Westinghouse

Westinghouse Electric Sweden AB

Halden and Kjeller Decommissioning - Task 4 - Decommissioning Programme

Author, telephone
Niklas Leveau, +46 (0)21-34 70 23
Jan Nordin, +46 (0)21-440 18 20

Dept
WP

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Abstract

This report presents a general decommissioning programme for the Halden and Kjeller nuclear research facilities. The aim has been to cover all of the important phases during decommissioning, from the initial planning to site restoration. Only structures that contains radioactive parts or has a history of being part of the owner, IFE's, nuclear research programme has been studied.

Three decommissioning strategies have been studied; immediate dismantling, deferred dismantling and entombment. These strategies are in turn divided into three different end-states (unrestricted use, light industry, other nuclear activities) and three different types of waste management (direct disposal, recycling off-site, recycling on site) summing up to a total of 19 separate alternatives.

The expected total duration of the decommissioning programme is about 10 years for each site, while the actual dismantling and demolition period is about 4 years.

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APPENDICES

ABBREVIATIONS

IFE	Institutt For Energiteknikk
HVAC	Heating, Ventilation, Air Condition
WBS	Work Breakdown Structure

0 SUMMARY

This report presents a general decommissioning programme for the Halden and Kjeller nuclear research facilities. The aim has been to cover all of the important phases during decommissioning, from the initial planning to site restoration. Only structures that contains radioactive parts or has a history of being part of the owner, IFE's, nuclear research programme has been studied.

Three decommissioning strategies have been studied; immediate dismantling, deferred dismantling and entombment. These strategies are in turn divided into three different end-states (unrestricted use, light industry, other nuclear activities) and three different types of waste management (direct disposal, recycling off-site, recycling on site) summing up to a total of 19 separate alternatives. Halden only have 18 separate alternatives since entombment is not considered as a realistic option by the Ministry of Trade, Industry and Fisheries.

The expected total duration of the immediate dismantling decommissioning programme is 10 years for each site, while the actual dismantling and demolition period is 4 years. If deferred dismantling is chosen the advantage of lower radioactivity levels could reduce the time needed for the nuclear dismantling period.

1 INTRODUCTION AND METHOD

1.1 PURPOSE

This report was prepared as a part of the concept choice study (KVU) for future decommissioning of the nuclear facilities in Norway. The KVU is conducted by DNV GL with Studsvik, Westinghouse and Samfunns- og Næringslivsforskning (SNF) commissioned by the Ministry of Industry and the Ministry of Fisheries in Norway (NFD).

The KVU will provide a recommendation on the most optimal socio economic level for decommissioning when the facilities in Halden and Kjeller are shut down in the future. In addition the KVU will provide a recommendation on decommissioning strategies and provide input to the decision about how to allocate the total costs.

The Institute for Energy Technology (IFE) has a license for the operation of Norway's two research reactors at Kjeller and in Halden. It is not decided when or if any decommissioning of the nuclear facilities is to take place.

During previous applications for operating licenses IFE has established decommissioning plans that vary somewhat from this study both in regards to scope – what buildings and areas are included - and the way the level of decommissioning is defined.

In the report a detailed decommissioning time schedule for each of the decommissioning alternatives is presented, described in section 1.3.2, for each of the two sites. The time schedule is meant be used as a complement to [1] and both reports uses the same WBS to facilitate this. Dependencies and sequences of the decommissioning time schedule can be seen in Appendices 3-8.

1.2 METHOD

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 decommissioning project. Also, the level of detail has been set in order to give a sufficient basis for the cost estimation presented in [1].

The programme covers the whole decommissioning time span from the initial years of planning before shutdown to the chosen end state. The programme will be limited to activities that the owner is responsible for and that are related to the decommissioning and defueling. Consequently, activities related to site operation and maintenance before start of the dismantling are excluded.

The programme starts with the initial planning during the last years of normal operation. The defueling period starts after final shut down of the research reactors and this phase proceeds until all fuel is removed from the reactors. During the initial planning and defueling period preparation is required to prepare and maintain vital functions at the sites needed for dismantling. An overview of the decommissioning phases can be seen in Figure 1.

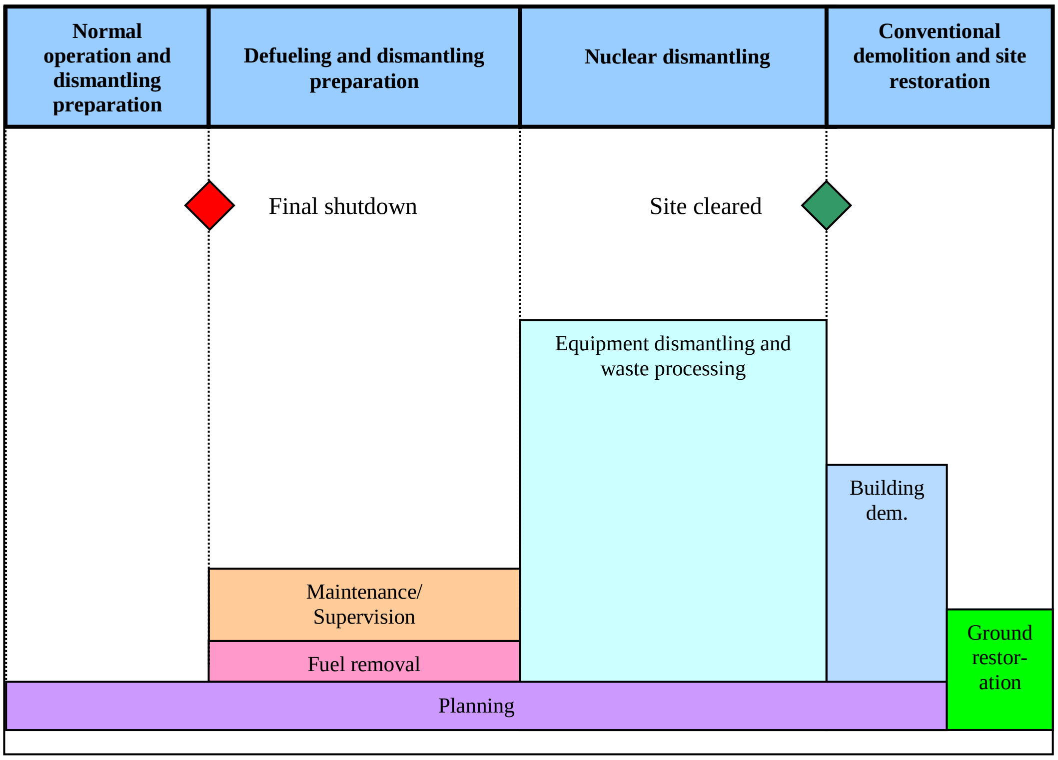

Figure 1: Schematic outline of the decommissioning phases.

The construction of the decommissioning programme has been based on a high-level optimization of the time schedule. The objective of this optimization is 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 be in a building at the same time.

With the principle and the prerequisites according to section 1.3, a high-level sequence has been structured for the decommissioning programme. 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. This issue has been considered for the removal of large components but would also need to be considered at a much lower level during a more detailed planning.

1.3 SCOPE AND ASSUMPTIONS

1.3.1 Scope

Three decommissioning strategies have been evaluated in this study; immediate dismantling, deferred dismantling and entombment. These strategies are in turn divided into three different end states and three different types of waste management summing up to a total of 19 separate alternatives. Halden only have 18 separate alternatives since entombment is not considered as a realistic option by the Ministry of Trade, Industry and Fisheries. This is discussed further in the KVU under section Mulighetsstudiet. The end states are:

- Unrestricted use where everything down to one meter below ground is free released and demolished

- Light industry where everything is free released, but the buildings are left standing

- Other nuclear activities where the process equipment is dismantled, but the buildings are left standing without being free released, so there is still radiological activity at the site after the decommissioning

The alternatives for waste management are direct disposal, recycling off-site and recycling on site. For more information about the alternatives, see [1].

For easier overview, the different alternatives have been given a combination of numbers, capital letters and lowercase letters, e.g. 1Aa. The number represents strategy, the capital letter end state and the lower case letter waste management option accordingly:

1 Immediate dismantling

2 Deferred dismantling

3 Entombment

A Unrestricted use

B Light industry

C Other nuclear activities

a Direct disposal

b Recycling off-site

c Recycling on site

One alternative from each decommissioning strategy (1Ab, 2Ab and 3) has been used as representatives for the decommissioning time schedules. These were selected as representatives due to that they contain the largest amount of activities for each strategy.

Many different criteria could be applied when establishing a WBS for a large project. The following have been considered for both Halden and Kjeller:

- The top level items are divided by time-depending milestones and this leads to the division into the main phases: normal operation together with initial planning, defueling and dismantling preparation, nuclear dismantling and conventional demolition. For all phases only activities related to dismantling and demolition activities are included. This means that activities related to site 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 and information regarding personnel during decommissioning operation is based on [2] and [3]. 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 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 [4].
- 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.
- The site owner has their own staff for operation of the site during the dismantling phase.
- The decommissioning project organization will be 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 [1]. The time schedules presented in Appendices 3-8 is structured according to this WBS.

Halden
The buildings that belongs to the Halden site are marked in red and yellow in Figure 2. Areas marked in red (1-6) are considered to be controlled area (increased risk of radiation exposure) and are therefore to be decommissioned. The instrument workshop in downtown Halden (7), the rooms in the storage building (8) and the treatment room (9) are presumed to be non-radioactive. They will be considered as free released after verification by measuring the activity. The rest of the buildings at the site that is marked in black are not included in the study.

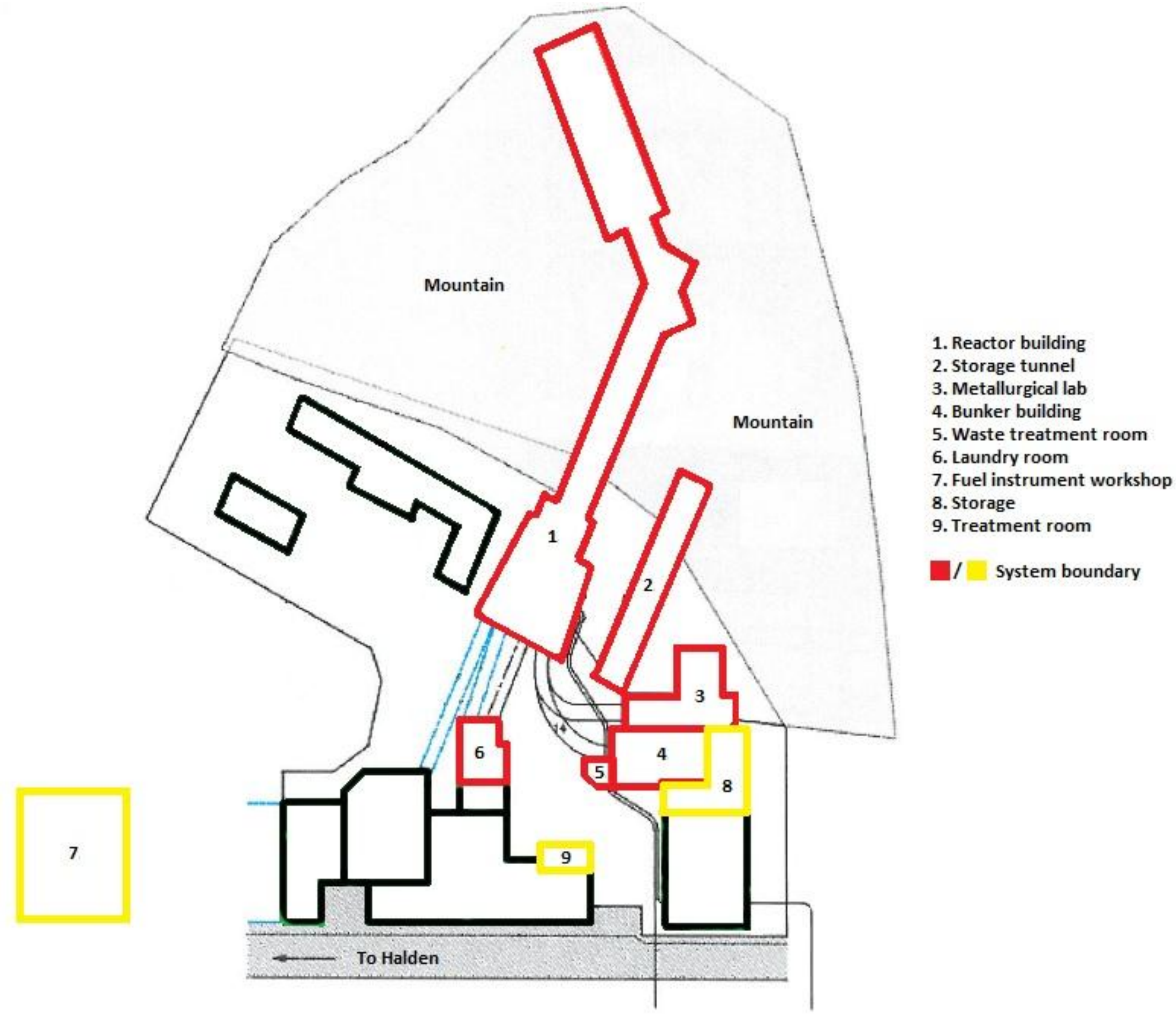

Figure 2: Overview of the Halden site. Red buildings are to be decommissioned, yellow will be classed as free released after verification and black buildings are in uncontrolled areas and will not be decommissioned (not within the scope of this study).

Kjeller
The buildings that will be decommissioned at the Kjeller site are the JEEP II reactor, JEEP I, Metallurgical laboratory I, Radiation waste facility, Metallurgical laboratory II with associated buildings and the NALFA waste pipe. All these buildings and the NALFA waste pipe are shown in Figure 3 respectively Figure 4.

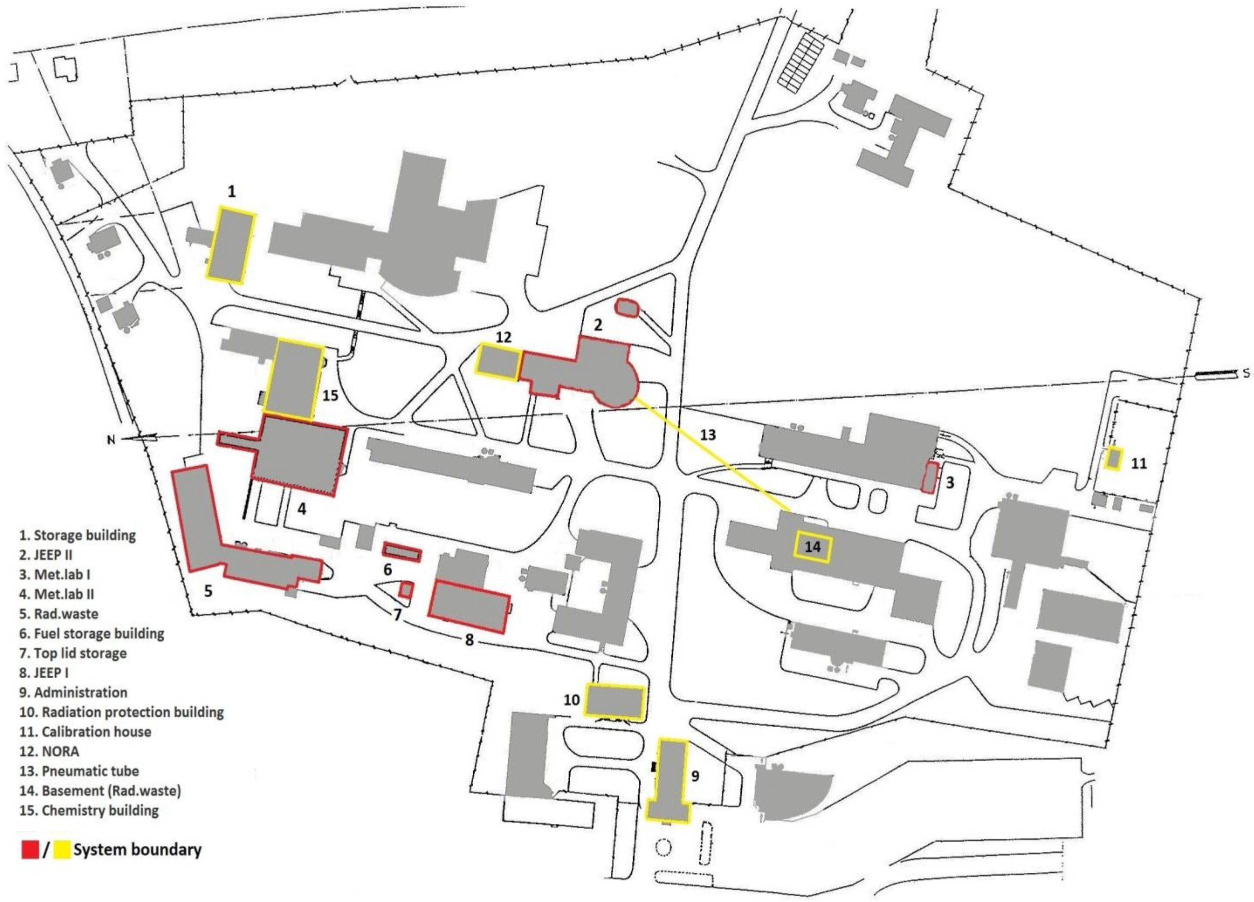

Figure 3: Overview of the Kjeller site. The buildings to be decommissioned are marked in red. Yellow buildings will be classed as free released after verification. Buildings without markings are not included in the scope of this study.

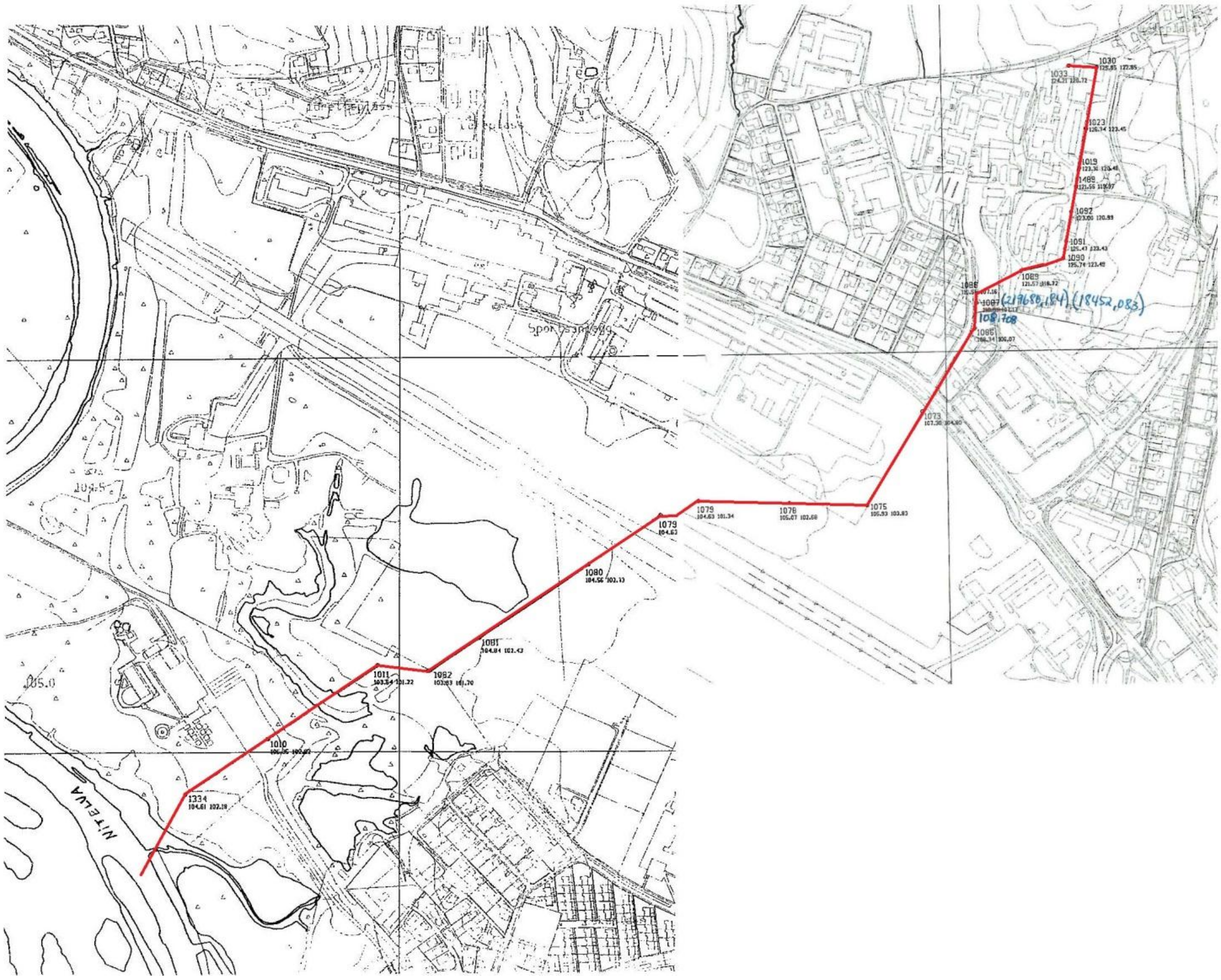

Figure 4: Overview of the waste pipe, NALFA, at Kjeller. The 3 kilometre pipe starts from the Radiation waste facility and ends in the river Nitelva [5].

Buildings marked in red are to be decommissioned while buildings in yellow will be considered to be free released after verification by measuring the activity.

For further information about the system boundaries at Halden and Kjeller see [6].

1.3.2 Assumptions

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

- The conditions and assumptions valid for the cost estimation [1] are valid for the decommissioning programme.
- The research reactors will be shut down after many years of operation and the actual date of decommissioning is not yet determined. Therefore the starting date for decommissioning is referred to as year 0 in this report.
- The research sites will be operated by the owner (IFE) 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 owner has the overall responsibility for the relations with the authorities and the public.
- Planning, EIA work etc. for the decommissioning of the site commences 2 years before the planned shutdown date.
- A suitable building at site 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 in order to prepare the different waste streams.
- The reactor vessels and the reactor internals in Halden and Kjeller will be segmented.
- All waste will be handled in the waste buildings available at the time of decommissioning, either on site or off site.
- The sites shall be restored after decommissioning and three different end state alternatives have been evaluated. In the first end state alternative the site is restored to that of the original landscape. Consequently the site can be used for any non-nuclear activities afterwards. In the second alternative the buildings will be left as they are after they are considered to be free released. Afterwards the buildings can be used for other non-nuclear purposes. In the third and last alternative the buildings will be left, but still contaminated and fit for other nuclear purposes. The process equipment will be dismantled in all end states.

- The normal decommissioning procedure for the buildings will be to be demolished to 1 meter below ground level and all buildings below ground shall be filled with crushed non-active concrete. This is necessary to do in order to reach the criteria of the end state unrestricted use. For some buildings all material will be removed leaving nothing left but soil.

- Sufficient manpower, commercial equipment and materials are assumed to be available on demand.

2 BACKGROUND

2.1 PRESENT SITUATION IN NORWAY

Up to this date two reactors has been decommissioned at the Kjeller site. The JEEP I reactor was shut down and decommissioned in 1967 followed by the NORA reactor in 1968. Today the NORA building is used as an archive while JEEP I is used for other industrial activities.

2.2 INTERNATIONAL EXPERIENCE

The decommissioning time schedule in this report is based on key factors from previous D&D, modernization and power uprate projects and international experience.

3 CONCLUSIONS AND RECOMMENDATIONS

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 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.

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.

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. The exceptions are segmentation of the reactors and internals where 5 working days a week year-round has been expected. Time estimation for segmentation of RPV and internals has been done by Westinghouse's experts on the area. Furthermore, a working time of 16 hours a day has been assumed during the segmentation activities and during the operation of the waste system. The waste system is however operated with 6 weeks of non-working time per year as described above.

The expected total duration of the immediate dismantling decommissioning programme is 10 years for each site, while the actual dismantling and demolition period is 4 years. If deferred dismantling is chosen the advantage of lower radioactivity levels could reduce the time needed for the nuclear dismantling period.

The time schedule for all the selected strategies are presented in Appendices 3-8 where one alternative for each strategy is presented.

4 GENERAL BASIS OF THE DECOMMISSIONING PROGRAMME

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

- **Normal operation**
  Meaning the normal operating cycle of the sites with various forms of experiments (together with heat production from the Halden reactor) as it is done today, which continues until the final shutdown of the site. The initial planning for the decommission starts two years before final shutdown and planning will continue throughout the project. Necessary permissions and approvals from the authorities will be acquired.

- **Defueling and dismantling preparation**
  The remaining fuel elements are removed and transported during 3 years to interim storage for 100 years. In the Appendices the duration of WBS 2.2.3.3 Interim storage is set to 460 days since MS Project cannot show an activity over 100 years. The vital systems and functions are maintained during this period.

- **Deferred dismantling**
  Deferred dismantling starts 5 years after year 0 and continues to year 55. Since MS Project cannot show an activity over 50 years WBS 3 will be set to 500 days in Appendix 4 and 7. During these 50 years the site is protected by guards and supervised by engineers to track leakage of activity or emissions to the environment. Documentation of events related to the site will be done continuously e.g. updates due to new regulations.

- **Nuclear dismantling**
  The period from when the dismantling has started in a greater extent until the site is cleared from nuclear activity. The following conditions would define the interface between the defueling operation 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 site documentation is identified and arranged in a specific decommissioning archive.
- A computer system that handles the outage labelling 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 the reactor vessel and other contaminated systems has been carried out and the decontamination waste has been taken care of.
- Individual decontamination has been carried out for selected components.
- Nuclear experiment fuel, control rods, neutron flux detectors and scrapped components from the storage are transported away.
- 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 site 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 is performed.
- Other service facilities are installed on site.

- **Conventional building demolition and site remediation**
  Demolition of non-contaminated buildings and site restoration.

  Surveillance and monitoring, WBS 5.6, is only included in the alternatives with end state C, other nuclear activities. In this alternative there will be need for physical protection and monitoring even after the decommissioning is concluded.

- **Entombment**
  The entombed facilities are protected and supervised for 100 years because the structures are considered as a near-surface repository. Since MS Project cannot show an activity over 100 years WBS 6.3 to 6.5 will be set to 1000 days in Appendix 5 and 8.

The milestones in the project plan presented in Figure 1 are mainly identified in [2], [7], [8] and [9]. Information in these reports has contributed to the specifics in the decommissioning time schedule.

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.

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

5 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.

5.1 PLANNING AND PRELIMINARY ACTIVITIES

In an ideal situation, the last years of the site 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 (EIA) for Decommissioning.
- Preparation of licensing documents required by the Norwegian regulatory system.
- 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 site 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 power supply for the site which feeds only those systems required beyond the end of generation and avoids buildings which will be demolished early.
- Establishing a 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 outsourcing to specialist contractors or labour. 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 drums expected to be needed during the early phases of decommissioning.

5.2 ON-SITE PREPARATORY ACTIVITIES

As well as the planning activities in section 5.1, 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 work areas 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. Other suitably areas are the departure and arrival area. Ideally an existing facility would have:

- Good connections to the various work areas 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 HVAC system to service the area)
- Easy access to the outside for dispatch of loaded waste containers
- A suitably rated overhead crane (where it is necessary)

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 hard standing 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.

5. Develop a programme of training for the site 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 work such 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 site to remove any redundant materials, spare parts etc. that may be stored within the various site buildings.

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

8. Install new independent power supplies for decommissioning using non-standard cable colour 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 colour. 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.

5.3 BUILDINGS AND SYSTEMS DISMANTLING AND DEMOLITION

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.

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.

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 a clean strip out or removal of items known to be radiological 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 work areas which can be scaffold 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 precede, 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.

History

Review and approval status (Organization, name)

Rev No	Prepared	Reviewed	Approved	Date
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Revision record

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APPENDIX 1

LIST OF CONTRIBUTORS

Niklas Leveau, Engineer, Decontamination, Decommissioning & Remediation, Westinghouse Electric Sweden AB

Jan Nordin, Engineer, Decontamination, Decommissioning & Remediation, Westinghouse Electric Sweden AB

Niklas Bergh, Product Lead, Decontamination, Decommissioning & Remediation, Westinghouse Electric Sweden AB

APPENDIX 2

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