2019

NUCLEAR WASTE MANAGEMENT IN SWEDEN

JOHAN SWAHN, MKG - SWEDISH NGO OFFICE FOR NUCLEAR WASTE REVIEW

BRUSSELS, JUNE 5, 2019

COMMISSIONED BY REBECCA HARMS, MEP

THE GREENS/EFA in the European Parliament

Overview

Sweden's nuclear efforts began with a combined military and civil nuclear program based on heavy-water reactors in the late 1940s. Two research reactors were started in 1954 and 1960. A third underground reactor was started in 1964, which delivered district heating to the local community and some electricity to the grid. But its main purpose was to provide plutonium for the Swedish nuclear weapons program. All three early reactors have been or are being decommissioned.

After a long public debate in the mid-1960s the government decided to abort the military program, together with the heavy-water power reactor program. Instead, nine boiling water reactors and three pressurized water reactors were commissioned between 1972 and 1985 at four sites.

Through the years and more rapidly in recent years, Sweden has reduced its nuclear capacity. Two reactors at the Barsebäck plant near the Danish border were shut down in 1999 and 2005. Two out of three reactors at the Oskarshamn plant were shut down in 2015 and 2017. At the Ringhals plant, two reactors will be shut down in 2019 and 2020 and two will remain. In 2018, Sweden's eight operating reactors supplied about a third of the country's electricity.[1]

Since 2016, there has been a political agreement that Swedish electricity generation should be 100 percent renewable by 2040. At the same time, there is no phase-out plan for the six reactors that will operate after 2020. The agreement just says that there shall be no subsidies for nuclear energy and the remaining reactors are to be shut down when they are no longer profitable. There are presently no plans to build new reactors in Sweden, although a legal ban against the construction of new nuclear power reactors was lifted in 2010.

In the 1960s an underground waste reprocessing plant was planned, but construction was never started. Reprocessing research and development was, however, carried out in the 1960s, leading to waste streams that are a major part of the Swedish legacy waste problem. The high-level reprocessing waste from these activities is no longer in Sweden.

In the late 1970s Sweden signed reprocessing contracts with France and the UK but finally only140 tons of spent fuel was reprocessed in the UK. For commercial and non-proliferation reasons it was decided around 1980 to instead opt for only direct disposal of spent nuclear fuel.

Sweden has an operational repository for short-lived low and intermediate-level waste and a repository for spent fuel is in a licensing process. A repository for long-lived intermediate-level waste is also planned for the future.

---

[1] World Nuclear Association 2018, *Nuclear Energy in Sweden*, viewed April 22 2019, https://www.world-nuclear.org/information-library/country-profiles/countries-o-s/sweden.aspx

Sweden had a uranium mining facility at Ranstad operating for a short time in the 1960s. It was decommissioned in the 1990s and environmental remediation is considered complete. Sweden also has a fuel fabrication plant in Västerås, presently owned by Westinghouse.

Waste classification system

Sweden differentiates nuclear waste based on its activity and lifetime. Its waste classification system was developed by the Swedish Nuclear Fuel and Waste Management Company (SKB) and lists the following five categories:[2]

- Very low-level waste, short-lived (VLLW-SL)
- Low-level waste, short-lived (LLW-SL)
- Intermediate-level waste, short-lived (ILW-SL)
- Low- and intermediate long-lived waste (LILW-LL)
- Spent fuel/high-level waste (HLW)

The classification differs slightly from the IAEA definition, in that instead of the agency's category of low-level waste (LLW) there is in Sweden a focus on the waste being short-lived. The Swedish low-level and intermediate-level short-lived waste (LLW-SL and ILW-SW) are thus LLW according to the IAEA classification.

Quantities of waste

The Ministry of the Environment and Energy and the regulator, the Swedish Radiation Safety Authority (SSM), publish inventories every three years in the report to the IAEA Joint Convention[3] and also report in line with the EU Radioactive Waste Directive.[4] The latest inventories in the reports refer to December 31, 2016 and are shown in the table below.

---

[2] Swedish Radiation Safety Authority August 3 2018, *Sweden's second National Report on Implementation of Council Directive 2011/70/Euratom*, viewed April 22, 2019. https://www.stralsakerhetsmyndigheten.se/en/press/news/2018/swedens-implementation-of-nuclear-waste-directive-reported-to-european-commission/

[3] Swedish Ministry of the Environment and Energy 2017, *Sweden's sixth national report under the Joint Convention on the safety of spent fuel management and on the safety of radioactive waste management, Ds 2017:51,* viewed April 22, 2019. https://www.regeringen.se/rattsliga-dokument/departementsserien-och-promemorior/2017/10/ds-201751/

[4] Swedish Radiation Safety Authority 2018, *Sweden's second National Report on Implementation of Council Directive 2011/70/Euratom,* viewed April 22, 2019. https://www.stralsakerhetsmyndigheten.se/en/press/news/2018/swedens-implementation-of-nuclear-waste-directive-reported-to-european-commission/

Table 1: Quantities of nuclear waste in Sweden as of 2016

Nuclear waste	Type of storage	Storage site	Quantity stored
HLW (only SNF)	Interim storage (wet)	Reactor storage pools at the nuclear power plants	2,387 FA or 492 tHM[5]
	Interim storage (wet)	Central near-surface interim storage facility (CLAB) in pools 75 meters underground at the Oskarshamn nuclear power plant	31,817 FA or 6,267[6] tHM
LLW-SL and ILW-SL	Interim storage	Interim storage facilities at the Studsvik site and at the nuclear power plants	8,500 m^3
ILW-LL	Interim storage	Interim storage facilities at the Studsvik site, at the nuclear power plants and at the intermediate storage facility (CLAB)	5,300 m^3
VLLW	Interim storage	Interim storage at the nuclear power plants	2,900 m^3
LLW-SL and ILW-SL	Disposed waste	Near-surface repository (SFR) 50 meters below the sea bottom outside the Forsmark nuclear power plant	38,922 m^3
VLLW	Shallow landfill	Shallow landfill burial at the nuclear power plants (except Barsebäck) and at Studsvik	27,841 m^3

Source: SKB (2017).

There are currently almost 7,000 tons of spent nuclear fuel in Sweden, mostly in a centralized wet storage facility (Clab). The spent fuel remains in pools at the reactor sites for only a few years. Around 8,500 m^3 of short-lived low- and intermediate-level waste and 5,300 m^3 of long-lived intermediate-level waste are currently in intermediate storage. Legacy waste is mainly at the Studsvik site, but increasing amounts are at the reactor sites where decommissioning is underway.

[5] Includes 0.04 tHM of spent research reactor fuel.
[6] Includes 2.7 tHM of spent fuel from the Studsvik nuclear research facility and 22.5 spent MOX fuel from Germany. In addition, 236 tHM of spent fuel has been sent abroad for reprocessing, 140 tHM of spent fuel and 4.8 tHM of spent research reactor fuel to the United Kingdom and 78 tHM of spent fuel to France.

Short-lived low- and intermediate-level waste from reactor operations is placed in an existing repository (SFR) where now close to 40,000 m^3 of waste have been disposed of. Very low-level waste is disposed of in shallow landfill burial sites and there are now almost 30,000 m^3 in four facilities. In addition, there are 2,900 m^3 of very low-level waste still in storage.

Based on industries scenarios of operation time, the final amount of spent fuel in Sweden is expected to add up to 11,400 tons. Estimated waste amounts after decommissioning all nuclear facilities sum up to 153,000 m^3 of short-lived low- and intermediate-level waste and 16,400 m^3 of long-lived intermediate-level waste.[7]

Waste management policies and facilities

Under the 1984 Nuclear Activities Act, it is the responsibility of the nuclear industry and its utilities to both finance and carry out management and final disposal of radioactive waste.[8] The act is presently under review. The industry has to deliver a research and development report every three years to the regulator, the Swedish Radiation Safety Authority (SSM). The government has to review and approve the report and can do so with conditions from the industry. This is the only possibility for the government to request changes to the industry's radioactive waste plans and it has seldom done so.

The regulator SSM reviews the licensing of nuclear facilities such as repositories based on the Nuclear Activities Act. Since the late 1990s, all nuclear facilities also need to have a permit according to the Swedish Environmental Code. The dual-path licensing process leads to recommendations from SSM and the Land and Environmental Court to the Swedish government, which makes the final licensing decision.

The nuclear industry has created a private company to carry out its responsibilities. The Swedish Nuclear Fuel and Waste Management Company (SKB) operates existing facilities and develops new ones. Another company, Svafo AB, was created to take responsibility for the legacy waste consisting mostly of nuclear waste from the historic military and civil research programs. Since 2009, Svafo AB has been owned by the nuclear industry.

Spent nuclear fuel from the nuclear power plants is first cooled over several years. It is then moved to a centralized intermediate storage facility, Clab, located at the Oskarshamn nuclear power plant. The wet storage facility has two water pools in caverns 50 meters underground in granite bedrock. The spent fuel is transported from the other reactor sites in a special ship, Sigrid, which is also used for transportation of other radioactive waste between nuclear sites.

---

[7] Swedish Nuclear Fuel and Waste Management Company (SKB) 2017, Plan 2016. Costs from and including 2018 for the radioactive residual products from nuclear power. Basis for fees and guarantees for the period 2018–2020, SKB TR-17-02, p. 35-36, viewed April 22, 2019. http://www.skb.com/publication/2487964/

[8] Swedish National Council for Nuclear Waste 2011, *Licensing under the Environmental Code and the Nuclear Activities Act of a final repository for spent nuclear fuel Report 2011:2e*, accessed April 22 2019, https://www.karnavfallsradet.se/sites/default/files/documents/report_2011_2.pdf

Like many other countries, Sweden has been working for a long time on a deep geological disposal for high-level waste. Since the mid-1970s, the nuclear industry has been developing a repository system called KBS-3 for final disposal of spent nuclear fuel. A repository is planned at about 500 meters deep in granite bedrock. The spent fuel is to be encapsulated in a 5-centimeter-thick copper canister and deposited in holes in the floor of underground tunnels. A buffer of bentonite clay is to be put around the canisters and the tunnels will also be filled with clay. The granite rock has water flowing through it, but the copper and clay are intended to provide a man-made barrier to isolate the waste from the environment for hundreds of thousand years.

The process of choosing the disposal site has been long and complicated. Finally, in 2009 the nuclear waste company SKB chose the bedrock at the Forsmark nuclear power plant. A license application was submitted in 2011 and after a long process the regulator SSM and the Environmental Court submitted their opinions to the government in January 2018. The court recommended declining to issue a permit under the Environmental Act, unless it was shown that the integrity of the copper canister could be demonstrated to assure sufficient long-term safety. The regulator SSM recommended that the government approve the permit, as any problems with the copper canister could be dealt with later in the step-wise decision-making process according to the Nuclear Activities Act. The license application is now under governmental review and it is unclear whether the copper corrosion issues will be a major problem going ahead. A government decision may come in 2020.

If the government decides to say yes, it will first give so-called “permissibility” according to the Environmental Code and can add conditions. The Environmental Court will have to give a permit with conditions. The government will then give a license according to the Nuclear Activities Act and the regulator SSM will start its step-wise decision-making process, where a decision will be taken for the beginning of construction, for operations, and for full operations. This will take several more years and it is unlikely that construction will start before 2025. If a license is given, it is estimated that the repository will take 10 years to build and that it will be operational for about 60 years.

In addition to the planned deep geological disposal for HLW, several repositories for other waste types are in operation or planned:

- There are plans for a specific repository called SFL for long-lived low- and intermediate-level waste (LILW-LL). However, so far SKB has not presented a method or begun the process of searching for potential sites.
- There is an interim storage facility for mostly long-lived LILW-LL inside a rock cavern at the Studsvik site. The waste comes from various sources, the majority being legacy waste.
- A repository called SFR was commissioned in 1983 for short-lived low- and intermediate-level waste (LLW-SL and ILL-SL) from nuclear power plants. The repository is situated 75 meters under the seabed outside the Forsmark nuclear power plant. There is an on-going licensing process for an expansion planned at 120 meters below the seabed for waste from decommissioning. There have been problems with the integrity of the

concrete barriers and with corrosion of canisters in the SFR repository. There are also a number of containers with legacy waste, of which many have to be retrieved due to uncertainty about what is in the containers, or because it is now known that they contain long-lived wastes.

- At the Studsvik nuclear research site, a hot lab carries out commercial testing of spent fuel specimens. At the facility there is also an incinerator to compact radioactive waste and a smelter to decontaminate and melt radioactive metal for free release. The facilities at Studsvik were gradually privatized beginning in the 1980s. In 2017, the French utility EDF's subsidiary Cyclife bought most of Studsvik AB's facilities, but not the hot lab.
- There are shallow landfill burial sites for very low-level radioactive waste at the Ringhals, Forsmark and Oskarshamn nuclear power plants and at the Studsvik site. The Studsvik landfill is permanently closed.

Costs and financing

In international comparison Sweden was early in financing radioactive waste management, as defined in the original 1981 Financial Act. The 2006 Financial Act defines the responsibility of the nuclear operator, or anyone producing radioactive waste, for decommissioning and guaranteeing that the full costs will be borne by the producer.[9] A fee on electricity from nuclear power and guaranteed securities by the power plant owners are the two main pillars of financing waste management and decommissioning of reactors. The nuclear industry produces a report called the PLAN report every three years with projections of future costs based on different scenarios. The report provides data for the calculation of radioactive waste fees and securities. It is scrutinized by the Swedish National Debt Office, which also puts it out for public review. Until 2018 this responsibility lay with the regulator SSM, but due the perceived increasing risk of the system being underfinanced the responsibility was moved. The debt office gives recommendations to the government, which makes the final decision.

For the period 2018-2020 the average fee is SEK0.05/kWh (US$0.0054/kWh) of produced nuclear electricity. The fee is set per nuclear power plant and is the highest for Oskarshamn (SEK0.064/kWh, around US$0.0069/kWh) and lowest for Forsmark (SEK0.033/kWh or around US$0.0035/kWh). The government also sets the levels of security amounts to be covered by the operators, both in the case that the fees do not cover the planned costs and to allow for unexpected costs. For the period from 2018-2020 the "financial amount" securities for possible cost increases are a total of SEK29 billion (US$3.1 billion) and the "complementary amount" securities for unforeseen new costs are a total of SEK15 billion (US$1.6 billion).

The fees from the operators are put in a special Nuclear Waste Fund that is separate from the government budget. At the end of 2017 the fund summed up

[9] Act on the Financing of Management of Residual Products from Nuclear Activities, Lag (2006:647) om finansiering av kärntekniska restprodukter. Available at https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-2006647-om-finansiering-av-karntekniska_sfs-2006-647

to SEK67 billion (US$7.2 billion). The total future costs for management and final disposal of all radioactive waste as well as for decommissioning of the nuclear reactors is estimated to be SEK100-110 billion (US$10.7-11.8 billion).[10] Since the financial crisis of 2008 has resulted in a much lower rate of return on long-term bonds than expected, risks increased that the system is underfinanced.

The Financial Act was extensively revised in 2017 to try and manage the risks to the financial system. The funds in the nuclear waste fund can now be put into less secure investments than government bonds to allow a higher estimate of a rate of return on the fund capital and the industry is allowed to calculate with the remaining operators operating for 50 years.

By using a separate Studsvik Act from 1988, Sweden has until recently sought to cover the costs for managing and disposal of the legacy radioactive waste.[11] These costs were also to the responsibility of the operators of the nuclear power plants, as they could be regarded as beneficiaries from the early nuclear research activities. The fee to the nuclear waste fund was on the order of SEK0.001-0.003/kWh (US$0.0001-0.0003/kWh) of nuclear electricity. However, the system was abolished at the end of 2017 and remaining responsibilities were incorporated into the revised Financial Act.

Summary

The current Swedish governance system for radioactive waste management and disposal was created in the early 1980s and puts the responsibility for both financing and implementation clearly on the nuclear industry.

Sweden is only using wet intermediate storage for spent nuclear fuel and all fuel is centralized in one facility. Sweden has an operational repository for short-lived radioactive waste that is under a re-licensing process to allow expansion for decommissioning waste.

It has advanced plans for a repository for spent nuclear fuel. The licensing process has advanced to government decision-making. There has been scientific criticism of using copper as a canister material making it uncertain whether a license will finally be given.

The Swedish financing system for radioactive waste management and decommissioning of reactors is well-developed and transparent. There are considerable sums available in a nuclear waste fund, but also discussions about increasing risks that the system will still be underfunded.

---

[10] Swedish Nuclear Fuel and Waste Management Company (SKB) 2017, Plan 2016. Costs from and including 2018 for the radioactive residual products from nuclear power. Basis for fees and guarantees for the period 2018–2020, SKB TR-17-02, viewed April 22, 2019. http://www.skb.com/publication/2487964/

[11] The act is named after the Studsvik nuclear research facility where most of the legacy wastes are stored. Studsvik Act. Lag (1988:1597) om finansiering av hanteringen av visst radioaktivt avfall m.m. Available at https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-19881597-om-finansiering-av-hanteringen-av_sfs-1988-1597.