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Miles Goldstick, 18 May 2019v2

Irradiated Nuclear Reactor Fuel Management in Sweden - 2019

Contents

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Introduction

This report[1] focuses on the situation in Sweden regarding management of irradiated nuclear fuel, commonly referred to as spent fuel, from Sweden's electricity producing commercial nuclear reactors. Particularly examined are uncertainties and impacts of the method and location proposed by the nuclear industry for a spent fuel repository.

The reason for the focus on spent fuel is because due to its radioactivity and heavy metal toxicity it is harmful to people and many other life forms forever. In addition, spent fuel is raw material that can be used in nuclear weapons.

Nuclear Waste in Sweden

In Sweden, creation of nuclear waste began with research into nuclear weapons shortly after the dropping of the Hiroshima and Nagasaki atomic bombs in 1945. In 1947, the Swedish government formed the Atomic Energy Company to pursue military and civilian nuclear research and development. The military work was abandoned in the late 1960s.[2] The early work in the late 1940s included research using plutonium, with resulting contamination and radioactive waste. As in Sweden there are now several facilities in the nuclear fuel chain, both active and out of service, there are also several types of nuclear waste that are managed in various ways.

In Sweden there is one decommissioned uranium mine (at Ranstad), one fuel fabrication plant (in Västerås), one permanently shutdown military research reactor (R1 in Stockholm), one permanently shutdown small commercial reactor (R3 at Ågesta), one military plutonium production reactor that was never fuelled (R4 at Marviken), four commercial nuclear power stations (Barsebäck, Ringhals, Oskarshamn and Forsmark) with a total of 12 nuclear reactors (of which the Barsebäck power station with two reactors is permanently shutdown, and two of the three reactors at Oskarshamn are permanently shutdown; one of the four reactors at Ringhals is scheduled to be shutdown in 2019 and another in 2020), an operating facility for storage of "short-lived" radioactive waste (SFR at Forsmark), and an operating interim storage facility for spent fuel (Clab at Oskarshamn, 32 m underground in bedrock). There is also a testing and treatment operation (Studsvik, near Nyköping). The spent fuel and other waste produced from the research programme is not specifically addressed here. In Sweden there is no conversion of yellowcake, no fuel enrichment and no fuel reprocessing. Sweden did however send spent fuel for reprocessing to Sellafield, England (140 tonnes) and La Hague, France (57 tonnes). Construction of commercial nuclear reactors began in the 1960s. Six reactors began commercial operation in the 1970s and by 1985 six more were in operation.[3]

In 1980, after the results of a non-binding referendum on the future of nuclear power, the government made a decision to phase-out nuclear power by 2010, but allow construction of new reactors to a maximum of 12.[4] The debate on the future of nuclear power continued and the 2010 phase-out date was retained until the mid-1990s. Then, in a new inter-party agreement, the government decided to start the phase-out earlier but abandoned the 2010 deadline. The first reactor (Barsebäck-1) was shut down in 1999 and the second one (Barsebäck-2) in 2005.

The controversy continued.[5] In June 2010, after a vote in the parliament that won by only two votes (174–172), the phase-out legislation was abandoned and it became permissable to build new reactors. In June 2016, another inter-party agreement was reached, this time on energy policy in

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[1] An earlier version of this text was a country report in the international Greenpeace publication, "Report - The Global Crisis of Nuclear Waste" published 30 January 2019, available in English and French at https://www.greenpeace.fr/report-the-global-crisis-of-nuclear-waste/.

[2] Jonter, T. 2002. "Nuclear Weapon Research in Sweden. The Co-operation Between Civilian and Military Research, 1947-1972." SKI Report 02:18. 82 pp. Available in PDF (533 KB) at (10 July 2018): https://www.stralsakerhetsmyndigheten.se/en/publications/reports/non-proliferation/2002/200218/

[3] IAEA. Undated. "Power Reactor Information System (PRIS), Sweden." Available at (5 October 2018): https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=SE.

[4] Lindström Marianne, Åhäll Karl-Inge, Holmstrand Olov, Helander Björn, Goldstick Miles.1998-06. "Nuclear Waste in Sweden - The Problem Is Not Solved!" Available at (5 October 2018): http://www.nonuclear.se/nuclear-waste-in-sweden1988. Direct link to the section on the 1980 referendum: http://www.nonuclear.se/nuclear-waste-in-sweden1988#nwchap4.

[5] Karlsson, Lasse. 2016-07-05. "Historien om avvecklingen som inte blivit av. Aktualiserad juni 2016. Framställt för Folkkampanjen mot Kärnkraft-Kärnvapen." ("The Story About the Phase-out that Didn't Happen. Updated June 2016. Preparted for the Swedish Anti-nuclear Movement.") (In Swedish only.) Available at (5 October 2018): http://www.nonuclear.se/historien-om-avvecklingen-lasse-karlsson.

general.[6] The current goal is for electricity production to be 100% from renewable energy sources by the year 2040. However, reactor operators have stated they will apply for life-time extension for six reactors into the early 2040s.

Since the mid-1970s, the nuclear industry and government have been putting great financial resources towards dealing with long-term management of the full range of nuclear waste, particularly spent fuel. Following is a description of the spent fuel management situation and the current and proposed low and intermediate level nuclear waste facilities. The industry's planned facility for "long-lived" low and intermediate level waste, called "SFL", is in the beginning stages of the planning process and not addressed here (SKB expects to submit a license application for SFL about the year 2030).

"Operating data plus electricity production and fuel quantities based on planned operation."

	Thermal capacity/net capacity	Electricity production up to and including 2016	Fuel up to and including 2016	Total for planned operation		Electricity production	Spent nuclear fuel
				Planned operating time	Operation up to and including		
Start of commercial operation	MW	TWh	Tonnes of uranium	Years		TWh	Tonnes of uranium
F1 (BWR) 10/12/1980	2928/984	251	883	60.0	08/12/2040	434	1348
F2 (BWR) 07/07/1981	3253/1120	245	864	60.0	05/07/2041	462	1418
F3 (BWR) 22/08/1985	3300/1167	270	897	60.0	20/08/2045	536	1509
O1 (BWR) 06/02/1972	1375/473	81	367	45.4	30/06/2017	82	367
O2 (BWR) 15/12/1974	1800/638	154	537	41.1	31/12/2015	154	537
O3 (BWR) 15/08/1985	3900/1400	256	841	60.0	14/08/2045	568	1577
R1 (BWR) 01/01/1976	2540/881	197	720	44.5	14/06/2020	219	773
R2 (PWR) 01/05/1975	2500/807	210	630	44.2	13/07/2019	224	671
R3 (PWR) 09/09/1981	3135/1063	225	607	60.0	07/09/2041	421	1126
R4 (PWR) 21/11/1983	3300/1118	217	672	60.0	20/11/2043	444	1235
B1 (BWR) 01/07/1975	1800/600	93	419		30/11/1999	93	419
B2 (BWR) 01/07/1977	1800/600	108	424		31/05/2005	108	424
BWR total	22696/7863	1657	5951			2656	8372
PWR total	8935/2988	651	1909			1089	3032
All total	31631/10851	2308	7860			3746	11404

The fuel's actual weight in the form of complete fuel assemblies is considerably larger. A BWR fuel assembly weighs about 300 kg whereof about 180 kilograms consist of uranium. After burn-up, the uranium weight decreases slightly. For a PWR fuel assembly, the corresponding weights are about 560 kg and about 460 kg respectively.

Source: SKB. 2017-04. "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." Technical Report TR-17.02. 52 pp. See p. 35. Available at (5 October 2018): https://www.skb.se/publikation/2487964/TR-17-02.pdf. Some of the spent fuel from the research reactors is included in the KBS-3 application but is not included in the estimated quantity in tonnes, though is included in the estimate in the number of canisters.

Low and Medium Level Nuclear Waste

There is currently an operating facility for storage of low and medium level nuclear waste, owned and operated by the Swedish nuclear industry. The facility is called SFR[7] and is located at Forsmark in the municipality of Östhammar, about 145 km north of Stockholm. SFR began operation in 1988. The facility is in bedrock from 50 to 140 meters below the Baltic Sea and consists of four caverns 160 meters in length and a chamber with a 50 m deep silo. The facility is connected to the surface with two parallel km long tunnels. SFR has a capacity of 63,000 cubic meters of waste, of which about 60% has been used to date.

[6] Government Offices of Sweden. 16 June 2016 ."Framework agreement between the Swedish Social Democratic Party, the Moderate Party, the Swedish Green Party, the Centre Party and the Christian Democrats." Available at (5 October 2018): https://www.government.se/49d8c1/contentassets/8239ed8e9517442580aac9bcb00197cc/ek-ok-eng.pdf.

[7] SKB. Undated. "SFR - Final Repository for Short-lived Radioactive Waste." Six pp. Available at (5 October 2018): http://www.skb.com/our-operations/sfr/. Direct link to download (5 October 2018): http://skb.se/upload/publications/pdf/SFR_folder_engelsk.pdf.

The facility is continually filling with water, which is being pumped out. Closure of the facility entails shutting off the pumps, thus allowing the facility to fill with water. A major uncertainty is the rate of contamination by radioactivity of the Baltic Sea that will result.

There is currently a legal review underway for an additional low and medium level waste facility proposed to be placed immediately adjacent to the currently operating one. The proposed new facility is twice as big as the current one, is proposed to also be underneath the Baltic Sea but at a depth of 120 – 140 m below the surface. This new facility is subject to the same decision making process described above for management of spent fuel. SKB has estimated that if all the approvals required are received, construction could begin sometime in 2020 and take about six years.[8]

The Polluter Pays Principle

The law in Sweden specifies that the producer of nuclear waste is responsible for its management and for covering the costs involved (i.e. the polluter pays principle). To manage nuclear waste, the nuclear power companies together formed the Swedish Nuclear Fuel and Waste Management Company (*Svensk Kärnbränslehantering AB*) (SKB). These nuclear power companies and their respective percent of the ownership of SKB are Vattenfall AB (36%), Forsmarks Kraftgrupp AB (30%), OKG Aktiebolag (22%), and Sydkraft Nuclear Power AB (12%).[9] Vattenfall AB is 100% owned by the Swedish state.[10]

The Swedish "Public Access to Information and Secrecy Act" is strong freedom of information legislation. There are established routines for the public to request and receive much of the information handled by all levels of government and government agencies. As SKB is a private company, this area of law does not apply to its work on the nuclear waste issue. The result is a lack of transparency.

Current and Projected Quantities of Spent Fuel

From the 12 commercial nuclear reactors listed below (not all of which are operating), according to SKB, up to and including 2016 there was a total of 7,860 tonnes of spent fuel, and the total estimated planned quantity is 11,404 tonnes (both measured as quantity of uranium).[11]

Financing and the Tri-annual Research and Development Programme

In 2017, SKB estimated total future costs to the point of closure of all the facilities for handling all the nuclear waste originating from nuclear reactors to be SEK 98 billion (about EUR 9.5 billion) of which the costs for spent fuel will be SEK 31.56 billion (about EUR 3 billion).[12] The major portion of the money intended for future management and storage of nuclear waste comes from funds paid according to law by the nuclear industry into the Nuclear Waste Fund,[13] which is managed by the government. At the end of 2017, the size of the fund was SEK 67.236 billion (about EUR 6.45 billion).[14] SKB has estimated the total expenditures from the Nuclear Waste Fund from 1982 and up until the end of 2017 to be about 4.8 billion SEK (about EUR 460 million),[15] which makes an average of about 190 million SEK per year (about EUR 18.22 million per year).

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[8] SKB. 2017-12-11. "Planned extention of the SFR." SKB website. Available at (5 October 2018): http://www.skb.com/future-projects/extending-the-sfr/.

[9] SKB. 2017-09-21. "Organisation." SKB website (10 July 2018): http://www.skb.com/about-skb/organisation/

[10] Vattenfall. 2015-10-22. "Ownership." Vattenfall website (10 July 2018: https://corporate.vattenfall.com/investors/key-facts/ownership/.

[11] SKB. 2017-04. "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." Technical Report TR-17.02. 52 pp. See p. 35. Available at (5 October 2018): https://www.skb.se/publikation/2487964/TR-17-02.pdf. Some of the spent fuel from the research reactors is included in the KBS-3 application but is not included in the estimated quantity in tonnes, though is included in the estimate in the number of canisters.

[12] Ibid. See pp. 37-38.

[13] The Nuclear Waste Fund. 2018. "Facts about the Nuclear Waste Fund 2017". 20 pp. Available at (5 October 2018): http://www.karnavfallsfonden.se/informationinenglish/annualreport.4.4945b3d81223a8cbbf8800024168.html. Direct link (5 October 2018): http://www.karnavfallsfonden.se/download/18.46d462c3159fb761aca1f4f/1523619691724/Fakta+om+K%C3%A4rnavfallsfonden+2017+engelska.pdf (276 KB).

[14] Ibid. See p. 2.

[15] Op. cit., note 8. See p. 39.

The annual disbursements are subject, according to government ordinances, to a review that began in 1986 of tri-annual research and development reports by the nuclear industry that cover a four-year period into the future.[16] It is of note however that though the government in these to date 12 tri-annual reviews has either implicitly or explicitly approved the KBS-3 method for demonstration and planning purposes, the government has made clear that the method itself has not been approved.[17] It is also of note that the government agency tasked with examining the tri-annual reports has after each examination recommended acceptance to the government, though has pointed out deficiencies. That government agency is the Swedish Radiation Safety Authority (SSM) (since it was founded in 2008 and before then its predecessors), the same agency that had the task of examining the 2011 application by the nuclear industry to build a facility that in each one of these tri-annual reviews continued to be developed. As described below, this application was also examined by the Land and Environment Court.

The Current, Ongoing Court and Regulatory Agency Review

There is an ongoing, formal review of a SKB application to build an underground spent fuel management system using the KBS-3 method (see box).[18] Below is a summary of the distinct phases and milestones in the decision-making process. It will take at least until the end of 2020 to reach the point of a final decision, though it could take several more years. If the government gives its approval, extensive regulation of implementation awaits.

The KBS-3 Method and Spent Fuel Management System, Proposed Location, and Some Main Uncertainties

There is no facility operating anywhere in the world, using any method, that is intended as a permanent storage for spent fuel produced by commercial electricity producing nuclear reactors. To deal with spent fuel, the nuclear industry worldwide favours a method termed “deep geological repository,” of which the KBS-3 method is a variation.[19] The nuclear industry in Finland has adopted the KBS-3 method.

“Deep” in this context means several hundred meters below the surface. A depth of kilometres deep is referred to as “very deep,” which is the proposed depth for the alternative approach called the deep borehole method. The suitability of the KBS-3 method as compared to alternative methods has been debated in Sweden since the KBS-3 method was first introduced. Alternatives proposed for further investigation are dry storage in a highly secure facility onsite at nuclear power stations (e.g. hardened on-site storage - HOSS[20]) or at a central location (e.g. dry rock deposit - DRD[21]), and very deep boreholes. Rolling stewardship can be applied with any method but monitoring requirements are small with very deep boreholes and great with dry storage.

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[16] SKB. 2016-09. "Programme for research, development and demonstration of methods for the management and disposal of nuclear waste." Technical Report TR-16-15. 314 pp. Available at (5 October 2018). https://www.skb.se/publikation/2485289/. The financial data is given in a separate document, of which “Plan 2016” referenced above is the companion volume for 2016.

[17] See e.g. the government’s decision on the 1995 and 1998 reports, for which the references follow. [1995] Miljödepartementet. 1996-12-19. “Regeringens beslut. Program för forskning m.m. angående kärnkraftavfallets behandling och slutförvaring.” In Swedish only. 6 pp. See p. 3. [1998] Miljödepartementet. 2001-11-01. “Regeringens beslut. Komplettering av program för forskning, utveckling och demonstration för kärnavfallets behandling och slutförvaring, Fud-program 98.” In Swedish only. 8 pp. See p. 1.

[18] Much of the application is available in English on the SKB website, e.g. (5 October 2018): http://www.skb.com/future-projects/the-spent-fuel-repository/our-applications/.

[19] See e.g.: Chatzis, Irena (IAEA Department of Nuclear Energy). 5 January 2018. “Solving the Back End: Finland's Key to the Final Disposal of Spent Nuclear Fuel.” Available at (5 October 12018): https://www.iaea.org/newscenter/news/solving-the-back-end-finlands-key-to-the-final-disposal-of-spent-nuclear-fuel#infobox.

[20] Kamp, Kevin. 2010-11-16. “Statement of Kevin Kamps, Beyond Nuclear to Blue Ribbon Commission on America’s Nuclear Future, November 16, 2010, Washington, D.C.” Available at (5 October 2018): http://www.nonuclear.se/KevinKampBRC20101116.

[21] Mörner, Nils-Axel. 2013. “Dry Rock Deposit - an alternative of handling the high level nuclear waste - the DRD method - a short presentation.” 30 pp. Available at (5 October 2018): http://www.nonuclear.se/drd_method2013morner.

KBS: refers to the 1976 "*KärnBränsleSäkerhet*" ("Nuclear Fuel Safety") project formed by the Swedish Nuclear Fuel Supply Co. (*Svensk kärnbränsleförsörjning AB*) (SKBF), the predecessor of Swedish Nuclear Fuel and Waste Management Co. (*Svensk Kärnbränslehantering AB*) (SKB).
KBS-1 (1977): dealt with reprocessed nuclear fuel, and was soon abandoned due to problems surrounding reprocessing.
KBS-2 (1979): the first description of direct deposition of nuclear fuel.
KBS-3 (1983):[22] the second and more detailed description of a repository several hundred meters underground, and based on the three barriers of copper canisters, bentonite clay, and the bedrock. The copper canisters and bentonite clay are mutually dependent, i.e. one will not function unless the other also functions optimally.

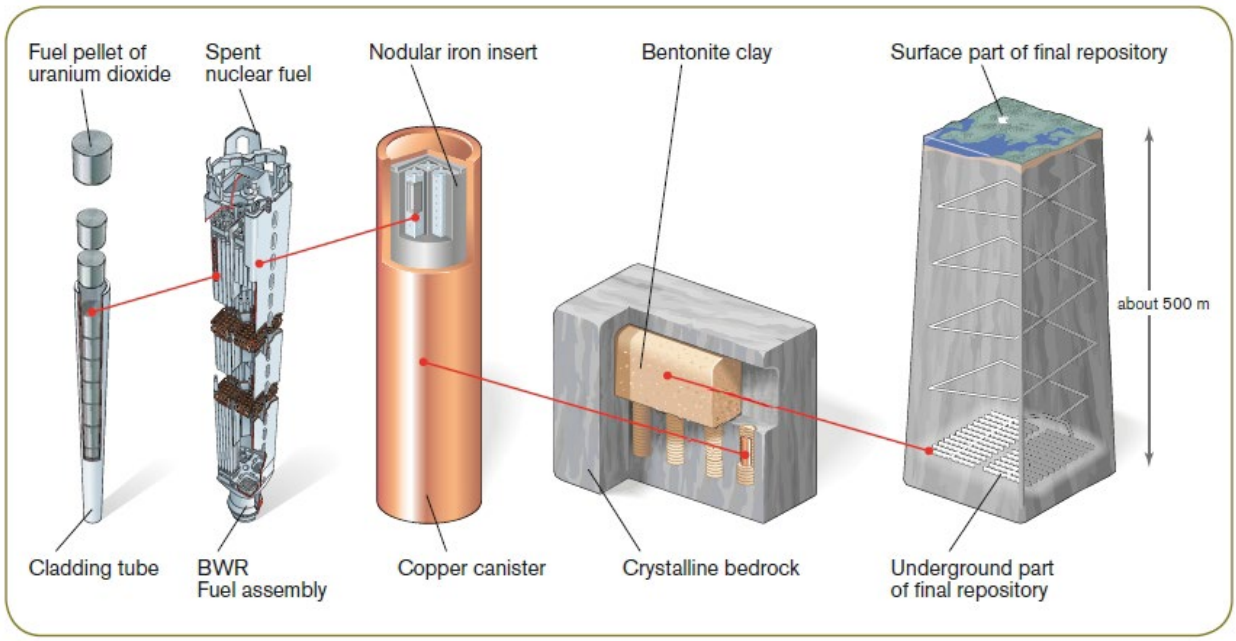
The KBS-3 method and spent fuel management system consists of:

- Storage under water for about a year on-site at the nuclear power station.
- Interim storage for about 30 years at the underground Clab facility, located at Oskarshamn and currently operating. *The Clab facility requires active cooling dependent on electricity. The local community, Oskarshamn municipality, wants the facility decommissioned. Clab may not have the capacity to hold the projected quantity of spent fuel. For that reason, SKB has investigated using temporary dry storage if there is a period when there is not enough room in Clab and deposition is not yet possible in a KBS-3 repository.*
- A multi-barrier system to delay release of radionuclides, with three components, granitic bedrock, bentonite buffer, and encapsulation in copper canisters with a cast iron insert. *There are concerns about all these barriers, as given below.*
- An encapsulation facility proposed to be located immediately adjacent to the Clab facility, together termed "Clink".
- An estimated 5,700 canisters.[23]
- Canister dimensions are: outer diameter 1.05 m, length 4.85 m, copper wall thickness 4.9 cm, average maximum weight about 2.5 tonnes.[24]
- Deposition of the canisters in bedrock 470 m below the surface in circular vertical holes eight meters deep and two meters in diameter, proposed to be located at Forsmark, about one km from the three Forsmark nuclear reactors. *The depth may not be adequate to withstand permafrost in the next ice age.*[25] *Impacts from bacteria at the depth of the canisters is also a concern. Further, the location may not be suitable due to geologic and geophysical conditions, e.g. earthquake risk. In addition, there are the risks associated with close proximity to the Forsmark nuclear power station. The coastal placement also adds the risk of contamination of the Baltic Sea, which according to HELCOM is one of the most radioactive seas on Earth.*[26]
- Surrounding the canisters with bentonite clay. *The clay buffer could be compromised by several processes, particularly due to exposure to water, heat and air. For example, water is needed for the clay to swell and protect the copper canister. The bedrock at Forsmark is*

[22] SKB. 2016-11-02. "Our method of final disposal." Available at (5 October 2018): http://www.skb.com/future-projects/the-spent-fuel-repository/our-methodology/. The "3" in "KBS-3" is sometimes interpreted as referring to the three barriers though that was not the meaning initially.
[23] Op. cit., note 8. See p. 36.
[24] SKB. 2010-12. "Design, production and initial state of the canister." Technical Report TR-10-14. See p. 28 re. weight, and pp. 33-34 for dimensions. Available from (10 July 2018): http://skb.se/upload/publications/pdf/TR-10-14.pdf (3.8 MB).
[25] SKB addresses the permafrost depth issue on e.g. page 200 in their March 2011 application in the document: "Long-term safety for the final repository for spent nuclear fuel at Forsmark. Main report of the SR-Site project. Volume I. Technical Report TR-11-01." A 2015 study by specialists at the University of Turku, Finland found that in the next ice age permafrost could reach to the depth of the planned repository in Finland and Sweden. Reference for the report: Räsänen, Matti E.; Huitti, Janne V.; Bhattarai, Saroj; Harvey Jerry III; Huttunen, Sanna. 2015. "The SE sector of the Middle Weichselian Eurasian Ice Sheet was much smaller than assumed." Quaternary Science Reviews 122 (2015) 131e141. All authors from University of Turku, Finland. Available at (5 October 2018): https://www.sciencedirect.com/science/article/pii/S0277379115002243.
[26] Swedish Environmental Movement's Nuclear Waste Secretariat (Milkas). 2006-12. "The Baltic Sea is Radioactive." 4 pp. Available at (5 October 2018): http://www.nonuclear.se/baltic-radioactive200612.html.

however relatively dry and swelling could take over a thousand years. Heat from the canisters over this long period may mean the clay will be dry due to the heat and never swell as required.

- Filling the underground tunnels up to the surface, closure, and abandonment by the nuclear industry, without any method of monitoring in place. *There is a long-term risk of unintentional and intentional intrusion. There is also the issue of whether or not a monitoring system should be designed, and how to preserve knowledge in the long-term about the site location and hazards of the materials in the repository.*



"**The KBS-3 method.** The method involves encapsulating the spent fuel in copper canisters which are then emplaced, surrounded by a buffer of bentonite clay, in deposition holes in a tunnel system at a depth of about 500 metres in the bedrock."

Source: SKB. 2011-03. "Environmental Impact Statement, Interim storage, encapsulation and final disposal of spent nuclear fuel." 337 pp. See Figure s-2, p. 12. Available (5 October 2018) at: http://www.skb.com/future-projects/the-spent-fuel-repository/our-applications/ (PDF, 37.3 MB). Direct link: http://www.skb.com/wp-content/uploads/2016/03/21014-MKB-ENG-webb-150dpi.pdf.

Copper Corrosion

The safety of the KBS-3 method is based on a number of principle assumptions, of which one is that the canister material, copper, will corrode so slowly that the radionuclides will not be released over the period the waste is dangerous to life forms. Copper was chosen in the 1970s as a material because of its well-known corrosion resistance.[27] In some environments, copper is immune to corrosion, as proven by geological formations containing copper. It is however not possible to replicate such environments due to the presence of water and air in any constructed system. Of concern is thus the rate of copper corrosion, not if corrosion will occur. The Swedish Radiation Safety Authority has carried out a detailed assessment and continues to examine concerns.[28]

Several factors influence the rate of copper corrosion. Main factors are the ability of the bentonite buffer to isolate the copper from water and air and the resulting chemical processes, and

[27] Copper Development Association Inc.. December 1998. "Copper's Role in the Safe Disposal of Radioactive Waste: Copper's Relevant Properties - Part I." Available at (5 October 2018): https://www.copper.org/publications/newsletters/innovations/1998/12/nuclear.html.

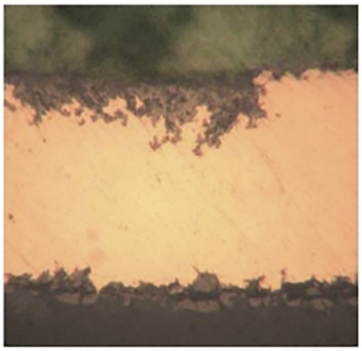
[28] Macdonald Digby D.; Sharifi -Asl, Samin; Engelhard, George R.; Urquidi-Macdonald, Mirna. "Issues in the corrosion of copper in a Swedish high level nuclear waste repository." 2012. Swedish Radiation Safety Authority (SSM) Report number 2012:11. 160 pp. Available at (5 October 2018): https://www.stralsakerhetsmyndigheten.se/en/publications/reports/waste-shipments-physical-protection/2012/201211/.

how these processes are influenced by heat, radioactivity, and the presence or absence of oxygen.[29] The Swedish Land and Environmental Court identified five main concerns (see below).

Due to the complex factors that cause corrosion, it is uncertain if copper and iron are suitable materials. Research independent of the nuclear industry has found that leakage due to copper corrosion may begin after 100 years, and leakage from most canisters would occur after about 1,000 years.[30] Further, tests simulating the intended system with spent fuel in a canister have not been carried out.[31]

Above: Appearance of copper after 15 years of exposure in distilled water at room temperature. Hydrogen from corrosion can escape from the left container but not from the container to the right. The water volume was equal in the flasks in beginning of the exposure.

Below: Light optical cross-section of a green area seen in the left flask above of the initially 100µm metallic copper foil after 15 years exposure in distilled water. Localised corrosion attack is clearly visible.



Source: Hultquist, G. B., Szakálos, P., Graham, M. J., Sproule, G. I., & Wikmark, G. 2008. Detection of hydrogen in corrosion of copper in pure water. In Int. Corros. Congr.: Corros. Control Serv. Soc. (pp. 2378–2386). Available at (10 July 2018): https://www.researchgate.net/publication/238102363_Detection_of_hydrogen_in_corrosion_of_copper_in_pure_water (PDF, 2.5 MB).

[29] Regarding the presence or absence of oxygen see: He, Xihua & M. Ahn, Tae & Gwo, Jin-Ping. 2017. Corrosion of Copper as a Nuclear Waste Container Material in Simulated Anoxic Granitic Groundwater. CORROSION. 74. 10.5006/2471.

[30] Szakálos Peter, Leygraf Christofer, Rosengren Anders, Seetharaman Seshadri, Grinder Olle, Linder Jan. 2018-04-26. ”Analys av kärnbränsleförvarsfrågan efter mark-och miljödomstolens yttrande till regeringen.” (”Analysis of the nuclear fuel management issue after the Land and Environment Court's statement to the government.”) In Swedish only. 4 pp. Available at (5 October 2018): http://www.nonuclear.se/szakalos-et-al20180426analys-av-karnbransleforvarsfragan. This document was submitted to the government for its ongoing review, and the government has requested comments from SKB by 30 April 2019. The authors include a group of specialists at The Royal Institute of Technology (KTH) in Stockholm, who are at the forefront of copper corrosion research worldwide, and a former employee of SSM. Research in Sweden on copper corrosion by independent specialists was spearheaded by KTH Associate Professor Gunnar Hultquist, who died in February 2016. He initiated an experiment in 1986 showing that copper corrodes in oxygen-free water. His results were eventually confirmed internationally by independent methods.

[31] Ibid.

The Nuclear Family

The current legal review can be considered to have started in 2002 when SKB started the consultation process required for its license application. Many people involved in the legal review are veterans who have followed the spent fuel management issue since the mid-1970s when the nuclear industry first presented the KBS concept. Beginning in 2002, the interaction between the full range of stakeholders intensified. Typically, there were more than a dozen meetings a year with all of the stakeholders present, whereas before, the public and environmental NGOs were often excluded. There has thus been much opportunity for all stakeholders to interact. This led in the early 2000s to describing the regular meeting attendees as the "nuclear family".

Meeting organisers often made a special effort to attract all stakeholders. The Nuclear Waste Council, a committee appointed by the government, usually at least once a year invited most stakeholder organisations, excluding SKB, to send a few representatives to a roundtable discussion about current priorities.

The Decision Making Process and Milestone Dates

1. **Public consultation**: From 2002 to 2014. Beginning in 2005, funding became available from the Nuclear Waste Fund for environmental NGOs to participate in the public consultation process. Municipalities involved in site investigation studies began to receive funding from the Nuclear Waste Fund in about 2001. In 2007, an evaluation of the support to the NGOs was carried out by the Swedish Agency for Public Management (*Statskontoret*), the government agency for analysis and evaluation of state and state-funded activities. The result was a recommendation to continue the funding.[32] Funding has continued to date, though in 2017 began to come from the government's general budget, rather than the Nuclear Waste Fund.
2. **Formal submission of applications:** 16 March 2011. The law requires submission of applications according to two areas of law, as well as compliance with laws that are the responsibility of the respective county and municipality. One of these areas of law is the Environmental Code, which is handled by the Land and Environment Court (*Mark- och miljödomstolen*) (MMD), that addresses environmental impacts in general, including impacts on human health. The other area of law is the Nuclear Activities Act, which is handled by the Swedish Radiation Safety Authority (*Strålsäkerhetsmyndigheten*) (SSM) and focuses on radiation safety issues. The applications together comprise about 9,000 pages (excluding later submitted supplementary information) of which there is an approximate 2,000 page overlap.
3. **Assessment of the applications with regard to completeness:** During this phase, both SSM and MMD carried out rounds of public consultations where the public was invited to submit comments on the completeness of the initial application documents, and then on SKB's replies, which included supplementary information both requested by SSM and MMD, as well as provided on SKB's own initiative.
4. **Release of the applications for public review:** 29 January 2016 by both SSM and MMD. The ensuing review included further rounds of public comment.
5. **Formal, legal, public, oral hearings held by MMD:** Five weeks of hearings were held in September and October 2017, including three weeks in Stockholm and one week in each of the municipalities of Östhammar and Oskarshamn, and on-site inspections of the two locations.

   During these hearings, independent scientists who made submissions took the position that the application should not be approved because of uncertainties in the area of their particular expertise. All the environmental NGOs and members of the general public who participated also took the position that the application should not be approved, for a wide range of reasons including the moral and ethical dimension. Many of the independent scientists and representatives of the environmental NGOs were veterans who had followed the nuclear waste issue since the 1970s.

   The municipality of Oskarshamn expressed support for the proposal, and the municipality of Östhammar declined to take a position.

[32] Statskontoret. 2008-04-17. Samråd, stöd och slutförvar – en utvärdering av stöd till ideella organisationer ur Kärnavfallsfonden. 104 pp. In Swedish only. Available at (5 October 2018): http://www.nonuclear.se/statskontoret20080417.html.

6. **Final statements to the government by SSM and MMD:** 23 January 2018. These statements cannot be appealed in the court system.

   Reuters reported the same day that Environment and Energy Minister Karolina Skog stated no decision would be made during 2018.[33] That was to be expected due to the date for Swedish parliamentary elections set for 9 September 2018. Östhammar municipality had planned a non-binding referendum 4 March 2018. Only hours after the announcement on 23 January 2018 of the "no" by MMD , Östhammar municipality cancelled their referendum, stating they would re-examine the need for a referendum in the future.

   SSM had been examining the nuclear industry's waste plans since the agency was founded in 2008, and had inherited responsibility from the agency's predecessors. For MMD the review was a first worldwide for a court of law.
7. **Initial government review:** began 23 January 2018 and is currently underway. The government appointed a working group that has requested SKB provide comments on specific information by 30 April 2019. Taking place at the same time as this government review is a special government examination of the Nuclear Activities Act, which is planned to be completed by April 2019 at the latest.[34]
8. **Request by the government for the respective municipality to make a decision regarding permissibility.** If the government does not at the outset reject SKB's application, before making its decision, which is termed a decision on permissibility, the government must ask the local municipalities of Östhammar and Oskarshamn if they will permit the respective local activity. If a municipality says no, but the government wants to approve permissibility, the government can regardless give approval under certain conditions, i.e. force the municipality to accept the facility.

   Though the government has not yet communicated with the two municipalities on the subject, on 11 June 2018 the municipality of Oskarshamn gave their approval to the government for continued operation of the Clab interim storage facility and for construction of the encapsulation facility, referred to as Clink.

   The municipality of Östhammar has stated that they will wait for contact from the government, and may carry out a non-binding municipal referendum before making a decision.
9. **Final government review and decision.** In this phase the government has authority to decide whether or not a full parliamentary debate will be held. Previous Ministers and some individual Members of Parliament have stated that they favour a full parliamentary debate.

   If the government gives its approval, it is possible to appeal the decision to the Supreme Administrative Court. Environmental lawyers have pointed out that without adequate facts, government approval would not comply with the Environmental Code due e.g. to uncertainty regarding the risks of corrosion of the copper canisters.[35]
10. **If government approval is granted, regulation of implementation.** If the government gives its approval, the industry application goes back to both SSM and MMD who must set conditions for implementation according to their respective laws. The nuclear industry is obligated to comply with these conditions. In theory, a condition can be so stringent that the industry is unable to comply. The conditions set by the MMD can be appealed to a higher court. The industry can apply to be able to carry out its implementation unhindered during an appeal process.

    Once implementation begins, the County Administrative Board (*Länsstyrelsen*) and the Environmental Protection Agency (*Naturvårdsverket*) have responsibility for monitoring compliance with the Environmental Code. The Radiation Safety Authority monitors compliance with the Nuclear Activities Act.

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[33] Reuters. 2018-01-23. "Swedish regulators disagree on safety of nuclear waste plan." Available at (5 October 2018): https://uk.reuters.com/article/us-sweden-nuclear-regulator/swedish-regulators-disagree-on-safety-of-nuclear-waste-plan-idUKKBN1FC21P

[34] See the Swedish government website at (5 October 2018): https://www.regeringen.se/rattsliga-dokument/kommittedirektiv/2017/06/dir.-201776/ (in Swedish only). The deadline may be extended.

[35] SVT Nyheter (Swedish Television News). 2018-01-25. "*Miljöjurister om slutförvaret: Osäkerhet bör leda till ett nej*." ("Environmental lawyers comment on the final repository: uncertainty should lead to a no.") In Swedish only. Available at (5 October 2018): https://www.svt.se/nyheter/lokalt/uppsala/miljojuristen-regeringen-borde-saga-nej.

"Decision-making in the Face of Uncertainty"

"Decision-making in the Face of Uncertainty" is the title of the 2018 annual "Nuclear Waste State-of-the-Art Report" published by the Swedish Council for Nuclear Waste. The council is a committee of specialists appointed by the government to "clarify matters relating to nuclear waste and decommissioning and dismantling of nuclear facilities and to advise the Government in these matters".[36] The subject matter, for which about 118 pages are devoted, and title of the report was well chosen as at the time of this writing, more than 40 years after the KBS project began, there is a general consensus among all stakeholders, with few exceptions, that there are many uncertainties. The stakeholders with this common ground include both proponents and opponents of the industry proposal currently being examined: the nuclear industry, all levels of government, independent researchers, and environmental NGOs. There is however a wide range of views among this diverse group of organisations and individuals about the severity of the uncertainties and how to deal with them, with seemingly all possible combinations present. This is particularly evident when comparing the results of the reviews by the Land and Environment Court (MMD) and the Swedish Radiation Safety Authority (SSM). The main results of their reviews are given below, followed by a short comparison of the two.

The MMD Review - The Only Review Worldwide by a Court of Law

The review by a court of law in Sweden of the application by the Swedish nuclear industry to build a system for managing spent fuel is the only review by a court of law ever to have taken place anywhere in the world dealing specifically with an application for a spent fuel management system.[37] The review was based on the area of law termed the Environmental Code (*Miljöbalken*), which came into force in 1999 in order to better formulate regulations spread over a multitude of other laws.[38] Compliance with the Environmental Code is handled by a special branch of the court

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[36] This quote is from the Council's website, Available at (5 October 2018): http://www.karnavfallsradet.se/en. The annual reports are available in Swedish and English at the Council's website. For the 2018 report see: http://www.karnavfallsradet.se/en/nuclear-waste-state-of-the-art-report-2018-decision-making-in-the-face-of-uncertainty. Direct link (10 July 2018) (1.1 MB): http://www.karnavfallsradet.se/sites/default/files/documents/sou_2018_8_eng_webb.pdf.

[37] There have however been court proceedings that have included spent fuel management in a general sense as part of the case. Two Greenpeace initiated examples are the rejection in 1995 by the Supreme Court regarding construction of a reprocessing plant in Zheleznogorsk in the Krasnoyarsk Territory of Russia, and the High Court ruling in the UK in 2007 that a "misleading" and "seriously flawed" consultation process had been carried out by the government on the construction of new nuclear power plants.

An IAEA report from 1993 "Nuclear Energy Inquiries - National and International" documents more than 30 inquires that vary widely in nature (http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/25/026/25026317.pdf).

In Canada, in 1997 a 10-year federal environmental assessment review of AECL's planned concept for a geologic repository was concluded. No site was chosen and the conclusion was that there were many unanswered questions about the system and thus it was not ready to be implemented (see e.g.: www.ccnr.org/fearo_hlw.html and www.ccnr.org/hlw_fearo_summary.html).

Also in Canada there is a 1980 report of nuclear waste management that followed 15 weeks of hearings by the Parliamentary Select Committee on Ontario Hydro Affairs.

The California Energy Conservation and Development Commission under the guidance of Emilio Varanini III conducted a series of hearings in the 1970s on the question of whether or not there exists a safe method for disposing of spent fuel and concluded that such a method did not currently exist, and also stated that such a method may never exist. Emilio Varanini III, in an interview, famously said that the belief in safe disposal was based not so much on scientific evidence but rather on "engineering euphoria". The California Report had legislative consequences, as the California Legislature had previously enacted a law banning any further nuclear reactors in California unless a safe disposal method could be shown to exist. The Legislature accordingly asked the Commission to determine whether or not such was the case. The Legislature accepted the advice of the Commission and so no new reactors were allowed in California.

[38] Government Offices of Sweden. 1999. "The Swedish Environmental Code, Ds 2000:61." 164 pp. Available at (5 October 2018): https://www.government.se/legal-documents/2000/08/ds-200061/. Direct link (10 July 2018): https://www.government.se/49b73c/contentassets/be5e4d4ebdb4499f8d6365720ae68724/the-swedish-environmental-code-ds-200061 (PDF, 559 KB). This English version does not include revisions that came into force on 1 August 2018, which changed the clause regarding nuclear activities from Chapter 17, Section 1 (6) to Chapter 17, Section 1 (1).

system called the Land and Environment Court (*Mark- och miljödomstolen*) (MMD).[39] An MMD review is a formal court process that results in either a judgment or in some specific situations in a statement to the government regarding permissibility. For such exceptions, if the government decides to permit the activity, the case is returned to MMD to examine details of the permit and conditions that apply. According to Chapter 17, Section 1 (1) of the Environmental Code an application to build a spent fuel management system is such an exception. Thus, responsibility for the final decision rests with the government. The statement by MMD, and by the Radiation Safety Authority (SSM) according to the Nuclear Activities Act, are considered recommendations to the government and cannot be appealed in a court process.

The Land and Environment Court is usually made up of a four-member panel consisting of one judge, one technical counsellor, and two special members with technical competence. In exceptional situations, so as to broaden the expertise available to the court, two more members may be added. This occurred with the application to build a spent fuel management system, which was heard by a six-member panel, the maximum number that may be appointed. There were two judges, two court technical councillors, and two special members.

Result of the Review by the Court: No, Unless Certain Conditions are Met

MMD wrote in their press release regarding their 23 January 2018 statement to the government:

> The court cannot, based on the current safety assessment, find that the final repository is safe in the long-term.[40]

Though the overall result of the Land and Environment Court (MMD) review was that the industry application should not be permitted, some aspects of the application were considered permissible, e.g. the encapsulation plant, where the copper canisters are intended to be built and loaded. The formulation used for the overall result was not that the activity should be prohibited due to certain deficiencies, but rather the activity can be permitted if specific uncertainties are resolved. The court wrote the following on page one of its 23 January 2018 statement, which is also included as page one in the separately published summary.

> The activity is permissible if:
>
> 1. The Swedish Nuclear Fuel and Waste Management Co. provides documentation that the final repository will meet the requirements of the Environmental Code in the long term, despite remaining uncertainties regarding how the protective capability of the canister is affected by:
>   a. corrosion due to reactions in oxygen-free water
>   b. pit corrosion due to reaction with sulphide, including the contribution of the sauna effect to pit corrosion
>   c. stress corrosion due to reaction with sulphide, including the contribution of the sauna effect to stress corrosion
>   d. hydrogen embrittlement
>   e. radioactive radiation impact on pit corrosion, stress corrosion and hydrogen embrittlement.

[39] See the website of the Swedish Courts, e.g. (10 July 2018): http://www.domstol.se/Funktioner/English/The-Swedish-courts/District-court/Land-and-Environment-Courts/

[40] Mark- och miljödomstolen, Nacka tingsrätt. 2018-01-23. ”Mark- och miljödomstolen lämnar sitt yttrande till regeringen i målet om ett slutförvar för kärnavfall”. (Unofficial translation: ”The Land and Environment Court submit their statement to the government in the case regarding a final repository for nuclear waste”.) In Swedish only. Available at (5 October 2018): http://www.nackatingsratt.domstol.se/Om-tingsratten/Uppmarksammade-mal/Ansokan-om-slutforvar-for-anvant-karnbransle-mm/.

> 2. The long-term responsibility for the final repository according to the Environmental Code has been clarified.[41]

Regarding various uncertainties, following are more quotes from the court's statement.

Long term responsibility (emphasis added)**:**
According to the SKB application their responsibility ends after a few decades when the facility is sealed. The court however clearly opposed the industry approach of abandonment.

> The Land and Environment Court is of the view that the final storage of nuclear waste is an activity that will continue even after the final repository is sealed. According to the Environmental Code, **the licensee has a responsibility for the activity until further notice, i.e., there is no time limit.** ... Östhammar municipality is opposed to taking ultimate responsibility for the final repository. ... **It is of urgent importance to clarify who has long-term responsibility** under the Environmental Code.[42]

Risk of copper corrosion (emphasis added)**:**

> The investigation shows that there are uncertainties, or risks, regarding how much certain forms of corrosion and other processes can impair the ability of the canister to contain the nuclear waste in the long term. **Overall, these uncertainties about the canister are significant and have not been fully taken into account** in the conclusions of SKB's safety analysis.[43]

Radiation safety (emphasis added)**:**

> SKB and SSM have expressed the view that conditions relating to radiation safety should not be prescribed in a permit under the Environmental Code. **The Court finds that the evidence presented to date does not provide a sufficient basis on which to assess the issue.**[44]

Risk in general (emphasis added)**:**

> **...a new calculated result of the entire safety assessment is required...** [45]

Uncertainties in general concerning the repository, radiation safety, and the geologic conditions (emphasis added)**:**

> The Land and Environment Court finds that a number of uncertainties regarding the protective capability of the repository remain outstanding. The investigation of radiation safety issues to date shows that the effects of

[41] Nacka District Court, Land and Environmental Court. 2018-01-23. "Summary Statement of the Land and Environmental Court, Case no. M 133-11, Matter: Permit according to the Environmental Code for an integrated system for final disposal of spent nuclear fuel and nuclear waste; at this time a matter of a statement to the government." Unofficial translation. Available at (5 October 2018): http://www.nonuclear.se/mmd20180123summary-statement-case-m1333-11spent-fuel.
[42] Ibid. See page 4 *
[43] Op. cit., note 41, see page 4.
[44] Op. cit., note 41, see page 11.
[45] Op. cit., note 41, see page 10.

> the activity cannot be predicted with enough certainty to permit the formulation of any final conditions. There may therefore be a need to provide for a probationary period for evaluation under the Environmental Code. However, further investigation and deliberation are necessary. **The Court however emphasizes that the study of the bedrock formation at Forsmark, for example, leaves ambiguities that may justify a probationary period** for evaluation for the determination of conditions regarding respect distances or other precautionary measures.[46]

Unintentional and intentional intrusion:

> The issue of long-term knowledge retention should be resolved at the latest when the repository is sealed in about 70 years.[47]

Result of the Review by SSM: Yes, Providing Certain Conditions are Met
SSM wrote in their 23 January 2018 statement to the government that they approve SKB's application provided certain conditions are met. Following are three quotes from the statement (emphasis added).

> **Preconditions for SSM's recommendation**
> SSM recommends approval of the licence applications **subject to the precondition that SKB ensures that the preparatory preliminary safety analysis reports (F-PSARs) as well as management systems for the facilities are further developed** in accordance with the established procedure for a step-wise permitting process under the Act on Nuclear Activities,... [48]
>
> **SKB may commence construction of the facility only after SSM has examined and approved a Pre-construction Safety Analysis Report (PSAR).**[49]
>
> SKB's preparatory preliminary safety reports for the encapsulation plant and the final repository, prior to the government's decision on

[46] Op. cit., note 41, see p. 14 (summary statement), and p. 554 in the full statement.
[47] Mark- och miljödomstolen, Nacka tingsrätt. 2018-01-23. "Yttrande, Mål nr M 1333-11, Saken: Tillstånd enligt miljöbalken till anläggningar i ett sammanhängande system för slutförvaring av använt kärnbränsle och kärnavfall; nu fråga om yttrande till regeringen". 566 sid. Se sid. 80. In Swedish only. Available at (5 October 2018): http://www.nackatingsratt.domstol.se/Om-tingsratten/Uppmarksammade-mal/Ansokan-om-slutforvar-for-anvant-karnbransle-mm/.
[48] SSM. 2018-01-23. "Pronouncement on licence applications for permission to develop facilities for final management of spent nuclear fuel - Statement of the Swedish Radiation Safety Authority." 5 pp. See p. 2. Ref. no: SSM2011-1135 and SSM2015-279. Document no: SSM2011-1135-23. Available at (5 October 2018): https://www.stralsakerhetsmyndigheten.se/en/areas/radioactive-waste/spent-nuclear-fuel-repository/final-repository-for-spent-nuclear-fuel/our-review-process/pronouncement-on-repository-applications/. Direct link to PDF (364 KB) (5 October 2018): https://www.stralsakerhetsmyndigheten.se/contentassets/078506f952ae4357847628edcc1785a4/pronouncement-on-licence-applications-for-permission-to-develop-facilities-for-final-management-of-spent-nuclear-fuel-statement-of-the-swedish-radiation-safety-authority.
Swedish original: SSM. 2018-01-23. "Yttrande över ansökningar om tillstånd till anläggningar för slutligt omhändertagande av använt kärnbränsle." 4 pp. See p. 2. Diarienr: SSM2011-1135 and SSM2015-279. Dokumentnr: SSM2011-1135-23. Available at (5 October 2018): https://www.stralsakerhetsmyndigheten.se/omraden/radioaktivt-avfall/slutforvar/slutforvar-for-anvant-karnbransle/stralsakerhetsmyndighetens-granskning-av-ansokan/slutforvarsyttrande-till-regeringen/. Direct link to PDF (5 October 2018) (345 KB): https://www.stralsakerhetsmyndigheten.se/contentassets/b99c23f76a044b57b76174051b587407/ssm2011-1135-23-yttrande-over-ansokningar-om-tillstand-till-anlaggningar-for-slutligt-omhandertagande-av-anvant-karnbransle.pdf.
[49] Ibid. See p. 3.

> a permit under the Nuclear Activities Act, aim primarily to justify the company's selection of location and method in the permit application. For the examination of SKB's documentation for the permit review regarding these issues, SSM takes into account that **certain supplementary information is expected** for details during the continued stepwise review process after a government decision on permission and before a decision by SSM to allow the facilities to begin operation.[50]

Specifically with regard to the copper corrosion issue SSM wrote that the issue might be resolved in the future. Three quotes from the statement on this topic follow (emphasis added).

> According to SSM **there is potential to achieve** an acceptable corrosion barrier with a 50 mm thick copper casing.[51]
>
> **A development phase is also required** to demonstrate appropriate techniques for manufacturing, sealing and testing such canisters to make it likely that the required requirements can be complied with.[52]
>
> **SSM has not formulated specific requirements** related to the speed of corrosion of the encapsulation.[53]

Comparison of the Statements by SSM and MMD to the Government

SSM gave a yes providing certain conditions are met, and MMD gave a no unless certain conditions are met. The legal tradition followed by MMD does not allow giving approval if events in the future eventually lead to compliance. On this topic MMD stated:

> When assessing the long-term safety of the final repository, no consideration can be given to research and development to be undertaken after a decision on permissibility.[54]

Though SSM and MMD used different formulations, for SKB the result in practice in some key areas is the same. Both SSM and MMD see the need for an improved overall safety analysis and resolution of the copper corrosion issue as severe. For both SSM and MMD the uncertainties surrounding copper corrosion are currently so great that the project should not be implemented unless the uncertainties are resolved. Both SSM and MMD recommended to the government that SKB not be allowed to begin construction of any part of the system applied for.

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[50] SSM. 2018-01-23. “2018:02. Sammanfattning. Beredning inför regeringens prövning Slutförvaring av använt kärnbränsle.” In Swedish only. Unofficial translation. 102 pp. See p. 10. Report no. 2018:02 ISSN 2000-0456. Available at (5 October 2018): https://www.stralsakerhetsmyndigheten.se/omraden/radioaktivt-avfall/slutforvar/slutforvar-for-anvant-karnbransle/stralsakerhetsmyndighetens-granskning-av-ansokan/slutforvarsyttrande-till-regeringen/. Direct link to PDF (10 July 2018) (2.3 MB): https://www.stralsakerhetsmyndigheten.se/contentassets/96342ee1d37e4111b032be88ccb158bf/201802-sammanfattning.

[51] Ibid. See p. 66.

[52] SSM. 2018-01-23. “2018:03. Remissammanställning. Beredning inför regeringens prövning Slutförvaring av använt kärnbränsle.” In Swedish only. Unofficial translation. 142 pp. See p. 48. Report no. 2018:03 ISSN 2000-0456. Available at (5 October 2018): https://www.stralsakerhetsmyndigheten.se/omraden/radioaktivt-avfall/slutforvar/slutforvar-for-anvant-karnbransle/stralsakerhetsmyndighetens-granskning-av-ansokan/slutforvarsyttrande-till-regeringen/. Direct link to PDF (10 July 2018) (2.6 MB): https://www.stralsakerhetsmyndigheten.se/contentassets/a3ade3d30e7944038eeed5dc33ef8edf/201803-remissammanstallning.

[53] Ibid. See p. 98.

[54] Op. cit., note 41, see page 6.

Abbreviations

- KBS-3: the third version of the *Kärnbränslesäkerhet* (Nuclear Fuel Safety) project formed by the Swedish nuclear industry
- MMD: *Mark- och miljödomstolen* (Land and Environment Court)
- SKB: *Svensk Kärnbränslehantering AB* (Swedish Nuclear Fuel and Waste Management Co.)
- SSM: *Strålsäkerhetsmyndigheten* (Swedish Radiation Safety Authority), the regulatory agency dealing with radiation issues

For More Information from Environmental NGOs in Sweden

- The Swedish NGO Office for Nuclear Waste Review (MKG): www.mkg.se/en
- The Swedish Environmental Movement's Nuclear Waste Secretariat (Milkas): www.milkas.se and www.nonuclear.se/en/kbs3

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