)	HP technician (cat.3)	Craftsmen (cat. 4)	Laborer (cat. 5)					
				no.	no.	no.	no.	no.	no.	no.	no.	days	hours	hours	hours	hours	hours	hours	hours	hours	hours	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK
	115	4.1.3	Fixed costs	0	0	0	0	0	0	0	0		0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0	3 531	0	0	3 531
2	116	4.1.3.1	Other fees, inspection costs									730									0									0	(52000)			0
2	117	4.1.3.2	Taxes									730									0									0				0
2	118	4.1.3.3	Insurances									730									0									0	3 531			3 531
	119	4.1.4	Organizational costs	0	7	0	0	0	0	0	0		0	40 880	0	0	0	0	0	0	40 880	0	14 308	0	0	0	0	0	0	14 308	0	0	0	14 308
2	120	4.1.4.1	Administration and information management		7							730	0	40 880		0	0	0	0	0	40 880	0	14 308	0	0					14 308	0			14 308
	121	4.2	PURCHASER'S PROJECT MANAGEMENT, ADMINISTRATION AND TECHNICAL SUPPORT	1	21	5	0	0	0	0	0		2 920	121 180	29 200	0	0	0	0	0	144 540	2 044	42 413		0	0	0	0	0	44 457	40 880	0	0	85 337
2	122	4.2.1	Project management			5,0						730	0	0	29 200	0	0	0	0	0	29 200	0	0	40 880	0	0	0	0	0	0	40 880			40 880
2	123	4.2.2	Planning and controlling		1,5							730	0	8 760	0	0	0	0	0	0	FALSE	0	3 066	0	0	0	0	0	0	3 066	0			3 066
2	124	4.2.3	Quality management and control		0,5							730	0	2 920	0	0	0	0	0	0	2 920	0	1 022	0	0	0	0	0	0	1 022	0			1 022
2	125	4.2.4	Technical support		15,0							730	0	87 600	0	0	0	0	0	0	87 600	0	30 660	0	0	0	0	0	0	30 660	0			30 660
2	126	4.2.5	Documentation		0,8							730	0	4 380	0	0	0	0	0	0	4 380	0	1 533	0	0	0	0	0	0	1 533	0			1 533
2	127	4.2.6	General and supplier administration	0,5	3,0							730	2 920	17 520	0	0	0	0	0	0	20 440	2 044	6 132	0	0	0	0	0	0	8 176	0			8 176
	128	4.3	DISMANTLING AND DEMOLITION ACTIVITIES	0	0	1	5	17	3	12	149		0	0	5840	18423	64056	10628	48600	394340	541887	0	0	8176	18423	51245	6908	31590	177453	0	295295	0	12900	308195
	129	4.3.1	Controlled area buildings	0	0	0	2	9	3	10	70		0	0	0	5 940	31 460	10 628	45 731	239 812	333 571	0	0	0	5 940	25 168	6 908	29 725	107 916	0	175 657	0	0	175 657
C	130	4.3.1.1	Room preparation				0,6	2,1	1,5	0,3	18,9	270				1 293	4 526	3 233	647	40 735	50 434	0	0	0	1 293	3 621	2 101	420	18 331	0	25 767			25 767
C	131	4.3.1.2	Process piping and equipment				0,7	3,3	0,9	8,8	24,1	610				3 493	16 254	4 165	42 784	117 714	184 410	0	0	0	3 493	13 003	2 707	27 810	52 971	0	99 984			99 984
C	132	4.3.1.3	Structural and various steel				0,0	1,3	0,3	0,0	7,5	600				148	6 201	1 468	0	35 844	43 662	0	0	0	148	4 961	954	0	16 130	0	22 193			22 193
C	133	4.3.1.4	Air treatment systems				0,2	0,8	0,2	1,0	9,7	290				554	1 850	554	2 300	22 446	27 705	0	0	0	554	1 480	360	1 495	10 101	0	13 991			13 991
C	134	4.3.1.5	Electrical Equipment and Cabling				0,2	1,1	0,5	0,0	9,9	290				451	2 629	1 207	0	23 073	27 360	0	0	0	451	2 103	785	0	10 383	0	13 722			13 722
	135	4.3.2	Demolition of radioactive concrete	0	0	0	0	0	0	0	10		0	0	0	0	0	0	0	4 800	4 800	0	0	0	0	0	0	0	2 160	0	3 660	0	300	3 960
3	137	4.3.2.1	Contaminated concrete									20									0									0	1 500		300	1 800
3	138	4.3.2.2	Radiation protection and measurement								10,0	60				0	0	0	0	4 800	4 800				0	0	0	0	2 160	0	2 160			2 160
	139	4.3.3	Cleaning and clearance of controlled area buildings	0	0	0	0	0	0	0	35		0	0	0	0	0	0	0	113 400	113 400	0	0	0	0	0	0	0	51 030	0	51 030	0	0	51 030
	140	4.3.3.1	Building surface decontamination									20									0									0	(0)			0
3	141	4.3.3.2	Building clearance survey				0,0	0,0	0,0	0,0	35,0	405								113 400	113 400				0	0	0	0	51 030	0	51 030			51 030
	142	4.3.4	Process dismantling uncontrolled area buildings	0	0	0	1	3	0	2	34		0	0	0	803	3 396	0	2 869	36 328	43 396	0	0	0	803	2 717	0	1 865	16 347	0	21 732	0	0	21 732
C	143	4.3.4.1	Room preparation				0,4	1,6	0,0	0,3	16,2	40				129	517	0	86	5 173	5 906	0	0	0	129	414	0	56	2 328	0	2 927			2 927
C	144	4.3.4.2	Process piping and equipment				0,1	0,4	0,0	1,0	2,9	110				74	352	0	910	2 583	3 919	0	0	0	74	281	0	592	1 162	0	2 110			2 110
C	145	4.3.4.3	Structural and various steel				0,0	0,2	0,0	0,0	1,2	20				6	31	0	0	192	229	0	0	0	6	25	0	0	86	0	117			117
C	146	4.3.4.4	Air treatment systems				0,2	0,5	0,0	0,7	6,0	340				409	1 294	0	1 872	16 447	20 022	0	0	0	409	1 035	0	1 217	7 401	0	10 062			10 062
C	147	4.3.4.5	Electrical equipment and cabling				0,1	0,8	0,0	0,0	7,9	190				185	1 202	0	0	11 934	13 320	0	0	0	185	962	0	0	5 370	0	6 516			6 516
	148	4.3.5	Misc undistributed costs	0	0	1	2	5	0	0	0		0	0	5 840	11 680	29 200	0	0	0	46 720	0	0	8 176	11 680	23 360	0	0	0	0	43 216	0	12 600	55 816
4	149	4.3.5.1	Process dismantling contractor project management and administration			1,0	2,0	5,0	0,0	0,0	0,0	730			5 840	11 680	29 200	0	0	0	46 720			8 176	11 680	23 360	0	0	0	0	43 216			43 216
4	150	4.3.5.2	Process dismantling contractor equipments and tools									730																		0			12 600	12 600
	151	4.3.5.3	Deommissioning system adaption									730																		0				0
	152	4.4	WASTE HANDLING AND STORAGE	0	0	0	0	2	2	3	7		0	0	0	443	4 187	5 680	7 893	17 520	35 723	0	0	0	347	2 773	3 380	4 507	7 020	0	23 386	1 170	0	24 556
	153	4.4.1	Waste Management System	0	0	0	0	2	2	3	7					443	4 187	5 680	7 893	17 520	35 723	0	0	0	347	2 773	3 380	4 507	7 020	0	20 499	0	0	20 499
C	155	4.4.1.1	Operation of the waste systems				0,1	0,7	1,0	1,3	3,0	650				347	3 467	5 200	6 933	15 600	31 547	0	0	0	347	2 773	3 380	4 507	7 020	0	18 027			18 027
C	156	4.4.1.2	Decontamination and dismantling of the systems and buildings				0,2	1,5	1,0	2,0	4,0	60				96	720	480	960	1 920	4 176				96	576	312	624	864	0	2 472			2 472
	159	4.4.2	Containers for transport and storage	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 170	0	1 170
C	161	4.4.2.1	SFR containers									660																		0		1 170		1 170
	163	4.4.3	Transports to repository and landfills	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2 887	0	0	2 887
	165	4.4.3.1	Transports to SFR									660																		0	(0)			0
C	166	4.4.3.2	Transports to landfills									660																		0	2 887			2 887
	167	4.4.4	Repository and landfill storage fees	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	168	4.4.4.1	Landfill fees									660																		0	0			0
	171	4.4.5	Handling of nonradioactive hazardous waste	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	172																																	
	173		Subotal WBS 1 to 4										9 520	631 040	56 480	24 465	71 443	19 308	72 093	419 860	1 295 450	6 664	220 864	38 192	24 369	56 578	12 238	46 237	188 073	227 528	447 815	1 170	54 260	730 773
	174																																	

Reference	ID	WBS no.	TASK / Component	Average Number of People								Duration
				Utility Manager (cat.M)	Utility Engineer (cat.E)	Project Manager (cat. P)	Engineer (cat.1)	Foreman (cat. 2)	HP technician (cat.3)	Craftsmen (cat. 4)	Laborer (cat. 5)	
				no.	no.	no.	no.	no.	no.	no.	no.	days
	175	**5**	**CONVENTIONAL DEMOLITION**	1	26	3	0	0	0	0	5	
	176	5.1	PLANT OPERATING COSTS	1	16	0	0	0	0	0	0	
	177	***5.1.1***	***Personnel costs***	1	5	0	0	0	0	0	0	
2	178	5.1.1.1	Management and administration	0,5	0,9							565
2	179	5.1.1.2	Surveillance and environment protection		1,0							565
2	180	5.1.1.3	Maintenance		2,8							565
	181	***5.1.2***	***Operational costs***	0	7	0	0	0	0	0	0	
2	182	5.1.2.1	Surveillance and environment protection		3,0							565
2	183	5.1.2.2	Maintenance		4,0							565
2	184	5.1.2.3	Energy and water									565
	185	***5.1.3***	***Fixed costs***	0	0	0	0	0	0	0	0	
2	186	5.1.3.1	Fees, inspection costs									565
2	187	5.1.3.2	Taxes									565
2	188	5.1.3.3	Insurances									565
	189	***5.1.4***	***Organizational costs***	0	4	0	0	0	0	0	0	
2	190	5.1.4.1	Administration and information management		4,0							565
	191	5.2	PURCHASER'S PROJECT MANAGEMENT, ADMINISTRATION AND TECHNICAL SUPPORT	1	10	3	0	0	0	0	0	
2	192	***5.2.1***	***Project management***			3,0						565
2	193	***5.2.2***	***Planning and controlling***		0,8							565
2	194	***5.2.3***	***Quality management and control***		0,0							565
2	195	***5.2.4***	***Technical support***		7,0							565
2	196	***5.2.5***	***Documentation***		0,8							565
2	197	***5.2.6***	***General and supplier administration***	0,5	1,9							565
	198	5.3	DISMANTLING AND DEMOLITION ACTIVITIES	0	0	0	0	0	0	0	5	
3	199	***5.3.1***	***Receiving building, auxiliary building and electrical building***									450
3	200	***5.3.2***	***Encapsulation building***									350
3	201	***5.3.3***	***Underground buildings***									310
3	202	***5.3.4***	***Other buildings***									30
3	203	***5.3.5***	***Building rubble random activity check***								5,0	440
	204	5.4	WASTE HANDLING AND STORAGE	0	0	0	0	0	0	0	0	
	205	***5.4.1***	***Transports and repository***	0	0	0	0	0	0	0	0	
C	206	5.4.1.1	Transports									460
C	207	5.4.1.2	Landfill fees									460
	208	***5.4.2***	***Handling of nonradioactive hazardous waste***	0	0	0	0	0	0	0	0	
	209	5.5	SITE RESTORATION	0	0	0	0	0	0	0	0	
	210	***5.5.1***	***Independent radiological survey***									20
3	211	***5.5.2***	***Ground restoration***									85
			Total WBS 1 to 5									

ID	WBS no.	Worked hours								Total Labor
		Utility			Contractors					
		Utility Manager (cat.M)	Utility Engineer (cat.E)	Project Manager (cat. P)	Engineer (cat.1)	Foreman (cat. 2)	HP technician (cat.3)	Craftsmen (cat. 4)	Laborer (cat. 5)	
		hours	hours	hours	hours	hours	hours	hours	hours	hours
175	5	4 520	117 520	13 560	0	0	0	0	17 600	153 200
176	5.1	2 260	70 625	0	0	0	0	0	0	72 885
177	5.1.1	2 260	20 905	0	0	0	0	0	0	23 165
178	5.1.1.1	2 260	3 955	0	0	0	0	0	0	6 215
179	5.1.1.2	0	4 520	0	0	0	0	0	0	4 520
180	5.1.1.3	0	12 430	0	0	0	0	0	0	12 430
181	5.1.2	0	31 640	0	0	0	0	0	0	31 640
182	5.1.2.1	0	13 560	0	0	0	0	0	0	13 560
183	5.1.2.2	0	18 080	0	0	0	0	0	0	18 080
184	5.1.2.3	0		0	0	0	0	0	0	
185	5.1.3	0	0	0	0	0	0	0	0	0
186	5.1.3.1									
187	5.1.3.2									
188	5.1.3.3									
189	5.1.4	0	18 080	0	0	0	0	0	0	18 080
190	5.1.4.1	0	18 080	0	0	0	0	0	0	18 080
191	5.2	2 260	46 895	13 560	0	0	0	0	0	62 715
192	5.2.1	0	0	13 560	0	0	0	0	0	13 560
193	5.2.2	0	3 390	0	0	0	0	0	0	3 390
194	5.2.3	0	0	0	0	0	0	0	0	0
195	5.2.4	0	31 640	0	0	0	0	0	0	31 640
196	5.2.5	0	3 390	0	0	0	0	0	0	3 390
197	5.2.6	2 260	8 475	0	0	0	0	0	0	10 735
198	5.3	0	0	0	0	0	0	0	17 600	17 600
199	5.3.1									
200	5.3.2									
201	5.3.3									
202	5.3.4									
203	5.3.5			0	0	0	0	0	17 600	17 600
204	5.4	0	0	0	0	0	0	0	0	0
205	5.4.1	0	0	0	0	0	0	0	0	0
206	5.4.1.1									
207	5.4.1.2									
208	5.4.2	0	0	0	0	0	0	0	0	0
209	5.5	0	0	0	0	0	0	0	0	0
210	5.5.1									
211	5.5.2									
	Total WBS 1 to 5	**14 040**	**748 560**	**70 040**	**24 465**	**71 443**	**19 308**	**72 093**	**437 460**	**1 448 650**

ID	WBS no.	Labor Cost (kSEK/hour)								Total Utility Labour Cost	Contractor cost	Material Cost	Equipment Cost	Total Cost
		0,700	0,350	1,400	1,000	0,800	0,650	0,650	0,450					
		Utility Manager (cat.M)	Utility Engineer (cat.E)	Project Manager (cat. P)	Engineer (cat.1)	Foreman (cat. 2)	HP technician (cat.3)	Craftsmen (cat. 4)	Laborer (cat. 5)					
		kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK	kSEK
175	5	3 164	41 132	18 984	0	0	0	0	7 920	44 296	80 896	0	0	125 192
176	5.1	1 582	24 719	0	0	0	0	0	0	26 301	5 192	0	0	31 493
177	5.1.1	1 582	7 317	0	0	0	0	0	0	8 899	0	0	0	8 899
178	5.1.1.1	1 582	1 384		0	0	0	0	0	2 966	0			2 966
179	5.1.1.2	0	1 582		0	0	0	0	0	1 582	0			1 582
180	5.1.1.3	0	4 351		0	0	0	0	0	4 351	0			4 351
181	5.1.2	0	11 074	0	0	0	0	0	0	11 074	2 460	0	0	13 534
182	5.1.2.1	0	4 746	0	0	0	0	0	0	4 746				4 746
183	5.1.2.2	0	6 328	0	0	0	0	0	0	6 328				6 328
184	5.1.2.3	0	0		0	0	0	0	0	0	2 460			2 460
185	5.1.3	0	0	0	0	0	0	0	0	0	2 733	0	0	2 733
186	5.1.3.1									0	(25000)			0
187	5.1.3.2									0				0
188	5.1.3.3									0	2 733			2 733
189	5.1.4	0	6 328	0	0	0	0	0	0	6 328	0	0	0	6 328
190	5.1.4.1	0	6 328	0	0	0	0	0	0	6 328				6 328
191	5.2	1 582	16 413	18 984	0	0	0	0	0	17 995	18 984	0	0	36 979
192	5.2.1	0	0	18 984	0	0	0	0	0	0	18 984			18 984
193	5.2.2	0	1 187	0	0	0	0	0	0	1 187	0			1 187
194	5.2.3	0	0	0	0	0	0	0	0	0	0			0
195	5.2.4	0	11 074	0	0	0	0	0	0	11 074	0			11 074
196	5.2.5	0	1 187	0	0	0	0	0	0	1 187	0			1 187
197	5.2.6	1 582	2 966	0	0	0	0	0	0	4 548	0			4 548
198	5.3	0	0	0	0	0	0	0	7 920	0	33 020	0	0	33 020
199	5.3.1									0	10 100		0	10 100
200	5.3.2									0	8 000		0	8 000
201	5.3.3									0	5 800		0	5 800
202	5.3.4									0	1 200		0	1 200
203	5.3.5				0	0	0	0	7 920	0	7 920			7 920
204	5.4	0	0	0	0	0	0	0	0	0	0	0	0	0
205	5.4.1	0	0	0	0	0	0	0	0	0	0	0	0	0
206	5.4.1.1									0	0			0
207	5.4.1.2									0	0			0
208	5.4.2	0	0	0	0	0	0	0	0	0	0	0	0	0
209	5.5	0	0	0	0	0	0	0	0	0	23 700	0	0	23 700
210	5.5.1									0	(0)			0
211	5.5.2									0	23 700		0	23 700
	Total WBS 1 to 5	**9 828**	**261 996**	**57 176**	**24 369**	**56 578**	**12 238**	**46 237**	**195 993**	**271 824**	**528 711**	**1 170**	**54 260**	**855 965**

A5.2 ISDC cost matrix

Clink Decommissioning Study

ISDC COST MATRIX

"NEA-key" - level 1	"NEA-key" - level 2	"NEA-key" - level 3	TASK / Component	Total Cost kSEK
01			**Pre-decommissioning Actions**	**14 812**
01	**0100**		**Decommisioning Planning**	**4 347**
1	100	0	Technical support	483
1	100	102	Decommissioning planning work	3 864
01	**0200**		**Facility Characterisation**	**2 174**
1	200	0	Information gathering	1 932
1	200	0	Documentation	242
01	**0300**		**Safety, Security and Environmental Studies**	**3 381**
1	300	0	Surveillance, fire protection	0
1	300	0	Surveillance, fire protection	0
1	300	302	Preliminary EIA work	1 932
1	300	0	Radiation and environment protection	161
1	300	0	Radiation and environment protection	0
1	300	302	EIA work	1 288
01	**0400**		**Waste Mamagement Planning**	**0**
1	400	0	Chemistry, waste	0
1	400	0	Chemistry, waste	0
01	**0500**		**Authorisation**	**0**
1	500	0	Maintenance of buildings and equipment	0
1	500	0	Plant system operation	0
1	500	0	Maintenance	0
1	500	0	Administraton and information management	0
1	500	0	Quality management and control	0
1	500	502	Information and public relations	0
01	**0600**		**Preparing Management Group and Contracting**	**4 911**
1	600	601	Management and administration	644
1	600	0	Planning and controlling	966
1	600	0	Project management	2 576
1	600	0	General and supplier administration	725
02			**Facility Shutdown Activites**	**35 290**
02	**0300**		**Decontamination of Closed Systems for Dose Reduction**	**34 120**
2	300	0	System decontamination	34 120
02	**0400**		**Radiological Inventory Characterisation to Support Detailed Planning**	**1 170**
2	400	0	Radiological inventory characterisation, Tank inventory	1 170
03			**Additional Activities for Safe Enclosure**	
04			**Dismantling Activities within the Controlled Area**	**242 947**
04	**0200**		**Preparation and Support for Dismantling**	**12 300**
4	200	0	Pre-decommissioning system adaption	6 840
4	200	0	Object decontamination, conservation	900
4	200	201	General prepatory activities	4 560
04	**0600**		**Dismantling of Other Systems and Components**	**175 657**
4	600	0	Room preparation	25 767
4	600	0	Process piping and equipment	99 984
4	600	0	Structural and various steel	22 193
4	600	0	Air treatment systems	13 991
4	600	0	Electrical Equipment and Cabling	13 722
04	**0700**		**Removal of Contamination from Building Structures**	**1 800**
4	700	0	Contaminated concrete	1 800
4	700	0	Building surface decontamination	0
04	**0900**		**Final Radioactivity Survay for Release of Buildings**	**53 190**
4	900	0	Radiation protection and measurement	2 160
4	900	0	Building clearance survey	51 030
05			**Waste Processing, Storage and Disposal**	**58 123**
05	**0100**		**Waste management system**	**54 066**
5	100	0	Chemistry, waste	2 898
5	100	0	Chemistry, waste	2 576
5	100	0	Chemistry, waste	2 555
5	100	0	Chemistry, waste	4 088
5	100	102	Adaption of waste systems and buildnings	21 450
5	100	0	Operation of the waste systems	18 027
5	100	0	Decontamination and dismantling of the systems and buildings	2 472
05	**0900**		**Management of Decommissioning Low-level Waste**	**1 170**
5	900	0	Transports to SFR	0
5	900	0	SFR containers	1 170

"NEA-key" - level 1	"NEA-key" - level 2	"NEA-key" - level 3	TASK / Component	Total Cost kSEK
05	**1200**		**Management of Decommissioning Exempt Waste and Materials**	**2 887**
5	1200	0	Transports to landfills	2 887
5	1200	0	Transports	0
5	1200	0	Landfill fees	0
5	1200	0	Landfill fees	0
05	**1300**		**Management of Decomissioning Waste and Materials Generated Outside Controlled Areas**	**0**
5	1300	0	***Handling of nonradioactive hazardous waste***	0
5	1300	0	Handling of nonradioactive hazardous waste	0
06			**Site Infrastructure and Operation**	**154 632**
06	**0100**		**Site Security and Surveillance**	**12 726**
6	100	0	Surveillance, fire protection	1 932
6	100	0	Surveillance, fire protection	7 728
6	100	0	Surveillance, fire protection	3 066
06	**0200**		**Site Operation and Maintenance**	**58 468**
6	200	0	Maintenance of buildings and equipment	2 254
6	200	0	Maintenance of buildings and equipment	2 555
6	200	0	Maintenance	14 168
6	200	0	Maintenance	22 484
8	200	0	Surveillance and environment protection	1 582
6	200	0	Surveillance and environment protection	4 746
6	200	0	Maintenance	4 351
6	200	0	Maintenance	6 328
06	**0300**		**Operation of Support Systems**	**50 095**
6	300	0	Energy and water	0
6	300	0	Surveillance, fire protection	12 264
6	300	0	Plant system operation	2 576
6	300	0	Plant system operation	4 088
6	300	0	Energy and water	2 225
6	300	0	Energy and water	26 482
6	300	0	Energy and water	2 460
06	**0400**		**Radiation and Environamental Safety Monitoring**	**33 344**
6	400	0	Radiation and environment protection	1 610
6	400	0	Radiation and environment protection	6 440
6	400	0	Radiation and environment protection	7 154
6	400	0	Radiation and environment protection	10 220
6	400	0	Building rubble random activity check	7 920
07			**Conventional Dismantling, Demolition and Site Restoration**	**70 532**
07	**0100**		**Procurment of Equipment for Conventional Dismantling and Demolition**	**5 036**
7	100	0	Room preparation	2 927
7	100	0	Process piping and equipment	2 110
07	**0200**		**Dismantling of Systems and Building Components Outside the Controlled Area**	**16 578**
7	200	0	Air treatment systems	10 062
7	200	0	Electrical equipment and cabling	6 516
07	**0300**		**Demolition of Buildings and Structures**	**25 217**
7	300	0	Receiving building, auxiliary building and electrical building	10 100
7	300	0	Encapsulation building	8 000
7	300	0	Underground buildings	5 800
7	300	0	Other buildings	1 200
7	300	0	Structural and various steel	117
07	**0400**		**Final Cleanup, Landscaping and Refurbishment**	**23 700**
7	400	0	Ground restoration	23 700
08			**Project Management, Engineering and Site Support**	**273 366**
08	**0100**		**Mobilisation and Prepartory work**	**0**
8	100	0	Deommissioning system adaption	0
08	**0200**		**Project Management**	**147 014**
8	200	0	Management and administration	3 220
8	200	207	Management and administration	5 110
8	200	0	Project management	25 760
8	200	0	Planning and controlling	1 932
8	200	0	Quality management and control	644
8	200	0	General and supplier administration	8 050
8	200	0	Administration and information management	14 308
8	200	0	Project management	40 880
8	200	202	Planning and controlling	3 066
8	200	205	Quality management and control	1 022
8	200	206	General and supplier administration	8 176
8	200	0	Management and administration	2 966
8	200	0	Administration and information management	6 328
8	200	0	Project management	18 984
8	200	0	Planning and controlling	1 187
8	200	0	Quality management and control	0
8	200	207	Information and public relations	322
8	200	0	Information and public relations	511
8	200	0	General and supplier administration	4 548

ISDC COST MATRIX

"NEA-key" - level 1	"NEA-key" - level 2	"NEA-key" - level 3	TASK / Component	Total Cost kSEK
08	**0300**		**Support Services**	**70 536**
8	300	0	Technical support	16 100
8	300	0	Documentation	966
8	300	0	Administration and information management	9 016
8	300	0	Technical support	11 074
8	300	0	Documentation	1 187
8	300	301	Technical support	30 660
8	300	306	Documentation	1 533
08	**1000**		**Demobilisation by contractors**	**55 816**
8	1000	0	Process dismantling contractor project management and administration	43 216
8	1000	0	Process dismantling contractor equipments and tools	12 600
9			**Reasearch and Development**	**0**
10			**Fuel and Nuclear Material**	**0**
11			**Miscellaneous Expenditures**	**6 264**
11	**0100**		**Owner Costs**	**0**
11	100	0	Other fees, inspection costs	0
11	100	0	Independent radiological survey	0
11	100	0	Fees, inspection costs	0
11	**0200**		**Taxes**	**0**
11	200	0	Taxes	0
11	200	0	Taxes	0
11	**0300**		**Insurances**	**6 264**
11	300	0	Insurances	3 531
11	300	0	Insurances	2 733
			Total	**855 965**

A5.3 Work team composition

Clink Decommissioning Study

MACROCOMPONENT BASED MANHOUR CALCULATION - PROCESS EQUIPMENT
WORK TEAM COMPOSITION

WP	**Personnel categories (no.)***					**Short description of WP scope**
	Cat. 1	*Cat. 2*	*Cat. 3*	*Cat. 4*	*Cat. 5*	
1a	0,2	0,7	0,5	0,1	6,3	Preparations of work area - radiolgical areas
1b	0,15	0,6	0	0,1	6	Preparations of work area - non radiolgical areas
2	0,1	0,3	0,2	0	2,5	Removal of insulation from pipes and components
3a	0,1	0,4	0,2	1	2,5	Dismantling of high-active pipes >DN50
3b	0,1	0,4	0,2	1	3	Dismantling of low-active pipes >DN50
3c	0,1	0,3	0,2	0	2,5	Dismantling of pipes up to and including DN50
3d	0,1	0,3	0,2	0	2,5	Dismantling of valves and actuators
4	0,1	0,4	0,1	0	4	Internal transports of waste
7	0,1	0,5	0,1	1,5	3,5	Dismantling and internal transportation of large components and tanks
8	0,1	0,5	0	0	5	Dismantling of steel (pipe supports, greeting, ladders, beams etc)
10	0,05	0,3	0,15	0	2,5	Dismantling of cables and cabletrays etc
11a	0,1	0,3	0,1	0,5	4	Dismantling of HVAC ducts
11b	0,1	0,5	0,1	0	4,3	Dismantling of HVAC components
13a	0	1	0	0	4	Pool liner - preparations, scaffolding and lifting preparations
13b	0	0,2	0,5	0	3	Pool liner - decontamination by HP-cleaning
13c	0	0,5	0	0	3	Pool liner - cutting, dismantling and removal
14	0,1	0,5	0	0	3	Dismantling and transportation of cranes
15a	0	0,2	0	0	2	Dismantling and transportation of cabinets
15b	0	0,2	0	0	4	Dismantling and transportation of electrical components

* Definition of categories:
Cat.1: Engineer
Cat.2: Foremen
Cat.3: Health Physics (HP) Technician
Cat.4: Craftsmen (electricians, cutters etc)
Cat.5: Laborer (cleaners, scaffolders etc)

A5.4 Productivity rates

Clink Decommissioning Study

MACROCOMPONENT BASED MANHOUR CALCULATION - PROCESS EQUIPMENT
PRODUCTIVITY RATES

MACROCOMPONENT	WP	SHORT DESCRIPTION OF ACTIVITY	Productivity Rate	PR-unit	Previous	New SF					SF Corr. Factor				
					SF	A	B	D	K	OK	A	B	D	K	OK
	[no.]	[-]	[value]	[team h/?]											
WORK AREAS															
- Preparation of work areas, radiological	1a	Preparations of work area - radiolgical areas	13,750	no.	2,5				2,61		0,00	0,00	0,00	1,05	
- Preparation of work areas, non radiological	1b	Preparations of work area - non radiolgical areas	13,750	no.	2,5					1,57					0,63
PUMPS															
- Pumps, <500 kg	7	Dismantling and internal transportation of large components and tanks	2,217	no.	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Pumps, >500 kg	7	Dismantling and internal transportation of large components and tanks	0,0049	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
HEAT EXCHANGERS															
- Heat exchangers, 3501-10000 kg	2	Removal of insulation from pipes and components	0,390	m^2	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	7	Dismantling and internal transportation of large components and tanks	0,0050	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Heat exchangers, 501-3500 kg	7	Dismantling and internal transportation of large components and tanks	0,0061	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Heat exchangers, 0-500 kg	7	Dismantling and internal transportation of large components and tanks	2,534	no.	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
TANKS															
- Tanks, 0 - 200 kg	7	Dismantling and internal transportation of large components and tanks	1,700	m^2	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Tanks, 201 - 750 kg	7	Dismantling and internal transportation of large components and tanks	2,500	m^2	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Tanks, 751 - 115000 kg	7	Dismantling and internal transportation of large components and tanks	2,900	m^2	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
PRESSURE VESSELS ETC.															
- Pressure Vessels, 5001 kg -	7	Dismantling and internal transportation of large components and tanks	0,0049	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Pressure Vessels, 1501 - 5000 kg	7	Dismantling and internal transportation of large components and tanks	0,0056	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Pressure Vessels, 501 - 1500 kg	7	Dismantling and internal transportation of large components and tanks	0,0066	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Pressure Vessels, 0 - 500 kg	7	Dismantling and internal transportation of large components and tanks	2,529	no.	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
VALVES (>DN50) & ACTUATORS															
- Valves, >DN50	3d	Dismantling of valves and actuators	0,009	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	4	Internal transports of waste	0,781	no.	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Actuators, valves >DN50	3d	Dismantling of valves and actuators	2,139	no.	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	4	Internal transports of waste	0,756	no.	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Actuators, valves <DN50	3d	Dismantling of valves and actuators	2,139	no.	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	4	Internal transports of waste	0,756	no.	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
PIPING															
- Piping, diam. up to and incl. DN25	2	Removal of insulation from pipes and components	0,175	m	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	3c	Dismantling of pipes up to and including DN50	0,100	m	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	4	Internal transports of waste	0,008	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Piping, DN25 < diam. up to and incl. DN50	2	Removal of insulation from pipes and components	0,175	m	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	3c	Dismantling of pipes up to and including DN50	0,150	m	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	4	Internal transports of waste	0,008	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Piping, DN50 < diam. up to DN300	2	Removal of insulation from pipes and components	0,175	m	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	3b	Dismantling of low-active pipes >DN50	0,035	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	4	Internal transports of waste	0,008	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
- Piping, DN300 and above	2	Removal of insulation from pipes and components	0,350	m	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	3a	Dismantling of high-active pipes >DN50	0,010	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	4	Internal transports of waste	0,008	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
HVAC															
- HVAC, components	11b	Dismantling of HVAC components	0,010	kg	1				1,09	1,00	0,00	0,00	0,00	1,09	1,00
- HVAC, ducts	2	Removal of insulation from pipes and components	0,021	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63
	11a	Dismantling of HVAC ducts	0,034	kg	1				1,09	1,00	0,00	0,00	0,00	1,09	1,00
CABLES (& cable trays)															
- Cables, cable trays	10	Dismantling of cables and cabletrays etc	0,034	kg	2,5				2,18	1,42	0,00	0,00	0,00	0,87	0,57
	4	Internal transports of waste	0,0032	kg	2,5				2,18	1,42	0,00	0,00	0,00	0,87	0,57
CABINETS															
- Cabinets	15a	Dismantling and transportation of cabinets	0,0067	kg	1				1,63	1,09	0,00	0,00	0,00	1,63	1,09
ELECTRICAL COMPONENTS															
- Electrical components	15b	Dismantling and transportation of electrical components	0,0050	kg	1				1,63	1,09	0,00	0,00	0,00	1,63	1,09
POOL LINING															
- Pool lining	13a	Pool liner - preparations, scaffolding and lifting preparations	0,311	m^2	1				1,09		0,00	0,00	0,00	1,09	0,00
	13b	Pool liner - decontamination by HP-cleaning	0,214	m^2	1				1,09		0,00	0,00	0,00	1,09	0,00
	13c	Pool liner - cutting, dismantling and removal	0,103	m^2	1				1,09		0,00	0,00	0,00	1,09	0,00
STEEL															
- Steel	8	Dismantling of steel (pipe supports, greeting, ladders, beams etc)	0,009	kg	2,5				2,72	1,63	0,00	0,00	0,00	1,09	0,65
	4	Internal transports of waste	0,0026	kg	2,5				2,72	1,63	0,00	0,00	0,00	1,09	0,65
MISCELLANOUS PROCESS COMPONENTS															
- Miscellanous process components	7	Dismantling and internal transportation of large components and tanks	0,009	kg	2,5				2,61	1,57	0,00	0,00	0,00	1,05	0,63

A5.5 Contingencies

Clink Decommissioning Study

Contingencies

"NEA-key" - level 1	"NEA-key" - level 2	"NEA-key" - level 3	TASK / Component	Contingencies %	Cont cost kSEK	Reasons for cont and comments
01			**Pre-decommissioning Actions**	**10%**	**1 507**	
01	**0100**		**Decommissioning Planning**	**10%**	**435**	
1	100	0	Technical support	10%	48	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
1	100	102	Decommissioning planning work	10%	386	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
01	**0200**		**Facility Characterisation**	**8%**	**169**	
1	200	0	Information gathering	8%	145	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
1	200	0	Documentation	10%	24	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
01	**0300**		**Safety, Security and Environmental Studies**	**12%**	**405**	
1	300	0	Surveillance, fire protection	-	-	
1	300	0	Surveillance, fire protection	-	-	
1	300	302	Preliminary EIA work	10%	193	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
1	300	0	Radiation and environment protection	11%	18	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
1	300	0	Radiation and environment protection	-	-	
1	300	302	EIA work	15%	193	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
01	**0400**		**Waste Mamagement Planning**	**0%**	**0**	
1	400	0	Chemistry, waste	-	-	
1	400	0	Chemistry, waste	-	-	
01	**0500**		**Authorisation**	**0%**	**0**	
1	500	0	Maintenance of buildings and equipment	-	-	
1	500	0	Plant system operation	-	-	
1	500	0	Maintenance	-	-	
1	500	0	Administraton and information management	-	-	
1	500	0	Quality management and control	-	-	
1	500	502	Information and public relations	-	-	
01	**0600**		**Preparing Management Group and Contracting**	**10%**	**499**	
1	600	601	Management and administration	11%	72	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
1	600	0	Planning and controlling	10%	97	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
1	600	0	Project management	10%	258	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
1	600	0	General and supplier administration	10%	72	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
02			**Facility Shutdown Activites**	**30%**	**10 455**	
02	**0300**		**Decontamination of Closed Systems for Dose Reduction**	**30%**	**10 236**	
2	300	0	System decontamination	30%	10 236	Costs for decontamination and system adaptation are not based on experiences and may be underestimated. More flushes could be required.
02	**0400**		**Radiological Inventory Characterisation to Support Detailed Planning**	**0%**	**219**	
2	400	0	Radiological inventory characterisation, Tank inventory	19%	219	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
03			**Additional Activities for Safe Enclosure**			
04			**Dismantling Activities within the Controlled Area**	**20%**	**48 321**	
04	**0200**		**Preparation and Support for Dismantling**	**29%**	**3 530**	
4	200	0	Pre-decommissioning system adaption	28%	1 881	
4	200	0	Object decontamination, conservation	31%	281	
4	200	201	General prepatory activities	30%	1 368	
04	**0600**		**Dismantling of Other Systems and Components**	**23%**	**40 875**	
4	600	0	Room preparation	16%	4 123	The costs are based on the number of rooms in the building, not the size of the rooms.
4	600	0	Process piping and equipment	25%	24 996	Increased duration/work due to difficulty in activity sequencing, tool troubles, not specified equipment etc. The inventory for uncontaminated equipments is not as accurate as for the contaminated equipment.
4	600	0	Structural and various steel	25%	5 548	Increased duration/work due to difficulty in activity sequencing, tool troubles, not specified equipment etc. The inventory for uncontaminated equipments is not as accurate as for the contaminated equipment. Data for some equipment are scaled from the inventory for F1 and F2.
4	600	0	Air treatment systems	25%	3 498	Increased duration/work due to difficulty in activity sequencing, tool troubles, not specified equipment etc. The inventory for uncontaminated equipments is not as accurate as for the contaminated equipment.
4	600	0	Electrical Equipment and Cabling	20%	2 710	Increased duration/work due to difficulty in activity sequencing, tool troubles, not specified equipment etc. The inventory for cables is not satisfactory.
04	**0700**		**Removal of Contamination from Building Structures**	**20%**	**360**	
4	700	0	Contaminated concrete	20%	360	Some contingency is considered to be included for key figures. Data for buildings is based on mathematic method.
4	700	0	Building surface decontamination	-	-	
04	**0900**		**Final Radioactivity Survay for Release of Buildings**	**7%**	**3 556**	
4	900	0	Radiation protection and measurement	15%	324	Some contingency is considered to be included for key figures. Data for buildings is based on mathematic method.
4	900	0	Building clearance survey	6%	3 232	Contingency is considered to be included for key figures. Data for buildings is based on mathematic method.
05			**Waste Processing, Storage and Disposal**	**20%**	**11 601**	
05	**0100**		**Waste management system**	**20%**	**10 587**	
5	100	0	Chemistry, waste	11%	326	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
5	100	0	Chemistry, waste	8%	213	The costs are partly based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
5	100	0	Chemistry, waste	15%	383	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
5	100	0	Chemistry, waste	14%	562	The costs are partly based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
5	100	102	Adaption of waste systems and buildnings	30%	6 435	Not specified equipment, adaptation to existing building and installations .
5	100	0	Operation of the waste systems	12%	2 223	Not specified equipment.
5	100	0	Decontamination and dismantling of the systems and buildings	18%	445	Not specified equipment, adaptation to existing building and installations .
05	**0900**		**Management of Decommissioning Low-level Waste**	**25%**	**293**	
5	900	0	Transports to SFR	-	-	
5	900	0	SFR containers	25%	293	The accuracy in dividing into Activity Categories and accuracy in inventory.

"NEA-key" - level 1	"NEA-key" - level 2	"NEA-key" - level 3	TASK / Component	Contingencies %	Cont cost kSEK	Reasons for cont and comments
05	**1200**		**Management of Decommissioning Exempt Waste and Materials**	**25%**	**722**	
5	1200	0	Transports to landfills	25%	722	Increased number of transports due to not specified equipment.
5	1200	0	Transports	-	-	
5	1200	0	Landfill fees	-	-	
5	1200	0	Landfill fees	-	-	
05	**1300**		**Management of Decomissioning Waste and Materials Gernerated Outside Controlled Areas**	**0%**	**0**	
5	1300	0	***Handling of nonradioactive hazardous waste***	-	-	
5	1300	0	Handling of nonradioactive hazardous waste	-	-	
06			**Site Infrastructure and Operation**	**13%**	**19 348**	
06	**0100**		**Site Security and Surveillance**	**10%**	**1 315**	
6	100	0	Surveillance, fire protection	11%	217	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	100	0	Surveillance, fire protection	8%	638	The costs are partly based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	100	0	Surveillance, fire protection	15%	460	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
06	**0200**		**Site Operation and Maintenance**	**11%**	**6 598**	
6	200	0	Maintenance of buildings and equipment	11%	254	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	200	0	Maintenance of buildings and equipment	15%	383	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	200	0	Maintenance	8%	1 169	The costs are partly based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	200	0	Maintenance	14%	3 092	The costs are partly based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	0	Surveillance and environment protection	10%	158	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	200	0	Surveillance and environment protection	10%	475	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	200	0	Maintenance	10%	435	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	200	0	Maintenance	10%	633	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
06	**0300**		**Operation of Support Systems**	**13%**	**6 660**	
6	300	0	Energy and water	-	-	
6	300	0	Surveillance, fire protection	14%	1 686	The costs are partly based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	300	0	Plant system operation	11%	290	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	300	0	Plant system operation	15%	613	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	300	0	Energy and water	8%	184	The costs are partly based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	300	0	Energy and water	14%	3 641	The costs are partly based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	300	0	Energy and water	10%	246	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
06	**0400**		**Radiation and Environamental Safety Monitoring**	**14%**	**4 775**	
6	400	0	Radiation and environment protection	11%	181	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	400	0	Radiation and environment protection	8%	531	The costs are partly based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	400	0	Radiation and environment protection	15%	1 073	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	400	0	Radiation and environment protection	14%	1 405	The costs are partly based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
6	400	0	Building rubble random activity check	20%	1 584	Increased cost due to not specified material/work.
07			**Conventional Dismantling, Demolition and Site Restoration**	**20%**	**14 100**	
07	**0100**		**Procurment of Equipment for Conventional Dismantling and Demolition**	**22%**	**1 101**	
7	100	0	Room preparation	16%	468	The costs are based on the number of rooms in the building, not the size of the rooms.
7	100	0	Process piping and equipment	30%	633	Increased duration/work due to difficulty in activity sequencing, tool troubles, not specified equipment etc. The inventory for uncontaminated equipments is not as accurate as for the contaminated equipment.
07	**0200**		**Dismantling of Systems and Building Components Outside the Controlled Area**	**28%**	**4 626**	
7	200	0	Air treatment systems	30%	3 019	Increased duration/work due to difficulty in activity sequencing, tool troubles, not specified equipment etc. The inventory for uncontaminated equipments is not as accurate as for the contaminated equipment.
7	200	0	Electrical equipment and cabling	25%	1 607	Increased duration/work due to difficulty in activity sequencing, tool troubles, not specified equipment etc. The inventory for cables is not satisfactory.
07	**0300**		**Demolition of Buildings and Structures**	**20%**	**5 055**	
7	300	0	Receiving building, auxiliary building and electrical building	20%	2 020	Increased cost due to not specified material/work.
7	300	0	Encapsulation building	20%	1 600	Increased cost due to not specified material/work.
7	300	0	Underground buildings	20%	1 160	Increased cost due to not specified material/work.
7	300	0	Other buildings	20%	240	Increased cost due to not specified material/work.
7	300	0	Structural and various steel	30%	35	Increased duration/work due to difficulty in activity sequencing, tool troubles, not specified equipment etc. The inventory for uncontaminated equipments is not as accurate as for the contaminated equipment. Data for some equipment are scaled from the inventory for F1 and F2.
07	**0400**		**Final Cleanup, Landscaping and Refurbishment**	**14%**	**3 318**	
7	400	0	Ground restoration	14%	3 318	Increased cost due to not specified material/work.
08			**Project Management, Engineering and Site Support**	**15%**	**40 759**	
08	**0100**		**Mobilisation and Prepartory work**	**0%**	**0**	
8	100	0	Deommissioning system adaption	-	-	
08	**0200**		**Project Management**	**13%**	**18 832**	
8	200	0	Management and administration	11%	362	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	207	Management and administration	15%	767	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	0	Project management	10%	2 576	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	0	Planning and controlling	10%	193	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	0	Quality management and control	10%	64	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	0	General and supplier administration	10%	805	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	0	Administration and information management	15%	2 146	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	0	Project management	15%	6 132	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	202	Planning and controlling	15%	460	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	205	Quality management and control	15%	153	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	206	General and supplier administration	15%	1 226	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	0	Management and administration	10%	297	Personnel from earlier period not immediately phased out.
8	200	0	Administration and information management	10%	633	The costs are derived from an organization based on Barsebäck experience so some contingency is included. However, by experience organizational costs tend to increase so some contingency is added.
8	200	0	Project management	12%	2 231	Personnel from earlier period not immediately phased out.