# The Review of the Swedish Spent Fuel Repository License Application

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*The paper is an analysis of the on-going legal review of the Swedish nuclear industry's application for a license to build a final repository for spent nuclear fuel at the Forsmark nuclear power plant. The industry's nuclear waste company, the Swedish Nuclear Fuel and Waste Management Co., SKB, submitted the license application in March 2011. Since then the application is under review by the Swedish regulator, the Swedish Radiation Safety Authority, and in parallel by the Swedish Environmental Court. The review process is presently considering what additional work has to be done by SKB in order for the application to be reviewed on its merits. A number of issues are being considered, including alternative siting and methods, i.e. the use of very deep boreholes. However, the most problematic issue for the nuclear waste company is the possible lack of sufficient scientific evidence that the artificial barriers of copper and bentonite clay – that are fundamental for the long-term safety case – will work as intended. If the company fails to provide the regulator and the court with sufficient evidence that the safety case is valid the application may be rejected.*

## I. INTRODUCTION

Twelve light-water nuclear reactors at four nuclear power plants were put on line in Sweden between 1972 and 1985. Two reactors at the Barsebäck nuclear power plant were decommissioned in 1999 and 2005. The oldest reactor, Oskarshamn 1, is now over 40 years old and legal preparations are under way for decommissioning. With the rapid expansion of renewable electricity production from biomass and wind in the Nordic countries the price of electricity is now low and varies with wind power intermittency. This is making it more and more difficult for base-load nuclear electricity to be competitive. Nuclear new-build is possible since a change in the Nuclear Activities Act in 2010. However, state subsidies are not allowed making it unlikely that a decision is taken to build a new Swedish nuclear reactor.

The production of spent nuclear fuel from the Swedish nuclear reactors is thus likely to be a finite problem. The spent fuel is transported by ship from the reactors to an underground wet central storage facility called Clab at the Oskarshamn nuclear power plant. At the end of 2013 there was a a total of 5,740 tonnes of spent nuclear fuel in the facility [1]. In addition, there were 556 tonnes of SNF in the cooling pools and approximately 1,000 tonnes of fuel in the cores of the 10 operating reactors. In the cores of the ten operating reactors there is approximately an additional 1,000 tonnes of fuel. The licensed capacity of Clab is 8,000 tonnes but this can be expanded to 11,000 tonnes within the present two pools with repackaging of the fuel in more compact storage cassettes. The final repository for spent nuclear fuel is planned for a capacity of 12,000 tonnes, but this amount assumes that the existing Swedish reactors are in operation for the 50 to 60 years. Even though these operating lifetimes are what the nuclear industry is presently planning for, it is an unlikely scenario with the present development of the Swedish energy system. It is likely that all Swedish spent fuel after the shutting down of the reactors will fit in Clab if the plans for a repository for the spent fuel do not materialize.

The Swedish program to develop a final repository for spent nuclear fuel was started in the mid-1970s. The history of Swedish radioactive waste management and the development of a system for governance has been covered elsewhere [2, 3], but by the 1980s the responsibility for financing, management and final disposal of the spent nuclear fuel had legally been placed firmly with the nuclear industry. The nuclear power plant owners created a special company to take this responsibility, the Swedish Nuclear Waste Management Company AB, with the acronym SKB. In 1983 the company presented the third version of the so-called KBS concept or method for final disposal of spent nuclear fuel [4]. The method has only gone through minor modifications since then.

The KBS method relies on a system of man-made barriers to hinder the migration of radionuclides from the deposited spent nuclear fuel for hundreds of thousands of years. The spent fuel is to be put into a cast iron insert and then encapsulated within a 5 cm thick copper canister. The canister is to be 5 meters high and have a diameter of 1 meter. The canisters are to be lowered into bored holes in mined tunnels at a depth of about 500 metres in granite bedrock. A bentonite clay buffer will be placed around the copper. The deposition tunnels are then filled with more clay.

The safety case of the KBS method relies primarily on the integrity of the copper canister when protected by the bentonite clay buffer. The copper canister should be corrosion resistant in the repository environment which, when completed, should contain water but no molecular oxygen. Biological and chemical processes consume the oxygen in the repository quickly after the deposition holes

are sealed. In the late 1970s and the early 1980s, several theoretical studies bearing on the behaviour of copper in anoxic conditions were conducted and the case for using copper as a canister material was thought to be solid. Later reviews carried out by the nuclear waste company SKB have continued to make this case, even though some problems were perceived due to possible corrosion by sulphides from bacterial activity in the repository.

The risk of sulphide corrosion increased the importance of the bentonite buffer in the safety case. The bentonite clay buffer absorbs water from the surrounding bedrock and swells. The water-saturated clay should prevent the movement of ground water with corrosive substances towards copper surface as well as hindering the transport of corrosion products from the surface. Thus, for the safety case to be valid, the clay has to swell and protect the copper.

In addition, the safety case has to ensure that the repository will not be affected by mechanical and chemical changes that could take place during repeated ice ages. The bedrock surrounding the repository has some retaining and retarding capacity in the safety case, but function of the artificial barriers of copper and clay are critical to the safety case.

Since the 1970s a complicated and lengthy site selection process was carried out by SKB [2, 3]. In 2009 a site for a Swedish repository for spent nuclear fuel was chosen at the Forsmark nuclear power plant. An alternative site investigation had been carried out at the Oskarshamn nuclear power plant, but the bedrock at Forsmark was considered better as the mean distance between fractures in the rock was longer. It was however decided to plan for a copper canister encapsulation plant to be built at the site of the Clab interim storage facility. The combined facility is to be named Clink.

From 2002 until 2010 the nuclear waste company SKB carried out an extended consultation process for the development of the Environmental Impact Statement for a license application for a repository for spent nuclear fuel. On March 16, 2011, the company submitted a licence application for a repository at the Forsmark nuclear power plant and a combined encapsulation and interim storage facility Clink at the Oskarshamn nuclear power plant.

In this paper the review process of the application until the present is described and scenarios for how the application review process will likely proceed are presented.

## II. THE STATUS OF THE REVIEW OF THE LICENSE APPLICATION FOR A SWEDISH SPENT FUEL REPOSITORY

On March 16th, 2011, the Swedish nuclear waste company SKB submitted a license and permit application to build a final repository for spent nuclear fuel at the Forsmark nuclear power plant and a combined encapsulation and interim storage facility Clink at the Oskarshamn nuclear power plant. The application comprised of 7000 pages and included a safe analysis called SR-SITE and an environment impact statement.

As the Swedish legislation prescribes the application was submitted to the regulator, the Swedish Radiation Safety Authority, SSM, as well as to the Land and Environmental Court [5, 6]. The regulator is carrying out a review according to the Nuclear Activities Act and the Radiation Protection Act. The court is carrying out a review according to the Environmental Code. At the end of the regulator's review an opinion is given to the Swedish Government that will decide whether to give a license or not. At the end of the court's review and procedures an opinion is also given to the Government that will decide whether a permit is to be given or not. Before making the decisions the Government will according to the Environmental Code also have to ask the local communities of Östhammar, where the Forsmark nuclear power plant is situated, and Oskarshamn if they will accept the facilities. The communities have a veto, but the Government can under certain conditions override the veto. It the Government's decision is positive the court and the regulator will them proceed and give conditions for the license and permit.

But the review process is so far very far away from a Government decision. The licence applications are, after almost four years review, still not complete enough for a more comprehensive review.

The application review process of the regulator and the court is clearly divided into two parts. First the applications are examined in order to make sure that they are complete enough for a more comprehensive review on the merits of the applications on the issues involved. Once the regulator and the court decide that the applications are complete enough the application is formally announced for general comment. There is a then a comprehensive process of review on the merits of the applications on the issues involved. Once this review is completed the regulator and the court submits their opinions to the Government for a final decision.

The legislation is very clear on the issue that the regulator's and the court's review processes are to be done in parallel and be well coordinated. Especially important is that the formal announcement of a complete application is done at the same time by the regulator and the court. Also, as the regulator and the court have to approve the same Environmental Impact Statement, they have to agree on what is to be included in it.

The review process of the court and the regulator differ quite considerably. The regulator, the Swedish Radiation Safety Authority, SSM, mainly interacts with the applicant, the nuclear waste company SKB, in the license review. The court reviews the permit application by letting SKB interact with all other parties, including the regulator. The court process is thus a more open and

democratic process. The regulator does send out the application for opinions but uses the input mainly for its own review. Of interest is that in the court process the regulator can influence the applicant, SKB, via the rulings of the court if the company refuses to comply with requests put directly to it.

To an outsider the whole legal review process appears to be complicated. And it has proven to be so, especially in the very large and complicated case of a repository for spent nuclear fuel. There is actually new legislation waiting that would integrate the Nuclear Activities Act and the Radiation Protection Act into a separate Chapter in the Environmental Code [7]. This would give more power to the court compared to the regulator but would streamline the license review process. It is possible that the new legislation can come into effect during the present license review process.

**II.A. The license review process until present**

The license review process is proceeding very slowly and is, as stated above, only in the phase where the completeness of the application is being discussed.

After the license application was submitted to the regulator, the Swedish Radiation Safety Authority and the Land and Environmental Court in March 2011 they both sent out the application for opinions regarding the quality and the completeness of the application. The regulator has a process with a broad outreach, including the universities, other state agencies, the nuclear waste communities and environmental NGOs. The regulator wanted the opinions to be submitted by June 1st 2012.

The Land and Environmental Court normally has a much more limited outreach for questions regarding the completeness of a license application. In this case, however, the court decided not only to ask other authorities, but also to ask the Swedish Council for Nuclear Waste, the nuclear waste communities and the environmental NGOs. The Swedish Council for Nuclear Waste is the Government's scientific advisory body and the council has decided that it can participate in the completeness phase of the court's review. The council has not been asked for its opinion by the regulator. As noted above, the regulator has to supply its opinion to the court, as it is a state agency. The court also wanted opinions on the completeness of the license application by June 1st 2012. An example of how such an opinion, put both to the court and the regulator, can be seen by the common opinion provided by the Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review [8].

While the court after having reviewed the opinions, sent them to the nuclear waste company SKB for comment, the regulator started a process of its own evaluation of the completeness of the application. The regulator set in process the commissioning of a number of consultancy studies on issues that it felt were of concern. The studies were within a wide range of issues, most of them oriented to looking at various parts of the safety analysis. Issues covered ranged from modelling of geology, hydrology and the biosphere, copper corrosion and clay integrity and erosion, rock mechanics and much more. The wide variety of issues can be seen in the consultancy reports that the regulator received from the consultants [9].

As the regulator during the autumn of 2012 did its own analysis of the licence application and as the consultancy reports started to arrive, a number of requests for additional information were sent to the nuclear waste company SKB. The passing of requests and the replies from the waste company have continued until the present. The volume of this exchange of information can be seen in act SSM 2011/2426 at the regulator where over 100 exchanges are registered [10].

The continuing work of the regulator to demand extra information from the nuclear waste company SKB has made it difficult for the Land and Environment Court to decide what additional work has to be done from the court's perspective. The nuclear waste company made its first response to the demands for additional work put by various parties, including the regulator to the court in April 2013. The parties were been given a new chance to respond in turn to the company's views by the autumn of 2013. Since then the court has basically been waiting as the to and fro with demands for additional work and answers between the regulator and the waste company continues.

One relatively important issue of contention within the licence review is how much the court should deal with issues that regard radiation safety. The nuclear waste company SKB has stated that the court not have to deal with issues that the regulator has the main responsibility for and does not send additional information provide to the regulator to the court. All other parties, including the regulator who wants to be able to argue on radiation safety aspects in the court, contest this decision by the waste company. As there are a number of contested issues, including copper corrosion, which the company with its action tries to keep out of the court, it will be interesting to see what the court decides on this issue. The court is waiting for the to and fro between the regulator and the waste company to end before deciding on this issue.

As of the autumn of 2014 it is known that the nuclear waste company SKB intends to send in additional information to the regulator and the court in the beginning of 2015. The regulator will receive additional information of the issue of anoxic copper corrosion. The regulator and the court will receive an additional request from the company to expand the license for how much spent fuel can be stored in the intermediate storage facility Clab from 8000 tonnes to 11000 tonnes.

After receiving the additional information in the beginning of 2015 the court has a plan to send out all the additional work sent in by the company for comments to the parties. The parties are asked to give their opinion on the material supplied and of more work is needed. Towards the summer or early autumn of 2015 it is possible that we for the first time will see decisions by the court. One issue that the court needs to decide is how much of the radiation safety issues, including copper corrosion, it will want in the court review. This decision as well as possible decisions that the nuclear waste company has to do more work and provide additional information may delay the review considerably.

**II.B. The major issues under consideration**

Of the issues that are under consideration in the regulator and the court review a few stand out. The most important one is the discussion whether the artificial barriers of copper and clay will behave in the repository as modelled in the safety analysis. Other issues that are of importance are whether better alternatives regarding choice of method and siting have been neglected. Also of some interest is the existence of a number of endangered species at the site chosen by the nuclear waste company SKB.

As stated in the introduction the safety case for the KBS method is dependent on whether the artificial barriers of the copper canister and the bentonite clay buffer can isolate the spent fuel from the surrounding flowing groundwater. On the early 1980s copper was considered as good as gold when it comes to corrosion resistance in the repository environment where there is no free oxygen. Already in the 1980s some contested this, but in 2007 a group of researchers based at the Royal Institute of Technology in Stockholm published results from research showing that when there is no free oxygen available water corrodes copper [11-13]. The oxygen in the water reacts with copper with the release of hydrogen. As long as the hydrogen can be allowed to escape or is consumed the reaction continues. The nuclear waste company has strongly contested this but has so far not been able to show that they are right. The evidence rather points in the direction of the results of the critics.

It is quite difficult to do experiments that allow the process to be analysed. This has led to a long and murky scientific debate right in the middle of the licence review. As of the spring of 2014 the regulator has said that it now is of the understanding that the contested corrosion process exists. In September 2014 the nuclear waste company SKB also acknowledged that the process exists theoretically and that it may have a surface influence but will stop very early. The regulator wants proof of this and in the beginning of 2015 some important results from work done by SKB will be presented.

It is difficult to judge how important for the long-term safety a "new" copper corrosion process introduced into the safety analysis would be. There are indications from research at the Äspö Hard Rock Laboratory that the rate of corrosion could be of the safe order under repository conditions as if the copper canisters were expose to air. If this were the case the corrosion rate would be on the order of 1000 times higher than acceptable in the safety analysis. Also, the corrosion process could influence other corrosion processes in a negative way. The nuclear waste company SKB has made a "what if" analysis in the safety analysis if copper corrodes with water which tries to show that as long as the clay buffer is very tight the process will stop. The problem with the bedrock in Forsmark is, however, that it is relatively dry. Water is needed for the bentonite buffer to swell and become tight, but in the Forsmark rock this may take 1000 years or more in most deposition holes. It has, however, also been questioned whether the clay will ever become tight due to the influence of heat from the canisters that may permanently damage the clay and stop it from swelling as modelled.

Another issue that is under discussion is how more information the nuclear waste company SKB needs to provide on alternative methods. According to the legislation it has to be shown that the method chosen, in this case the KBS method, is the best available technology. The company argues that there is no available alternative to the KBS method and therefore no description of legal alternatives have to be given in the application and the environmental impact statement. However, since the early 1990s there has been a constant demand from environmental NGOs that the nuclear waste company SKB further evaluate the alternative method very deep boreholes. The company has very reluctantly done any work, and in the original license application the description of very deep borehole disposal was so poorly done that not only the environmental NGOs but also the regulator and the Swedish Council for Nuclear Waste wanted a better description in the application. How the court and the regulator will value this issue remains to be seen.

Of interest in any environmental legal case in Sweden is the issue of whether the site chosen is the best one. In the case of Forsmark the site was chosen before a site at the Oskarshamn nuclear power plan because the mean distance between major cracks was larger. Whether this criteria is sufficient as a factor for site choice according to the law remains to be seen. Since the early 2000s there has been a discussion of whether an inland siting in a recharge area for large-scale regional groundwater flows could provide a safer site than a site in the seacoast. In addition the Forsmark site is situated in a geo-tectonic fault, which could give problems during an ice age compared to a site in a more central part of the Scandinavian shield. There is also a relatively new issue

connecting the Forsmark site to risks for corrosion. There are high-voltage direct-current seabed cables linking Finland and Sweden that appear to give a risk of corrosion by stray currents in the Forsmark bedrock. Also on this issue it remains to be seen how the court and the regulator value this issue.

Another issue that was perhaps not foreseen to be so much of an issue in the license review as it has turned out to be is the nature values of the site chosen. There are at least two red-listed species, a frog and an orchid, on the site and the whole area around Forsmark has high nature values. In the last decade the Land and Environmental Courts have been become very strict in how it values the existence of red-listed species on sites for projects. But whether this could be a problem for the nuclear waste company SKB after 40 years of developing a method and almost as many years in finding a site remains to be seen.

## III. SCENARIOS FOR THE FUTURE OF THE REVIEW OF THE LICENSE APPLICATION FOR A SWEDISH SPENT FUEL REPOSITORY

As described above it is possible that the review of the licence application for a Swedish repository for spent nuclear fuel at the Forsmark nuclear power plant gets closer towards the end of the completeness phase during 2015. The environmental court will move towards a number of decisions if the nuclear waste company can provide sufficient information to the regulator on the outstanding issues in the regulatory review.

Of interest is also that the regulator, the Swedish Radiation Safety Authority, has stated that it will not wait much longer to announce preliminary results of its review. During 2015 we are likely to how the regulator leans on major issues.

It is, however, not unlikely that the court will make decisions that will delay the continued review further. If the court decides that it will not allow the nuclear waste company SKB keep important radiation safety issues, such as copper corrosion, out of the courts jurisdiction there will be a delay while the company gives the court the information it has already given the regulator. It is then possible that the court will rule positively on requested demands from different parties for additional work by the company. Such work has to be done and completed before the court will continue its review.

So, at the earliest, but only if the court only allows the nuclear waste company claims and none of the oher parties, may we see an official announcement of a complete application by the court and the regulator by the end of 2015. After this takes place there will be an extended time period, likely for at least a year, for issues to be argued on merits. After which the court and the regulator will write opinions to the government.

Finally, at what date the Swedish Government can take a decision on a repository for spent fuel in Forsmark remains to be seen. But it is unlikely to take place before 2017.

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