

# Decommissioning of nuclear power plants



Replacement of steam generators at Ringhals nuclear power plant.

Photo: Börje Forsäter/Hallands Bild

# *Repairs provide experience*

Swedish experience of complete dismantlement of nuclear facilities is limited. But a great deal of knowledge is available from other countries and from repairs and modifications of nuclear power plants.

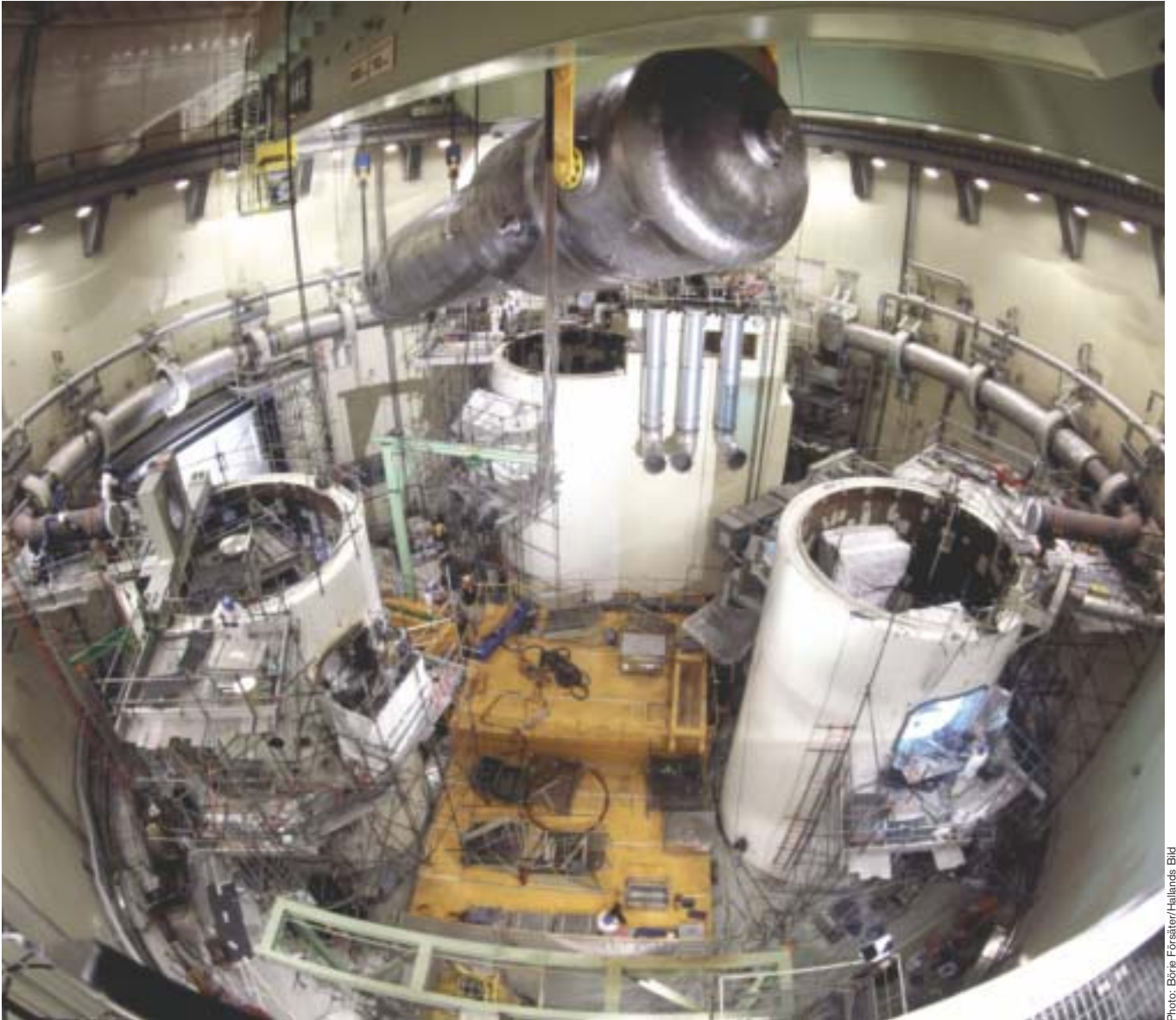


Photo: Börje Förestätter/Hallands Bild

Replacement of steam generator at Ringhals nuclear power plant.

**T**he Swedish Nuclear Fuel and Waste Management Company (Svensk Kärnbränslehantering AB, SKB) will have a major role in the work of decommissioning the Swedish nuclear power plants.

While the power utilities bear principal responsibility for dismantling the

actual facilities, SKB is responsible for managing and disposing of the resultant radioactive waste. By then we must have modified the transportation system and expanded SFR (Final repository for radioactive operational waste) at Forsmark to make room for the decommissioning waste.

Since the mid-1980s we have been following what has been happening internationally in terms of technology development and research. This gives us a good basis from a technological point of view as well as for comparison and judgment of our cost calculations.

Let us begin by observing that experience of complete dismantlement of Swedish nuclear facilities is limited. The decommissioning of the R1 research reactor at the Royal Institute of Technology in Stockholm is the only complete decommissioning that has been carried out. Decommissioning of a research facility in Studsvik is in its final phase at this time. This decommissioning project is not directly comparable with the decommissioning of a nuclear power plant, but provides a great deal of information and knowledge that can then be applied to the nuclear power plants.

#### Learning from repairs

This does not, however, mean that the power utilities have no knowledge in this field. A great deal can be learned from the repairs and modifications that have been done and are being done at the nuclear power plants.

In Ringhals 2 and 3, for example, the steam generators have been replaced, and in conjunction with the rebuild of Oskarshamn 1 an extensive decontamination (cleaning) was carried out, something which will also have to be done during decommissioning.

There is also a great deal to be learned from experience abroad. More than 60 reactors have been shut down all over the world. Most of them are small research reactors and reactors in small or half-scale nuclear power plants. Around 20 of these have been completely decommissioned.

#### Financial reasons

Decommissioning projects are currently under way in a number of countries, including Germany and the USA. In most cases, the reasons for the shutdowns have been purely financial.

There is no theoretical limit to how long a reactor can be operated. But after 40-60 years the costs of maintaining safety rise, making the plant more expensive to run, and

finally it becomes unprofitable. There are, however, cases where the plants have been closed for political reasons. Italy, for example, decided to shut down its reactors after a national referendum. In Sweden, Barsebäck 1 was shut down for political reasons in 1999 and Barsebäck 2 in 2005, after about 25 years of operation.

#### One reactor emptied

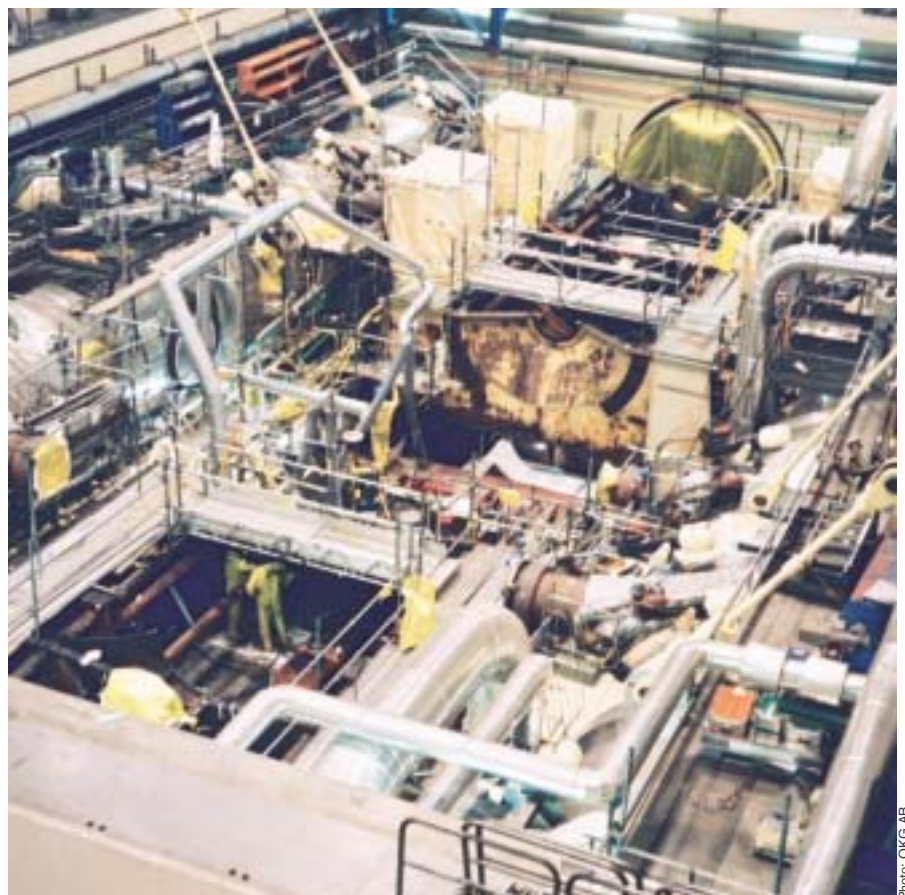
Today, Barsebäck 1 has been emptied of all fuel, but the reactor cannot begin to be dismantled until a waste handling system is fully operational.

The dismantling work cannot begin until at least one year after a reactor in a nuclear power plant has been shut down. A prerequisite for this is that no other reactor is located in the absolute vicinity. The advantages of dismantling a reactor so soon after it is taken out of service is



Contaminated areas are drilled away and disposed of.

that the operating personnel are still around and can contribute their special knowledge of the plant, and that the site can be used for other purposes sooner. The main disadvantage is that the radiation levels are higher, which hampers dismantling.



Turbine replacement at Oskarshamn nuclear power plant.

Photo: Studsvik AB

Photo: OIKG AB

# Decommissioning in three stages

A reactor can begin to be dismantled after it has been shut down and emptied of all nuclear fuel. During this time, some of the radioactivity decays and dismantling of the plant is facilitated.

**I**t is customary to speak of three stages in the decommissioning of a nuclear power plant. In the first stage, all fuel is removed from the reactor and the control systems are disconnected. The plant is kept under surveillance and inspected regularly.

In the next stage, most of the components containing radioactive material are collected and packed in suitable waste containers. The waste is then transported to an interim stor-

age or to a final repository. This stage requires less surveillance than the first one, but the plant cannot be left completely unsupervised. In the final stage, all radioactive material has been removed. The radiation levels are then so low as to be harmless to human beings. The site can then be released for unrestricted use.

## Planning is required

When several reactors in a country are nearly of the same age, the avail-

able decommissioning personnel and equipment may not suffice for all of them. This requires planning at the national level and can prolong the decommissioning process over a rather long period.

The foreign reactors that have not been dismantled have been “moth-balled”. This means that the fuel has been removed and, in many cases, the other radioactive components have been collected in a small, sealed space. They are then left there for



All surfaces that have been in contact with the water in the reactor are more or less contaminated with radioactivity.

decades so that some of their radioactivity decays and a final repository for the still-radioactive material can be completed. The plant is kept under surveillance throughout this period.

### Decommissioning in Sweden

Decommissioning of the Swedish nuclear power plants is being planned and carried out in cooperation with the power utilities and SKB. In some cases, the technology and strategy to be used have not yet been determined. One of these cases is how the reactor vessel and the concrete containment are to be dismantled and disposed of.

Previous experience of replacing the steam generators in Ringhals 2 and 3 suggest that it is possible to lift out large components in one piece.

Otherwise the components can be removed in smaller pieces. International experience of both methods is available from decommissioning work.

### Control rods removed first

Some of the components to be disposed of in connection with decommissioning are long-lived and so radioactive that they have to be radiation-shielded. Such components mainly include control rods and other reactor internals.

These components comprise only a very small portion of the total volume of decommissioning waste, but account for nearly all the radioactivity. The waste can be stored temporarily in Clab (Central interim storage facility for spent nuclear fuel) outside Oskarshamn, or somewhere else, pending deposition in a final repository. This final repository is expected to be ready to receive waste in around 2045.

### One-quarter of the Globe Arena

Less radioactive low- and intermediate-level components will be removed at the same time. They amount to a volume of about 150,000 cubic metres for all the Swedish nuclear power plants. This is equivalent to about

one-quarter of the volume of the Globe Arena in Stockholm. The short-lived low- and intermediate-level waste is planned to be deposited in SFR, which is located offshore at the Forsmark nuclear power plant beneath the seabed. The underground portion currently consists of four rock caverns and a silo with room for different types of operational waste.

### More rock caverns needed

In order to make room for all short-lived low- and intermediate-level decommissioning waste, we have to expand SFR by adding a number of rock caverns. Doing this will take about seven years and requires a special permit. Today the repository is only intended for operational waste, as the name implies.

Prior to decommissioning of the nuclear power plants, SKB intends to apply for a permit to expand SFR and to dispose of decommissioning waste there. According to the plans of SKB and the nuclear power companies, a final repository will be ready to take into operation in 2020.

### For unrestricted use

All surfaces that have been in contact with the water in the reactor are more or less contaminated with radioactivity. The radioactive particles can be dislodged and washed away with a



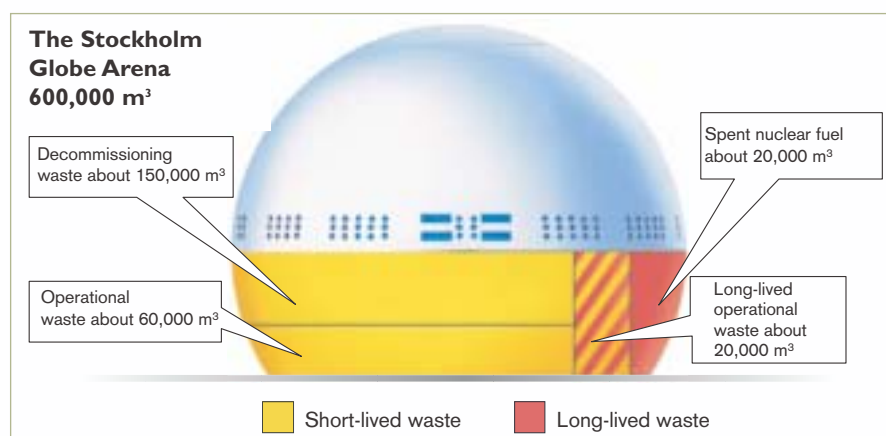
Photo: Börje Forsäter/Hallandis Bild

Personnel and equipment must suffice for the decommissioning of all Swedish nuclear power plants.

solution of, for example, citric acid. Washing with water is sufficient for many surfaces. The rinse water is then purified by filters and ion exchange resins.

By far most of the waste arising from the decommissioning of a nuclear power plant consists of concrete that is not at all radioactive. It can therefore be treated like any building waste, i.e. dumped on a landfill or reused.

We anticipate that more than 90 percent of the total volume of decommissioning waste can be released for unrestricted use, either directly or after cleaning. The exact percentage cannot be given today, since it depends on what the conditions for unrestricted release will be.



The long-lived waste comprises only a small fraction of the waste volume generated by the decommissioning of the nuclear power plants.

# Who pays?

Decommissioning of the Swedish nuclear power plants will cost more than twelve billion kronor, which is about one billion per reactor. Disposing of the waste will cost an additional three billion kronor. The owners of the nuclear power plants make regular payments for this purpose.



Photo: Pictorial/IBL

The cost of the electricity we use today should not burden future generations.

**N**o one knows today when the Swedish nuclear power plants will be decommissioned. Many different considerations, not least political ones, will determine the timetable.

Ultimately it is the power utilities who will decide whether the reactors are to be dismantled immediately or mothballed. The work will start no

earlier than 2015, since both design and licensing for final disposal of the radioactive waste require joint national planning.

### Costs vary

The cost of decommissioning a reactor and disposing of the resultant waste varies, depending on when it is done, the type of reactor in question,

and how well the process is coordinated with other decommissioning projects.

SKB's calculations show that the price will be roughly SEK one billion per reactor, in today's money. The cost of disposing of the waste comes on top of this, and is around SEK three billion for all the nuclear power plants. The idea is that the costs for

the electricity we use today should not burden future generations. Each year the owners of the nuclear power plants therefore set aside a sum of money in a fund which will pay for decommissioning of the plants. The money is deposited in the Nuclear Waste Fund's account with the National Debt Office.

The charge varies between 0.3 and 0.9 öre (SEK 0.01) per kilowatt-hour generated. It is set each year by the Government and is based on the cost calculations submitted by SKB to the Swedish Nuclear Power Inspectorate. Around SEK 500 million flows into the fund annually in this manner.

### One-quarter of the fund

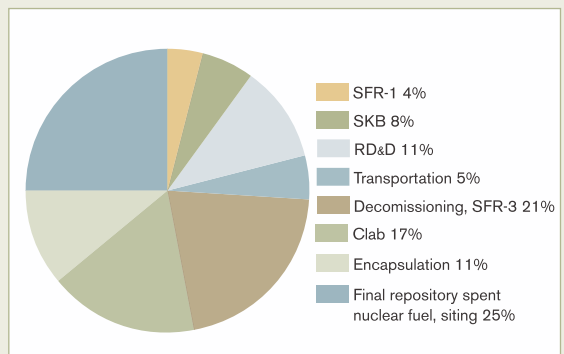
The book value of the fund at the end of 2004 was almost SEK 32 billion. The estimated future cost of waste management is just over SEK 52 billion (at 2005 prices). Up to and including 2004, approximately SEK 17 billion (in current money terms) has been spent.

Despite the fact that the nuclear power plants may have a life of 40–60 years, each plant will have paid in its share of the fund when the plants are 25 years old. This will ensure that there is enough money to decommission the plant even if it is shut down prematurely.



It costs just over SEK one billion to decommission a reactor. (SEK 1 eq. £ 0.11)

Just under one öre (SEK 0.01) per kilowatt-hour generated goes to finance nuclear waste management.



Distribution of total costs (incurred and future) for the Swedish nuclear waste programme in today's money, providing the reactors are operated for 40 years.

### Decommissioning websites

- [www.nea.fr/html/rwm/wpdd](http://www.nea.fr/html/rwm/wpdd)
- [www-ns.iaea.org/tech-areas/waste-safety/decommissioning.htm](http://www-ns.iaea.org/tech-areas/waste-safety/decommissioning.htm)
- [http://europa.eu.int/comm/energy/nuclear/decommissioning/index\\_en.htm](http://europa.eu.int/comm/energy/nuclear/decommissioning/index_en.htm)
- [www.world-nuclear.org/wgs/decom/index.htm](http://www.world-nuclear.org/wgs/decom/index.htm)

# Decommissioning of nuclear power plants

The Swedish Nuclear Fuel and Waste Management Company (Svensk Kärnbränslehantering AB, SKB) will have a major role in the work of decommissioning the Swedish nuclear power plants. While the power utilities bear principal responsibility for dismantling the actual facilities, SKB is responsible for managing and disposing of the resultant radioactive waste.

Sweden has three nuclear power plants and a total of ten reactors in operation. The two reactors in Barsebäck have been shut down, but so far no entire nuclear power plant has been decommissioned.

Decommissioning of the Swedish nuclear power plants is estimated to cost just over twelve billion kronor and take a couple of decades. Disposing of the waste will cost an additional three billion kronor.

The financing has been arranged, but the exact timetable for decommissioning has not yet been determined.



**Svensk Kärnbränslehantering AB**

Swedish Nuclear Fuel and Waste Management Co  
Box 5864, SE-102 40 Stockholm, Sweden  
Telephone +46 8 459 84 00  
[www.skb.se](http://www.skb.se)