Decommissioning Concepts for the Norwegian Nuclear Research Facilities Halden and Kjeller - 15022

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ABSTRACT

The Norwegian nuclear research facilities Halden and Kjeller are near the end of their current operational licenses. Thus, the Norwegian Ministry of Trade, Industry and Fisheries have decided that a concept evaluation study shall be made on the decommissioning alternatives for these facilities. This task was given to **ndcon** (Westinghouse and Studsvik) with their broad experience in decommissioning planning and decades of nuclear expertise, together with DNV GL, that is certified in Norway for concept evaluation studies.
The decommissioning alternatives that have been evaluated are strategy, end-state and waste management options. The decommissioning strategies are the IAEA defined immediate dismantling, deferred dismantling and entombment. The different end-states that have been evaluated are unrestricted use (green field), light industry (brown field) and other nuclear activity, in which the site will continue to have a nuclear license even after the decommissioning. The waste management options are direct disposal of materials, recycling of materials off-site and recycling on-site. The result of the cost estimation is that it is possible to identify viable alternatives for a chosen decommissioning strategy, end state and waste management options. The expected duration of the decommissioning program is 10 years for both sites, the dismantling and demolition period is expected to be able to perform within 4 years.

INTRODUCTION

A concept evaluation study is mandatory in Norway to understand the socio-economic consequences when preparing for larger investment projects in infrastructure and industry. It evaluates all possible alternatives for a certain task from a needs, goals and requirements perspective in an alternative analysis, to develop a recommendation that heavily involves the public interest in the investment.
The concepts of an evaluation study prior to decommissioning and evaluation of different options before going into active decommissioning is in line with what **ndcon** normally suggests. That gives the possibility to evaluate several parameters affecting the decommissioning in advance. In general, each plant has unique preferences and boundary conditions and a general decommissioning concept may not be applicable. The study of the nuclear facilities in Halden and Kjeller aims to discuss the decommissioning strategy, end state, the cost and what should be considered in future planning.

THE NORWEGIAN NUCLEAR RESEARCH SITES

The Norwegian nuclear program origins from 1948 when the atomic research institute “Institutt for Atomenergi” (IFA) was founded. In line with the global optimism in the 1950s about using nuclear power as a source for energy production, the Norwegian research program was progressing with the purpose of exploring and developing the new energy source. The first reactor in Norway was the Jeep I reactor at Kjeller. It operated from 1951 and was replaced by the current reactor, Jeep II, which first went critical in 1967 and is still operating today.

Fig. 1. The Kjeller site with the Jeep II reactor in the upper middle part of the picture. Other buildings on the site are laboratories, radwaste, storage buildings etc.

IFA started a co-operation with the Netherlands, where Norway contributed with heavy water and the Dutch provided uranium. The intention was first to build a large research reactor in the Netherlands, however the idea was abandoned and instead IFA started the Halden project in Norway. In 1956 the council of OECD investigated the possibility to have a joint research project and the following year IFA proposed the reactor in Halden. An agreement was established one year before the reactor first went critical in 1959.

Kjeller is located outside Lillestrøm, a suburb town of Oslo. The research reactor JEEP II is situated here. JEEP II is mainly used for material physics and medicine, where radiation exposure is required [2]. The JEEP II reactor and the Kjeller site can be seen in Figure 1.

The Halden site is known and associated with the Halden Reactor Project which is a joint OECD project and addresses nuclear fuel issues, materials and man-machine systems [1]. The activities at site are mainly governed by the international members of the Halden Reactor Project. The reactor is located underground in a bedrock cavern in the city of Halden in Southern Norway (see Fig. 2).

Fig. 2. The Halden site with the entrance to the underground facility to the left.

ALTERNATIVES FOR DECOMISSIONING

The alternatives that have been evaluated are decommissioning strategies, end-state definitions and waste management options. The decommissioning strategies are the IAEA defined immediate dismantling, deferred dismantling and entombment alternatives. The different end-states that have been evaluated are unrestricted use (green field), other industrial activity (brown field) and other nuclear activities, in which the site will continue to have a nuclear license even after the decommissioning. The waste management options are direct disposal of contaminated materials, recycling of materials off-site and recycling on site. The strategies evaluated in the project are defined by IAEA and are conventional procedures in nuclear decommissioning.

The end-states are defined by how the site or the buildings on the site will be further used after the dismantling and removal of the current facilities. There is also a reference alternative (defined as the minimum efforts alternative) that the other alternatives are compared with. The reference alternative assumes that the reactors are shut-down and that the spent fuel is transported off-site. The sites are then maintained and kept under safe conditions.

The entombment alternative was not evaluated for the Halden site due to leaking of water through the bedrock which makes the integrity of the entombment hard to be justified. Today about a cubic meter of water leaks into the rector hall per hour and ventilation and pumps has to be in operation continuously. Therefore an alternative where the site is left with radioactivity increases the risk of contamination spread to the surrounding environment. Despite the concrete covering the reactor cave, water is likely to penetrate the reactor hall and slowly release contamination from the site (reactor hall).

The cost for decommissioning is calculated for the three decommissioning strategies (1, 2 and 3), three different end states (A, B, C) and three different waste management options (a, b, c). Strategy 1 and 2 combine with end state A, B and C, and waste management options a, b, c to form 18 different combinations. The third strategy which is entombment can be considered as an in-situ decommissioning. The alternatives are summarized in Table I. Entombment does not involve any different end states or waste management options. The end states have the following meaning:

- Unrestricted use where everything down to one meter below ground is demolished and removed (A)
- Light industry where everything is free released, but the buildings are left standing (B)
- 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 process equipment needs to be removed so that other nuclear activities can operate unhindered of remnants from previous activities. (C)

TABLE I. The different alternatives in the concept evaluation.

Decommissioning strategy	End state	Waste management
1. Immediate	A. Un-restricted usage	a. Direct disposal
2. Deferred	B. Industrial	b. Recycling off-site
3. Entombment	C. Other nuclear activity	c. Recycling on-site

The waste management strategy is that buildings and rooms are emptied and decontaminated of all contamination, so the remaining structural material of a building, plus possibly some equipment, will be surveyed as clean in-situ and verified that it does not need to go to a nuclear waste repository. For all three end states and options the waste facility will be the last building to be decontaminated and dismantled on site. The different waste management options have the following meaning:

- On-site waste management of all the waste focusing on packaging for direct disposal. (a)
- Waste potentially possible for clearance without treatment will be handled on site. Material that requires treatment to be subject to clearance will be sent to a dedicated off-site facility for treatment. Residues from the treatment and material not subject to clearance after treatment will be returned. Material not found potentially possible or worth the cost to clear will be packed for disposal locally. (b)
- On-site waste management focusing on treatment for clearance to the extent possible. Packaging for disposal for the remaining material and the residues generated during the treatment operations. (c)

The concept evaluation study has provided suggestions regarding the strategy, what costs are related to the decommissioning and what are the needs to be dealt with in future planning. A time schedule has also been developed for execution of the decommissioning scenarios. The duration of decommissioning activities and the decommissioning cost are based on the inventory of materials and radioactivity.

COST ESTIMATION METODOLOGY

The basis is a hypothetical shutdown year 2018 and all assumptions taken within the concept evaluation is based on this year [3].

The cost estimation of the total study is based on the “bottom-up” technique to estimate labour requirements and activity durations for the decommissioning program. This means that the total decommissioning project is broken down to specific well-defined activities. Each activity requires a certain work force and has a certain duration. The combination of these two defines the cost for the specific activity. When all these individual activities information are summarized, a general time schedule and a total cost estimate are developed.

The duration of an activity is in most cases proportional to the amount of material to be handled as well as the contamination level. Thus, the inventories of masses and radioactive contamination are crucial. Inventories on a component level for the Halden and Kjeller plants were developed together with the licensee. The compiled database with the mass of components, building materials, structural steel constructions, weights, volumes, activity inventory, contamination levels was further complemented with a site walk-down and photo-documentation studies as well as with interviews with operating personnel, a measure proven to be useful. The compiled inventories for the reactors are given in Table II. The Jeep II reactor is a pool reactor, hence, the empty biological shield cell in Table II.

Table II. The major content of material from each site origins the reactor.

[tonnes]	HBWR	JEEP II
Components	260	116
Pipes	10	8
Ventilation	30	30
Cabling, chutes	30	18
Structural steel	20	15
Reinforcement	492	263
Reinforcement, bioshield	8	-
Concrete	23 620	5 340
Concrete, bioshield	380	-
Incinerable	50	20

When the existing radiological inventories of the plants were not sufficient, data were taken from older studies or similar buildings. Since the facilities are currently in operation, the radioactivity inventory may not be easily established and may change over time. Such data may therefore also be acquired by modelling.
The milestones in the project plan are mainly identified in [4] and [5]. Information in these reports has contributed to the specifics in the decommissioning time schedule.

RESULTS

The result of the analysis has made it possible to clearly distinguish alternatives, both regarding the decommissioning strategy as well as the waste management options that are more beneficial than others. The derived cost calculation includes several high contingencies due to several uncertainties in the inventory. A number of the cost items are based on other studies and their inventories, adjusted to the conditions at Halden and Kjeller.
If the permanent shutdown takes place beyond 2018, it is recommended to update the concept evaluation. That is also recommended if the license is changed, the regulations changes or if the site can be used for other purposes.

Table III. The total cost for the developed alternatives, which is including contingencies.

[kUS $]					
Alternative	Halden	Kjeller	Alternative	Halden	Kjeller
1Aa	187 000	188 000	2Aa	254 000	255 000
1Ab	180 000	183 000	2Ab	248 000	251 000
1Ac	190 000	188 000	2Ac	257 000	256 000
1Ba	183 000	185 000	2Ba	250 000	253 000
1Bb	177 000	181 000	2Bb	244 000	248 000
1Bc	184 000	186 000	2Bc	254 000	253 000
1Ca	169 000	164 000	2Ca	183 000	178 000
1Cb	163 000	160 000	2Cb	177 000	174 000
1Cc	173 000	165 000	2Cc	187 000	179 000
			3		316 000

The cost estimation for the decommissioning project is an input to the plant owners (stakeholders) and the broader socio-economic evaluation, the results for the different alternatives can be found in Table III. *Immediate dismantling* (strategy 1) has in general terms a lower decommissioning cost, this could also be said about the end-state *other nuclear activity* (C). The cost estimation process shows also that the waste management alternative with *recycling of material off-site* (b) has the lowest cost. The *entombment* (strategy 3) alternative differs a lot from the other alternatives and appears as a non-realistic alternative. This is also consistent with IAEA opinion that entombment is not a realistic strategy for a controlled decommissioning project.

The expected total duration of the decommissioning program is approximately 10 years for each site and the dismantling and demolition period is about 4 years. The other 6 year consists of planning with activities such as information gathering, technical documentation, EIA work and defueling with activities such as removal of fuel, decontamination, radiological characterisation, process system adaptation to decommissioning. The decommissioning program is divided into conventional dismantling phases and an overview of the program can be seen in Fig. 3.

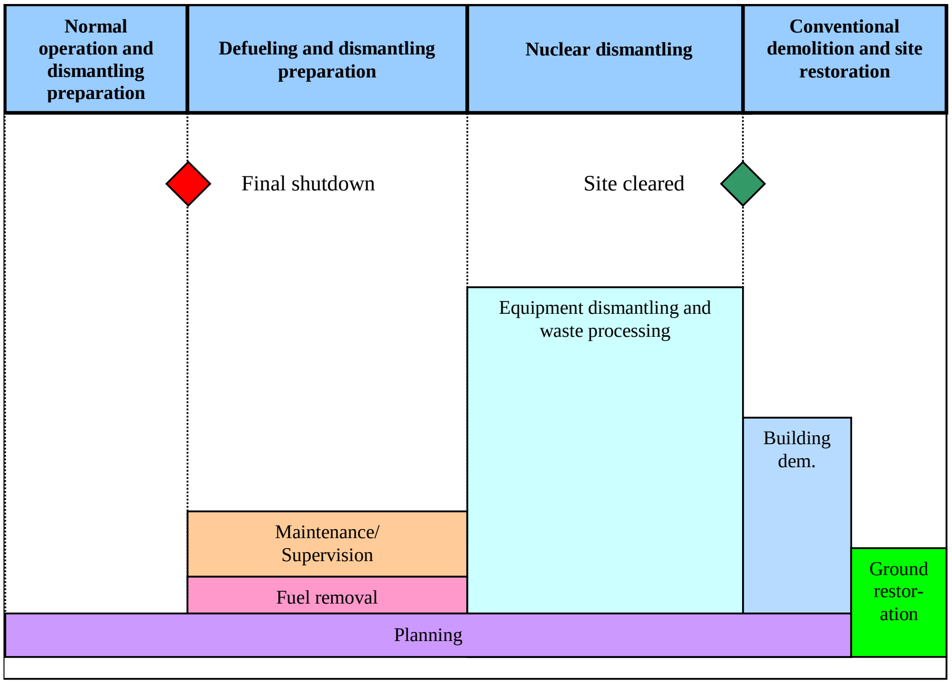

Fig. 3. Schematic outline of the decommissioning phases.

Several general conclusions can also be made. One is that it is very important that funding is available at the time for start of the decommissioning. The decommissioning organization is important to establish at an early phase. Workers from the sites with key expertise of the site and the site history are important to involve directly in the decommissioning organization. The division of responsibility and work needs to be clearly defined. In the report it is assumed that the owner will still be in charge of the site and have the overall responsibility but all major decommissioning work will be executed as projects with separate project management and administration for each project.

The decommissioning strategy chosen depends on the management for the spent fuel and that has to be settled. That also concerns the decommissioning waste. As long as fuel is stored on site the solution is forced into a sort of deferred dismantling or partially deferred dismantling.

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