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This report is the first approach by the Swedish authorities to formulate a decommissioning policy. It is not the final policy document but it discusses the principal questions from the special Swedish viewpoint.

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DECOMMISSIONING POLICY IN SWEDEN

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ABSTRACT

In Sweden the nuclear power program is, according to a parliamentary decision, limited to twelve power producing reactors. The last reactor shall be taken out of service no later than the year 2010. As a result of the Chernobyl accident the program for taking the reactors out of service will be accelerated.

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1. INTRODUCTION

In Sweden the first nuclear research reactor R1, situated in a rock cavern in the city of Stockholm, was operating from 1954 to 1970. The first energy producing reactor the Ågesta reactor, which generated 60 MW used for district heating of Ågesta, a suburb to Stockholm, and 20 MW electricity was operating during the time period 1964 to 1974. The large scale nuclear power program for electricity production in Sweden started with the first reactor at Oskarshamn in 1972. After a referendum in 1980 on the nuclear issue the parliament decided that the Swedish nuclear power program shall consist of no more than 12 reactors. The last reactor shall according to that decision be taken out of service no later than the year 2010. The last two reactors in this program were taken into service in 1985. The twelve reactors, 3 PWR and 9 BWR, have a total capacity of 9.6 GW(el). There is also a nuclear research centre at Studsvik with one nuclear reactor and a fuel fabrication plant in Västerås.

During 1982-1985 the research reactor R1 was decommissioned to stage 3 according the IAEA terminology (ref 1) and the location was declassified for unrestricted use (ref 2). The Ågesta reactor is now at stage 1.

This paper will discuss a Swedish decommissioning policy primarely for the nuclear power reactors. It deals mainly with questions relevant to radiation protection.

2. SWEDISH LEGISLATION

There are two laws in Sweden specially made for regulating nuclear activities of interest for decommissioning and one general law on radiation protection. The three acts are

Act on Nuclear Activities (SFS 1984:3) effected on 1 February 1984.

Act Concerning Financing of Future Expences for Spent Nuclear Fuel etc (SFS 1981:669) effected on 1 July 1981.

Act Concerning Protection Against Radiation (SFS 1958:110) effected on 1 January 1959.

All three acts are parallell acts in the sense they are regulating different aspects of the same activity. The first act regulates the nuclear safety, the second regulates financing of future decommissioning of power reactors, waste handling and disposal of decommissioning waste while the third act regulates the protection of workers, general public and the environment against ionizing radiation.

2.1 Act on nuclear activities

According to this act construction, possession and operation of a nuclear installation must be licensed by the Government. No special governmental license is needed for decommissioning a nuclear installation but permission must be given by the competent authorities.

The holder of a license shall ensure that such measures are taken as are needed in order to decommission plants in which operation is no longer to be conducted. The licenseholder is also responsible for handling and final disposal of all nuclear waste that is not recycled. This includes decommissioning waste.

The holder of a license shall ensure that such comprehensive research and development work is conducted as is needed in order that the requirements set forth in the law are met.

The Swedish Nucler Inspectorate is responsible for ensuring that all aspects of nuclear safety is met at nuclear installations and when fissile material and nuclear waste is handled which includes regulations and inspections.

2.2 Act concerning financing

The owner of a nuclear power reactor has full financial responsibility according to the act concerning financing for the decommissioning activity as well as for the research and development work carried out. He shall also defray the costs for the state for complementary research and development work, for review of applications and for surveillance and inspection work.

In order to ensure that funds are available to pay the costs that follow from the reactorowner's obligations the owner shall pay, during reactor operation, an annual fee to the state covering future expences for waste and decommissioning. The fee is in proportion to the electricity produced by the reactor. It is determined annually by the Government after recommendations from the National Board for Spent Nuclear Fuel. For 1987 the total fee is 0.019 SEK/kWh on an average of which 0.004 SEK/kWh relates to decommissioning.

2.3 Act concerning radiation protection

The radiation protection act covers all activities where ionizing radiation is generated. It is mainly intended for the protection of occupationally exposed personell but it also considers the protection of the general public and hospital patients. In the law, nuclear activities is not specifically mentioned but since ionizing radiation is generated and radioactive material is handled in nuclear installations the regulations given in the law are applicable.

The competent authority, the National Institute of Radiation Protection (NIRP) has according to the law the right and responsibility to give all necessary radiation protection regulations and to conduct inspections.

A new act on radiation protection will be issued and effected in 1988. The major change is the more general application for the protection of workers, general public, patient and the nature itself.

2.4 Authority responsibilities

As seen from the three acts mentioned before there are three authorities involved. They are all independent and working with different aspects of decommissioning as illustrated in fig 1.

The Swedish Nuclear Inspectorate is responsible for regulating the nuclear safety aspects. The National Board for Spent Fuel is responsible for assuring that the decommissioning of nuclear power reactors can be financed and the National Institute of Radiation Protection is responsible for regulating the radiation protection aspects.

In practice it is often impossbile to have a clear distinction between nuclear safety and radiation protection. It is thus essential that the two competent authorities responsible for the two different areas have an effective cooperation, which is also the case. Since decommissioning normally do not involve any handling of the fuel or other fissile material the dominating problems are of radiation protection character and thus the main responsibility of NIRP.

2.5 Utility organisation

The four Swedish nuclear power stations have different owners. One is fully state owned and three are privately owned. According to the act on nuclear activities the utilities have the responsibility of finding acceptable solutions on decommissioning and waste disposal problems. Already before this legal responsibility was formulated the utilities formed a jointly owned company, Swedish Nuclear Fuel and Waste Management Company, SKB, that should deal with some common questions such as waste disposal and decommissioning. SKB is now coordinating and conducting research and development work. Last year it published a report on technology and costs for decommissioning the Swedish nuclear power plants (ref 3). They are also annually presenting cost estimates to the National Board for Spent Fuel to be used as a basis for its recommendations to the Government on the fee per kWh generated electricity for the coming year. SKB has an extensive international research cooperation.

The Swedish authorities are rather satisfied with this organisation and the way it works. It gives the possibility to discuss with all nuclear power utilities through one body on problems concerning waste management and decommissioning.

2.6 Political constraints

The Swedish laws does not stipulate any time for decommissioning of the individual nuclear facilities. It gives the authorities the right to shut down a reactor for safety and radiation protection reasons. In a parliamentary decision taken 1980 after a referendum on the nuclear energy issue it is said however that the last nuclear power reactor shall be shut down no later than the year 2010. Nothing, however, is said about the time scheme for phasing out nuclear power. Some politicians have accused the Government of deliberately avoiding this question while others, before the Chernobyl accident, were discussing the possibility of having a new referendum and parliamentary decision on the topic.

After the Chernobyl accident voices were raised to speed up the outphasing of nuclear power. According to some political parties it could be started immediately and the last reactor be taken out of service in the middle of the 1990th.

The investigations done in Sweden show however that the Chernobyl accident does not give any new technical reasons to reconsider the safety of the Swedish nuclear reactors. Most of the investigations also points out that a too rapid replacement of nuclear energy can cause larger risks to people and the environment.

The existing laws does not give the possibility to phase out nuclear power for other than safety and radiation protection resons based on analysis of each indvidual reactor. A new parliamentary decision will therefor be needed if a faster program for replacement of nuclear power shall be implemented. In May this year the Government put a bill to the parliament with a proposal of taking the first nuclear power reactor out of service during 1993 - 1995 and the second during 1994 - 1996 provided that alternative energy sources are available. All the power producing reactors shall according to the bill be phased out by the year 2010.

3. POLICY QUESTIONS

There are many detailed questions, which have to be answered before a complete decommissioning policy is formulated. All of those have not yet been fully discussed and this paper, which is the first approach by the authorities in Sweden to formulate an overall decommission policy, will thus not be the final policy document.

3.1 What decommissioning level should be used

There are different levels of decommissioning of a nuclear installation. The least ambitious level is to decontaminate the installations, take away some systems and have extensive surveillance of the remaining installation for a very long time periode. In case where nuclear power will be generated in the future it may be suitable to reuse equipment and buildings for a new nuclear reactor.

When loose contamination and components containing the main activity of long lived radionuclides (mainly the pressure vessel) are removed it may be possible to fully seal off and entomb the rest of the installation.

It may also be possible to convert the site to a disposal facility for all or part of the dismantled installation as for instancediscussed by Ontairo Hydro for the Bruce reactors (ref 4).

All these decommissioning alternatives need surveillance of the site for radiation protection reasons for a long time period after decommissioning.

Total dismantling and removal of all radioactive waste from the site, decommissioning to stage 3 according to the IAEA definitions, is necessary if future surveillance of the site is to be avoided.

In Sweden the parliamentary decision to shut down the last nuclear power reactor by the year 2010 means that when an existing nuclear reactor is taken out of service it will not be replaced by another nuclear reactor.

In the background document to the act on nuclear activities the Minister stated that the owner of a nuclear reactor is responsible for the total dismantling of all parts of the facility and for transportation of the radioactive waste to a repository. This means that decommissioning of a nuclear reactor in Sweden must include total dismantling of the whole facility including all the installations and buildings. After decommissioning it must be possible to use the site, and remaining structures without restrictions.

It is not necessary however that all sites shall be left totally uncontrolled immediately after decommissioning. At some of the nuclear power plants there are for instance shallow land disposal sites which need administrative control for up to 50 years before the activity in the disposal have decayed to levels below regulatory concern. Also the geographical location of the sites are such that they probably will be of interest for other industrial purpose, such as coal fired power plant, which easily can operate with some given administrative constraints.

3.2 Storage with surveillance versus immediate dismantling

The question of storage with surveillance versus immediate dismantling has been subject to many discussions. A special OECD/NEA workshop discussed that very subject in 1984 (ref 5) where most of the argument were debated. It can be of interest to evaluate some of these arguments from the Swedish standpoint.

Sweden is a country with relative low population density which should indicate that there should be lot of alternative land available for all different applications. Also the Swedish nuclear power plants are located outside the most populated areas, maybe with the exception of Barsebäck. There are however valuable infrastructures at each site in the form of harbour, electricity distribution system and roads which are of interest for other industries such as coal fired power plant for generating replacement electricity. Such facility could however be constructed and operated without dismantling the nuclear power plant.

One of the strongest argument for a deferred dismantlement is the fact that the radionuclide inventory in a shut down nuclear reactor will decrease with time. Also the doserate will decrease with time. The doserate is normally dominated by cobolt-60, while nickel-63, which is a pure betaemmitter, after some ten years will significantly contribute to the total activity without giving any external radiation. This will result in a faster decrease of the doserate than decrease of activity. If the reactor has been subject to a major accident the decay-curves for activity and doserate may be different.

A lower total activity content will give lower costs for waste disposal and the lower doserate will also reduce the costs for radiation protection and remote handling during dismantling. Decontamination should however also give the same effect.

After approximately 50 to 100 years of decay both the external dosrate and total activity inventory will decay very slowly. It will for that reason be of little interest to further defer dismantling and this sets a suitable upper limit for a safe storage period.

Personal experience and knowledge of the plant history will be lost if dismantling is deferred more than 10 years. This can partly be compensated for by documentation and good record keeping. For Sweden the decision to shut down the last reactor by the year 2010 at the latest will effect the personnel situation at the plant. It can be expected that new technicians will chose other parts of the industry and also employee will leave the nuclear energy field for other areas which look more promising for the future. In fact this has already been a problem for some of the Swedish nuclear power plants. A few years after the shut down of the last Swedish nuclear power plant there will probably be rather few technicians who will keep their knowledge updated unless they have special reasons for it. For surveillance of a 1000 MW reactor in the state of safe storage only a few technicians are needed, which means that this is no way of maintaining technical competens for a large staff. These are all arguments for making dismantling rather soon after shut down and also to keep a sufficiant large number of technicians occupied with the planning of dismantling in the time period between shut down and the actual start of dismantling. It may also be of value to have a running plan to timely coordinate dismantling of all the Swedish nuclear power plants.

Development of technology will always take place around the world. This means that better dismantling techniques will exist in the future even if Sweden will not contribute in a situation with a terminated nuclear power program. It is however already demonstrated, although yet only on research and pilot plant reactors, that total dismantling is possible without unreasonable risks to the operating personnel and the environment. However, what is reasonable depends on available techniques, corresponding costs and resulting doses. Technical development and experience might justify improved radiation protection.

Very large volumes of waste is generated in a short time during decommissioning, approximately the same order of magnitude as generated during the whole operation period. Most of the waste will have a low specific activity. From radiation protection point of view it is important to have suitable disposal facilities in operation before large scale decommissioning starts. It can not be reasonable to build intermediate storage facilities for this types of waste and by that increasing the handling and transportation of the waste which will give occupational exposures. For some special decommissioning waste with small volumes such as components from the core region which have high specific activity it may however be an optimal solution to have an intermediate storage to facilitate disposal of similiar components from all reactors at a special repository.

No large scale decommissioning can take place before a repository for decommissioning waste is commissioned.

After a long time of safe storage most of the auxiliary systems which are needed during dismantling must be refurbished or totally renewed before the work can be started.

Beside these major arguments for and towards early dismantling also the following arguments can be taken into consideration. The funds raised for decommissioning will be of considerable size and will always be under political control. During a time period of the order of 100 years it is not unlikely that very special needs will show up which will justify the use of such large funds. If that happens it will however endanger a later dismantling since it may be difficult to once again raise such funds or to give dismantling high enough priority. This is thus an argument for not deferring dismantling.

The Swedish politicians have often in connection with discussion of nuclear waste stated that the existing generation shall not put unnecessary burden on future generation. This could also indicate that dismantling should not be deferred.

Table 1 gives a summary of the arguments for immendiate versus deferred dismantling

3.3 Protection

Since by definition decommissioning of reactors does not include handling of spent fuel there is mainly radiation protection problems involved.

The safety problems to be considered during decommissioning are mainly normal non-nuclear occupational safety problems such as falling objects, work with chemicals etc.

For the radiation protection the ICRP recommendations on optimisation (ALARA) and dose limitation are applicable (ref 6). Studies have indicated that dismantling a reactor will result in a collective dose commitment to the workers comparable to that caused by 5-10 years of normal operation of Swedish power plants. Future work will show if this is a reasonable estimate and in accordence with the ALARA-principle.

3.4 Decontamination

There are three reasons for decontamination:

1) to reduce the dosrate to facilitate work in the area where remote operation is not practicable

2) when an optimisation anlysis has shown a net benefit from decontaminating a given system

3) in order to facilitate reuse or declassification of contaminated scrap material and components

The two first reasons for decontamination results from application of the normal radiation protection principles of dose limits and optimization.

In Sweden as well as in many other countries there have been a general trend in trying to reuse material instead of disposing it as waste. This is a result of the general awareness of the limitation of natural resources and also of the fact that it is normaly less energy consuming to procuce something from scrap metal than to produce it from raw material which first have to mined.

NIRP has already in 1982 in connection with a decision on declassification of contaminated scrap metal made a statement where NIRP support decontamination in order to achieve declassification.

In connection with decommissioning large quantities of contaminated material are generated, most of which may be reused after decontamination.

It is the intention from NIRP that material which can be reused should be reused even if it has to be decontaminated in order to reach acceptable contamination level. Such decontamination should be performed even if the costs for recycling slightly exceeds that of disposal. However this approach must be further analysed before full implementation.

3.5 Decommissioning waste

In Sweden there are two established disposal options for low and intermediate level nuclear waste: rock repository and shallow land disposal. Most of the waste will be disposed of in a rock repository under construction at Forsmark, the SFR-1, It will according to plans be taken in oparation in the beginning of 1988. Some very low level waste can be disposed of in shallow land disposal of which one is operating at OKG power plant and one is under construction at Forsmark. They are licensed for very low level waste from normal operation and have a licensed capacity of only 100 GBq each. It is possible from radiation protection point of view to extend the capacity to at least 1 TBq.

None of these repositories, however, are licenced for decommissioning waste from nuclear power plants.

According to existing plans the main part by volume of the decommissioning waste from the Swedish nuclear power plants will be disposed of in rock repository of similar construction as SFR-1. It will probably be colocated with SFR-1 in order to have advantage of the existing infrastructure and of the transport tunnels down to the disposal area 50 m below surface.

The most highly activated components from decommissioning such as core grid, reactor vessel and other core components may have to be disposed of in deep geological repositories.

There is no generally applicable limit below which decommissioning waste can either be disposed of at ordinary land-fills or be reused as non-radioactive material.

It is important to be able to reuse scrap metal and other valuble material from decommissioning waste. For that reason Sweden has with great interest taken part in the work done by CEC on establishing limits for material to be reused. The present situation in Sweden however is more restrictive than the proposed CEC rules for instances by trying to make sure that the material to be recycled is melted before it is used as a product. This means avoiding direct reuse of contaminated components. NIRP is also supporting an experimental furnace set up at controlled area at Studsvik Energiteknik AB to melt contaminated material. The main advantage achieved by melting the material before declassification is that it facilitates a very accurate determination of the activity content of the batch and also removes loose contamination from the material which otherwise may give rise to internal contamination and spread of contamination during handling of the material.

Even if it should be possible, in principle, to find limits useful for declassification for reuse of concrete and similar construction material as well as for contaminated soil we do not at present find it useful because it is very little interest in such material and further concrete and soil does not represent a rare material resource in Sweden. It will however be large quantities of that type of material with such a low an activity concentration that it is not reasonable to dispose the material in an underground rock repository. On the other hand it will not be acceptable to let that waste category be uncontrolled. Since a site after decommissioning probably will be subject to administrative control for a limited time period after decommissioning some parts of that decommissioning waste could be used as back-filling material at the site during restauration of the site and landscaping. A study to evaluate that possibility and to what extend it may be used has been initiated.

Decommissioning of small reactors and other small nuclear installations may be part of the process leading to the establishment of such rules and also it may be possible to store those more limited waste volumes generated or in some cases also dispose the waste in SFR-1.

3.6 Responsibilities

As mentioned above the owners of the reactors are responsibile for dismantling the installation and taking care of the waste in a way accepted by the competent authorities. Their responsiblity also include all research and development work necessary to be able to make decommissioning, waste handling and disposal in an acceptable way.

The competent authorities are responsible for formulating the policy, giving rules and regulations as well as necessary limits for the owners to be able to fullfill their decommissioning work. To follow the international work and when necessary also initiate research and development activities are important activities for both the authorities and the owners.

At last the ultimate responsibility for the back end of the nuclear fuel cycle is taken by the State.

3.7 Research and Development

SKB is following and participating in the international R&D work. For instance they are participating in the OECD/NEA cooperating program on decommissioning.

Also the authorities are following the international work by participating in international meetings and working groups. NIRP is also, in cooperation with the Nordic Liason Committee for Atomic Energy, financing research projects on validation of radionuclide inventory and development of criteria for use of contaminated construction material for disposal at the site and for landscaping.

NIRP has encouraged Studsvik Energiteknik AB to set up a melter for contaminated scrap metal on controlled area. The melter will be used to develop and test melting of low-level contaminated scrap material for reuse.

The R&D work is considered important not only in order to be updated in the field but mainly to find optimised solutions for decommissioning of specific sites.

4 SUMMARY

In Sweden the last nuclear power reactor shall be shut down by the year 2010. According to a recent Governmental bill presented to the parliament the first reactor is planned to be phased out in the periode 1993 - 95. It is therefore necessary to establish a decommissioning policy that can be used for planning and implementation of the coming Swedish decommissioning program. This is the first approach by the authorities to formulate such a policy.

The costs for decommissioning nuclear power reactors are covered by funds from the generated electricity and financing should thus not be any problem.

Radiation protection is the major concern during decommissioning and the associated waste management. ICRP recommendations on optimisation and dose limitation are applicable.

Due to legal constraints only total dismantling of a nuclear reactor is an acceptable decommissioning option.

Although no large nuclear power reactor so far has been dismantled, enough experience on research reactors and pilot plants exist to ensure the technical feasibility of large scale dismantling. The optimised procedure for the Swedish reactors is still to be found.

When applied to the Swedish situation many arguments for an early dismantling, at least within 10 years after shut down, are emphasized while the arguments for a safe storage period of 50 to 100 years preceeding dismantling are not so strong.

Decontamination is important not only to reduce doserates in working areas but also to facilitate recycling of valuable scrap material. Decontamination to achieve recycling should be encouraged.

Before large scale decommissioning takes place in Sweden it is necessary

to have a licensed repository for the main part of the decommissioning waste

to have an interime storage for relatively small volumes of waste, such as core components with high specific activity of long lived radionuclides, which have to be disposed of in a deep geological repository (CLAB may be used).

to have established rules for reuse of contaminated material as backfill and landscaping material at the site

to have limits and established rules for scrap material to be reused for industrial and other purposes.

Both the utilities and the Swedish authorities will continue to follow and participate in the international work on decommissioning. The national R&D program will be extended.

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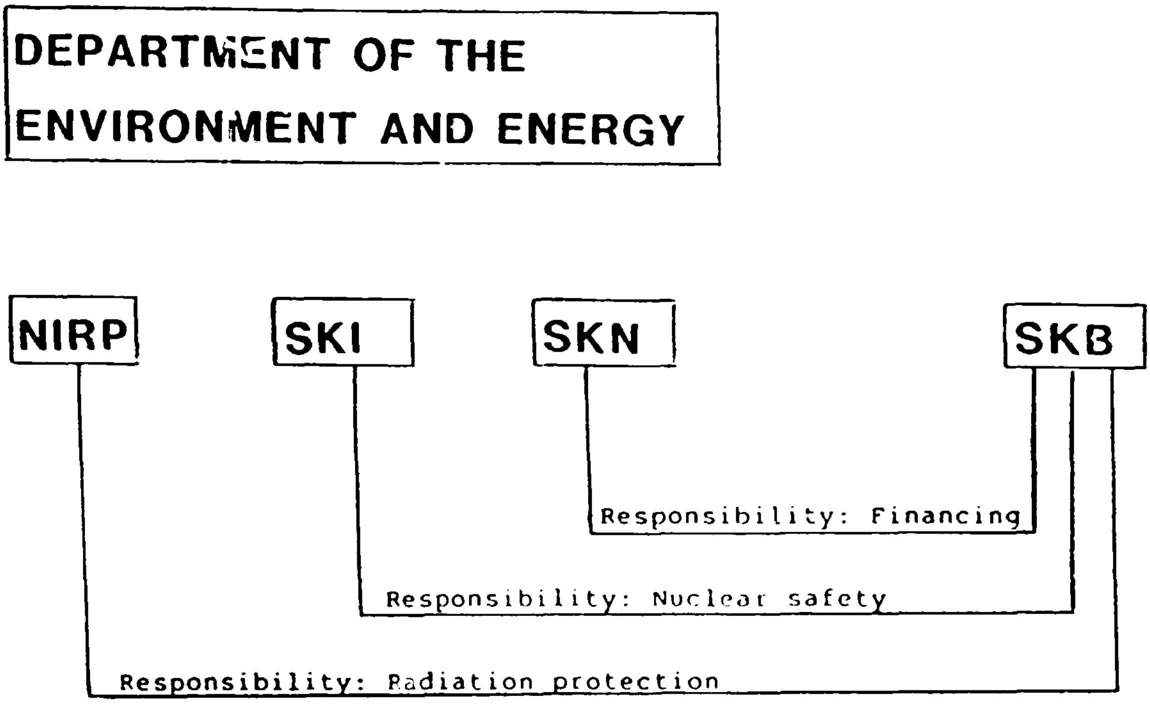

NIRP: National Institute of Radiation Protection

SKI: Swedish Nuclear Power Inspectorate

SKN: National Board for Spent Nuclear Fuel

SKB: Swedish Nuclear Fuel and Waste Management Co

<u>Fig 1</u>: Responsibilities for Swedish competent authorities in the field of nuclear energy

Table 1 A summary of the arguments for immediate versus deferred dismantling as discussed in section 3.2

Factor influencing the choice	Arguments for Immediate dismantling	Deferred dismantling	Neutral
Land use			X
Decay		X	
Costs for waste management		X	
Availability of competent personnel	X		
Technology development		X	
Status of auxiliary systems	X		
Availability of funds	X		
Burden on future generations	X		

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