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Identifying remaining socio-technical challenges at the national level: Sweden

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1 CHARACTERISING SWEDISH RADIOACTIVE WASTE MANAGEMENT

1.1 The development of nuclear activities in Sweden and government policy regarding radioactive waste

The Swedish civil nuclear programme commenced more or less in synergy with a Swedish military programme for the development of an independent Swedish nuclear weapons deterrent in the late 1940s (Kjellman 2001, Larsson 1987, Sundqvist 2002). It was argued that low-cost energy production could be combined with the reprocessing of spent fuel for the production of weapons grade plutonium for military ends. An Atomic Committee was formed bringing together representatives from the natural sciences and the military. This Committee recommended the exploitation of domestic resources of uranium and a new organization for the industrial development of atomic energy in Sweden. Thus, in 1947 the partly state-owned Atomic Energy Company was formed to co-ordinate the mining of uranium in Sweden and the development of Swedish reactor technology (Sundqvist 2002: 63). Three research reactors were soon commissioned including the Ågesta nuclear plant, a 10 MW heavy water reactor fed with natural uranium which provided domestic heating to a suburb of Stockholm between 1963 and 1974. The activities of the Atomic Energy Company culminated in 1970 with the costly cancelling of a larger scale heavy water reactor at Marviken which also coincided with the end of Sweden's ambitions to develop an independent nuclear weapons capability. Uranium mining operations which had been initiated in Randstad in Västergötland were also terminated (Sundqvist 2002: 64, Kjellman 2001: 13).

After the Marviken failure the Atomic Energy Company was fused with the nuclear division of the private company ASEA to form the ASEA Atom Company which soon became a leading producer of light-water reactor technology the development of which was encouraged by the growing availability of enriched uranium for import. Thus, Sweden embarked on a light-water reactor programme which led to 6 reactors being commissioned in the 1970s and 6 in the 1980s. These 12 reactors were located at 4 coastal sites: Oskarhamn, Ringhals, Forsmark/Östhammar and Barsebäck. Ten of these reactors remain in operation today accounting for 40-50% of Sweden's electricity production. The two Barsebäck reactors were decommissioned in 1999 and 2005 in line with a faltering government commitment to phase-out nuclear power to the extent that economic circumstance permitted this (Elam and Sundqvist 2009).

Sweden helped pioneer the field of radiation protection through the efforts of the medical physicist Rolf Sievert whose international actions directly contributed to the founding of the Swedish Radiation Protection Institute (SSI) in 1965. Already in 1956 an Atomic Energy Law was passed in Sweden to regulate the development of nuclear activities (Kjellman 2001: 12). A new government authority was established connected to this law, the Delegation for Nuclear Energy Issues, which in 1974 adopted the name of the Swedish Nuclear Power

Inspectorate (SKI). In 2008, SSI and SKI merged to form the new Swedish Radiation Safety Authority (SSM).

In accordance with the original 'Swedish Line' in the development of atomic energy linking up with a weapons programme, initial plans were made in the 1960s to construct a Swedish reprocessing plant on the Swedish west coast at Sannäs (Vedung 2005). This was considered a suitable site because it also offered bedrock conditions considered suitable for the geological disposal of high-level waste. Early local protests against these plans led to the first government investigation discussing the back-end of the nuclear fuel cycle in 1971. This report attached significant hopes to a collaborative OECD reprocessing project – the Eurochemic project – which involved the construction of a prototype reprocessing plant in Mol in Belgium. Sweden participated in this project and sent both spent fuel from its research reactors as well as technical workers to support its development (Sundqvist 2002: 59). However, this project proposing ambitious international collaboration in the management of radioactive waste and further development of advanced fuel cycles was terminated in 1974. In 1972 the first Swedish government committee to address the nuclear waste problem was set up the so-called AKA – utredningen (Använt Kärnbränsle och radioaktivt Avfall). This committee reported in 1976 and remained primarily concerned with issues of security of nuclear fuel supply rather than waste management per se (SOU 1976). The development of a reprocessing plant in Sweden for the future of the civil atomic energy programme was considered a priority. A technical approach to the geological disposal of high-level waste was proposed involving the encapsulation of vitrified waste in canisters of acid-proof steel to be surrounded by clay and deposited in bedrock (granite or gneiss) at a depth of at least 200m. The report also recommended the construction of a central interim storage facility for spent fuel prior to reprocessing. Two sites were suggested for the combined location of reprocessing, interim storage and geological disposal: the two existing reactor sites in Oskarshamn and Forsmark/Östhammar. The AKA investigation also led to the setting up of a government research organization called the Program Council for Radioactive Waste (PRAV) which worked closely with the Swedish Nuclear Fuel Supply Company (SKBF) set up in 1971 by Sweden's reactor owners to coordinate the future of nuclear fuel supply. As the waste problem became increasingly politicized in Sweden during the 1970s, so PRAV ended up being disbanded in 1981. As plans to develop reprocessing facilities in Sweden fell by the wayside due to growing disenchantment with nuclear power, so SKBF took over PRAV's concern with waste disposal as its own core concern and renamed itself the Swedish Nuclear Fuel and Waste Management Company (SKB) (Elam and Sundqvist 2009, Holmstrand 2001).

The nuclear waste issue was first discussed in the Swedish parliament in 1972. A key figure advancing anti-nuclear sentiment in Sweden during the 1970s was the Nobel prize winning physicist Hannes Alfvén who had been a member of the original Swedish Atomic Committee after World War II but who during the course of the 1960s experienced a combined change of nuclear heart and mind. Alfvén influenced greatly Thorbjörn Fälldin, the leader of the Swedish Centre Party who was elected Prime Minister in Sweden in 1976 heading the first bourgeois government to break the long run of Social democratic rule in Sweden after World

War II. Fälldin came to power determined to terminate the Swedish nuclear power programme which was just gaining momentum and which was strongly supported by the other parties in the new bourgeois coalition government which he led (Sundqvist 2002: chp 4, Anshelm 2006: chp 2).

Thus, anti-nuclear sentiment reached a new level in Sweden as a sixth Swedish reactor was due to be commissioned. The waste issue and the absence of a fully-developed solution to the long-term storage and disposal of high-level waste was presented as a vital stumbling block in the advancement of the nuclear power programme. Thus, a new government law was introduced resembling a 'trial of strength' between the opposing pro- and anti-nuclear forces in Swedish society. The Nuclear Power Stipulation Act introduced in 1977 made the fuelling of further reactors in Sweden dependent upon the fulfilment of certain conditions regarding the management and disposal of nuclear waste. If spent fuel was going to be reprocessed a contract which adequately provided for this needed to be secured and presented. More challengingly, before any new reactor could be fuelled, it had to be shown *how* and *where* the resulting high-level waste or non-reprocessed spent fuel could be finally stored with *absolute safety* (Sundqvist 2002: chp 4, Johansson and Steen 1981: 35, Anshelm 2006: chp 3). This can be seen as the original socio-technical challenge upon which contemporary Swedish nuclear waste management has been founded. It opened the way for a new and continually expanding mutual entanglement of technology and politics which has now been underway for more than 30 years. Over this period Swedish nuclear waste management has first and foremost remained a field of endeavour dedicated to publicly showing and demonstrating both technically and politically that safe disposal of spent nuclear fuel and/or high-level nuclear waste is possible to achieve (Elam et al 2010). This over-arching socio-technical challenge has then spawned other socio-technical challenges as attempts have been made to address its different component parts – for example, combined technical and political demonstrations of 'how' safe disposal can be achieved; of 'where' it can achieved; combined demonstrations showing what 'safety' itself should be reasonably interpreted as meaning; and even combined demonstrations of what constitutes a genuine and reliable 'demonstration' of nuclear safety.

The Nuclear Power Stipulation Act institutionalised nuclear waste management in Sweden establishing a clear division of responsibility between the implementer of nuclear waste management solutions and the government authority regulating this process of implementation. From the outset it has been the owners and developers of Sweden's nuclear reactors who have been held responsible for simultaneously financing and developing a long-term solution to the waste problem. Taking this task seriously has ultimately meant that the development of new reactor technology and new technologies of nuclear fuel supply has been subordinated to the development of new waste management technologies (Elam and Sundqvist 2009, 2011). SKBF established in 1971 to lead Sweden into a domestic engagement with nuclear reprocessing and a next generation of nuclear fuel cycles mutated into SKB at the beginning of the 1980s and became directly associated with incorporating the work of nuclear waste management into a planned phase out of nuclear power by 2010.

However, the formal clear cut division between implementer and regulator in Swedish nuclear waste management, resembling an agent-principal relation, is complicated by the fact that the Swedish state has always been highly involved in the development of nuclear activities in Sweden even after nuclear power generation was divorced from nuclear weapons production. State-owned industry was partly responsible for developing light-water reactor technology in Sweden and the wholly state-owned Vattenfall (originally the Royal Waterfall Board founded in 1909), has always remained the single most important reactor owner. This means that the Swedish state is the dominant owner of SKB alongside E.ON and the partly Finnish state-owned Fortum. Therefore, the Swedish state has always been both the leading agent and the leading principal in Swedish nuclear waste management and the successful careers of many individuals in the field have criss-crossed both sides of the divide since the mid-1970s (Elam and Sundqvist 2009, 2011).

In direct response to the Nuclear Stipulation Act, the Swedish reactor owners established the KBS Project (KBS = Kärnbränslesäkerhet = 'Nuclear Fuel Safety') in 1976-77. The original focus of this project KBS 1 was on the geological disposal of high-level waste after reprocessing of Swedish spent fuel abroad. However, after 1980 the focus changed to the direct geological disposal of spent nuclear fuel after a suitable period of interim storage (KBS 2 maturing into KBS 3), which remains the focus to this day. The combined technical and political demonstration of 'nuclear fuel safety' known as KBS 1 was specifically developed in order to allow for the fuelling of the Ringhals 3 reactor in Sweden in the late 1970s. Controversy over the extent to which KBS 1 successfully showed 'how' and 'where' a long-term solution to the nuclear waste problem could be pursued was intense (Anshelm 2006: chp 3). As SKI moved to accepting KBS 1 as evidencing the availability of an absolutely safe solution to the Swedish waste problem, so the Three Mile Island incident in the U.S. threw the future of the Swedish nuclear programme into uncertainty and a national referendum on the future of nuclear power was called. Reflecting the growing disenchantment with nuclear power at the end of the 1970s, all the voting options in the 1980 referendum supported a phasing out of the Swedish nuclear power programme which was still only half completed, the question was only whether this phase out should take place sooner rather than later (Elam and Sundqvist 2011: 252). As it turned out the result allowed for the completion of a twelve reactor programme (dependent on demonstration of an absolutely safe solution to the waste problem), to be followed by a decommissioning of each and every reactor after 25 years of operation. Thus, the last reactor to be commissioned in 1985 would be decommissioned in 2010. Support for this line strengthened after the Chernobyl accident in 1986 and then gradually waned during the course of the 1990s, although the decommissioning of the two reactors in Barsebäck did take place more or less in accordance with original plans. In 1997, a fixed date for the phasing out of nuclear power in Sweden was removed and made dependent upon economic circumstances permitting such a move. In 2009, the Swedish Centre Party revoked its historical opposition to nuclear power and plans for nuclear new build have been initiated (Elam and Sundqvist 2011: 254).

In 1984 both the Nuclear Power Stipulation Act and the Atomic Energy law were replaced by the Law on Nuclear Activities. This new law heightened the responsibility of the Swedish reactor owners to actively pursue a research, development and demonstration programme advancing a solution to the Swedish nuclear waste problem. Affirming the connection between nuclear waste management and the phasing out of nuclear power, the law also included a paragraph forbidding investments in new reactor technology in Sweden and the planning of new nuclear reactors. In 1985 a new government oversight body – the Swedish National Board for Spent Nuclear Fuel (SKN) - was created to evaluate SKB's progress towards a solution of the waste problem. This body was replaced in 1992 by the Swedish National Council for Nuclear Waste (KASAM recently renamed in Swedish Kärnavfallsrådet); an independent scientific board of advisors under the Ministry of the Environment (Kjellman 2001: 32). In 2007, this body changed its orientation somewhat in order to reach a broader public and heighten public engagement with nuclear waste issues in Sweden through, for example, the organization of regular public hearings and transparency forums on key issues.

In 1981 a law based on the 'polluter pays principle' was introduced to institutionalise the finance of nuclear waste management and the phase out of nuclear power in Sweden. A fee was levied at a given rate per kWh of electricity delivered by the reactor owner. The funds were originally deposited in interest bearing accounts in the Swedish Central Bank. These arrangements were then overhauled in 1995-1996 with the formation of the Swedish Nuclear Waste Fund which is a government authority specially tasked with managing the collected funds in order to achieve the best capital growth. SSM currently decides how the funds can be used following their assessments of SKB's programme of technical development (Andersson-Skog 2005, Kjellman 2001: 49).

Environmental legislation has come to play a growing role in Swedish nuclear waste management since the beginning of the 1990s. Legislation supporting the introduction of Environmental Impact Assessment consultations was first introduced in 1991 and the further piecemeal growth of environmental legislation culminated in the establishment of the Swedish Environmental Code in 1999. Therefore, after 1999 Swedish nuclear waste management is being pursued in relation two regulatory frameworks laid out in two 'framing laws': the Law on Nuclear Activities from 1984 and the Environmental Code from 1999 (Elam and Sundqvist 2009: 983). In relation to the first law the licensing process for nuclear waste facilities centres on the safety case submitted by SKB to SSM. In relation to the second law, licensing centres on the review of Environmental Impact Assessment statement submitted by SKB to the relevant regional Environmental Court in Sweden. In line with environmental legislation, funds have been made available from the Nuclear Waste Fund since 2004 to enable environmental groups and other non-governmental organizations to participate in the evaluation and public auditing of Swedish nuclear waste management policy. Such funding was already made available to municipalities participating in the siting process for a KBS-3 repository for spent fuel in the mid-1990s after lobbying firstly from the municipality of Oskarshamn (Elam and Sundqvist 2007).

1.2 Nuclear waste management as 'Nuclear fuel safety' (KBS): the Swedish research, development and demonstration process

An initial approach to the geological disposal of high-level waste was outlined in the AKA – utredningen in 1976. However, the priority for technical research remained innovations in nuclear fuel supply rather than nuclear waste management. The Nuclear Power Stipulation Act reversed this order of priority in 1977 and as nuclear power became subsequently more politicized, so Swedish plans for radical innovation in nuclear fuel technology were abandoned. Because the fuelling of reactors under construction was made dependent upon a demonstrated solution to the waste problem, radical innovation in nuclear waste management became a combined technical and political priority after the mid-1970s. Vattenfall co-ordinated the establishment of the KBS project and during an initial 9-month period roughly 450 scientists and technicians were employed to produce more than 60 technical reports launching the KBS concept for nuclear fuel safety (KBS 1977, Sundqvist 2002: 79). Given the time pressure, the concept built significantly on the one already outlined in the AKA – utredningen (Holmstrand 2001: 16, Anshelm 2006: 79). The KBS 1 concept remained based on the hope that if innovation in nuclear fuel technology was delayed in Sweden it would continue to rapidly develop elsewhere. However, after the Carter Administration decided to curtail nuclear reprocessing in the U.S. in the late 1970s, the only politically and technically 'safe' approach to nuclear waste management in Sweden became the direct geological disposal of spent fuel after a period of interim storage (Elam and Sundqvist 2009). As mentioned above, as a timetable for phasing out nuclear power was established in the early 1980s, so the nuclear fuel company SKBF became the nuclear waste management company SKB dedicated first and foremost to pursuing the KBS project as its core business. In this process initial plans for the deep disposal of vitrified waste (KBS 1) swiftly transmuted into plans for the direct disposal of spent fuel encased in copper canisters buffered by bentonite clay in crystalline bedrock at a depth of 500m (KBS 3).

The KBS 3 concept as a flexible concept for 'nuclear fuel safety' encompasses not only a deep repository for Sweden's spent nuclear fuel, but also a complete ensemble of nuclear waste facilities and handling methods. The majority of the elements in this ensemble have been successfully put into place after 1984. As early as 1982, the ship m/s Sigyn was commissioned for the transport of spent fuel between the different reactor sites on the Swedish coast. In 1985, a central facility (CLAB) for the interim storage of all of Sweden's spent nuclear fuel for at least 30 years was commissioned on the Simpevarp reactor site in Oskarshamn. In 1988, a separate repository for Sweden's low- and intermediate level waste was commissioned on the Forsmark reactor site in Östhammar municipality. In 1995, the Äspö Hard Rock Laboratory (what SKB call a 'dress-rehearsal facility') was commissioned in Oskarshamn, and three years later a canister laboratory for developing the copper canisters for deep disposal. In 2007, a bentonite clay laboratory was also established by SKB in Oskarshamn. In November 2006, SKB submitted a licensing application to establish an encapsulation plant in Oskarshamn. In March 2011 after the conclusion of detailed site investigations in both the municipalities of Oskarshamn and Östhammar, SKB submitted a licensing application to build a deep repository in the latter location.

To start with, in relation to the Nuclear Power Stipulation Act, government review of the KBS project was tied to applications to fuel new reactors. An absolutely safe solution to the waste problem had to be shown to be practically realisable before any new reactor could be fuelled. Thus, the very decision to fuel a reactor became testimony to the strength of Swedish designs for nuclear waste management. After the introduction of the 1984 Act on Nuclear Activities and the commissioning of the last Swedish nuclear reactor in 1985, the timing of government review of the KBS project had to be arranged differently. Thus, it was decreed in the 1984 Act that SKB should submit a new research, development and demonstration report (a so-called FUD report) every three years for government review in order to apply for continued funding from the Nuclear Waste Fund (Sundqvist 2002: 110). Previously, SKI and SSI were the most important reviewers of each FUD report, and after their merger in 2008, SSM is the key regulatory body. SSM also has the task of collecting other governmental and non-governmental reviews of each FUD report, for example from municipalities hosting SKB's activities and from environmental groups. SSM them summarizes all these review statements and composes a final audit document including its own views which is submitted to the government. The Swedish National Council for Nuclear Waste also makes its own separate independent review statement to the government. SKB is then given the opportunity to comment on the judgements put forward by the different reviewers. These reviewers are in turn allowed to provide final comment on SKB's reactions before the government makes a final decision whether or not to approve continued support of the KBS project. On occasion further research has been demanded requiring the production of a complementary FUD report.

1.3 Siting the geological disposal of radioactive waste in Sweden: essentially a tale of two communities

Already in the 1976 AKA report of the first governmental committee addressing nuclear waste management in Sweden, the two reactor sites in the municipalities of Oskarshamn and Östhammar were identified as the most logical sites for the geological disposal of the nation's nuclear waste (SOU 1976). It was recommended that geological investigations be initiated in both locations as soon as possible to assess their suitability for geological disposal (SOU 1976 – 30: 8 and 31: 89). Both sites were originally envisaged as capable of developing into 'nuclear industry parks' on the Swedish east coast where nuclear activities could be co-located in close proximity to each other. In the 1970s, nuclear waste management was seen as an activity developing hand in hand with nuclear reprocessing and innovations in nuclear fuel supply. Because the reactor sites in Oskarshamn and Östhammar were seen as alternative sites for a Swedish reprocessing plant, so they were also seen as alternative sites for the geological disposal of the high- and intermediate- waste resulting from reprocessing. Then, after the introduction of the Nuclear Power Stipulation Act in 1977 and the progressive reversing of the priorities for nuclear innovation from nuclear fuel supply (KBF) to 'nuclear fuel safety' (KBS) and the direct geological disposal of spent fuel, so the vision of Oskarshamn and Östhammar as nuclear industry parks was both preserved and modified

(Elam and Sundqvist 2009, 2011). The CLAB facility in Oskarshamn commissioned in 1985, for example, was originally planned as an interim storage facility for spent fuel prior to domestic reprocessing (KBF 1); then as a central national storage facility prior to the international reprocessing of Swedish spent fuel in France (KBS 1); and then as a storage facility prior to the direct geological disposal of spent fuel potentially in the same location (KBS 3).

The initial geological investigations in respect of the Nuclear Power Stipulation Act were carried out in 5 locations. Two of these sites were within 15km of the Forsmark reactor site in Östhammar and Tierp municipality and two were within 8km of the Simpevarp reactor site in the municipality of Oskarshamn (KBS 1977: chp 7). So an attempt was made to preserve not only the technical focus, but also the locational focus of geological disposal plans already outlined in the 1976 AKA report (Elam and Sundqvist 2009: 976). However, from 1978 onwards the demonstration of 'where' geological disposal could be safely implemented in respect of the Nuclear Power Stipulation Act became increasingly contested both politically and technically. In the process the locational focus temporarily shifted away from Oskarshamn and Östhammar/Tierp. The unique geology at Sternö outside of Karlshamn in the south of Sweden became the focus of attention at the end of the 1970s although controversy heightened as a panel of geological experts declared the existing state of geophysical knowledge insufficient to be able to give any firm assurances as to the 'absolute safety' of the KBS 1 safety case (Anshelm 2006: 83-84). After the national referendum on nuclear power in 1980 a new nationwide search was initiated to find the best available geology for the final disposal of Sweden's nuclear waste. Nationwide test-drillings, however, quickly gave rise to widespread local protests and although the fuelling of 6 reactors in Sweden after the introduction of the Nuclear Power Stipulation Act testified to the fact that an 'absolutely safe' solution to Sweden's nuclear waste problem had been successfully demonstrated to be available, this solution appeared to face insurmountable problems in finding a final geological home (Lidskog 1994).

The stalemate that arose with a readymade, and politically approved, technical concept for geological disposal left with no place to go due to widespread local opposition continued throughout the 1980s. At the beginning of the 1990s, however, SKB sought to win geological degrees of freedom for the geological disposal of nuclear waste by turning to a 'voluntary siting process' for a final repository in respect of a new principle of 'local acceptability' (Elam and Sundqvist 2007: 28). SKB argued in their FUD reports in 1986 and 1989 that the limited geological investigations they had been able to carry out confirmed that many locations in Sweden were most likely 'good enough' to host a KBS 3 repository. Research was also claimed to have demonstrated that excellence in engineering design can successfully compensate for less than perfect bedrock. Therefore, a turn to a voluntary siting process coincided with all municipalities in Sweden being invited to host initial 'feasibility studies'. Through such studies, which did *not* include detailed geological investigations, individual communities would be able to discover for themselves together with the nuclear industry if local acceptability of geological disposal plans could be won. Initially, few volunteer communities were forthcoming and only two feasibility studies were launched in isolated communities in the north of Sweden. However, after local referenda both these northern communities withdrew from the siting process for a geological repository. By 1994 SKB had decided to start focussing attention on communities already hosting nuclear facilities as the best sites for pursuing feasibility studies and securing local acceptability of the direct geological disposal of spent fuel. This marked the beginning of a re-centring of the KBS project on the two communities of Oskarshamn and Östhammar (Elam and Sundqvist 2007: 32).

In this process, the community of Oskarshamn in particular saw an opportunity to transform their historical relationship to the nuclear industry. Before agreeing to host a feasibility study they insisted on funds being made available to volunteer communities from the Nuclear Waste Fund to support local independent engagement with nuclear waste issues. They also insisted upon local powers of veto being guaranteed and assured so that volunteer communities could still always pull out of the siting process if they so desired. Just because SKB were now arguing that the geology was good enough to host a KBS 3 repository in many Swedish locations, so it was hardly justifiable to attempt to deny local powers of veto on the grounds that the larger national interest should override local interests. Also Oskarshamn argued that feasibility studies should be seen as conforming to and compliant with new environmental legislation and seen as early environmental impact assessment consultations (Elam and Sundqvist 2007: chp 7). However, SKB were reluctant to do this as they wanted to keep the KBS project more under the purview of the 1984 Law on Nuclear Activities and less under the purview of growing environmental legislation in the 1990s. Environmental legislation represented a new regulative game in town that the nuclear industry was as uncertain as others how to play. Oskarshamn also lobbied for greater independent national co-ordination of the siting process for a KBS 3 repository. Without doubt, Oskarshamn more or less single-handedly enhanced the legitimacy of SKB's programme of feasibility studies during the period 1993-1996. As a result of these efforts, not only did Oskarshamn and Östhammar agree to host feasibility studies after 1995 but also neighbouring municipalities to both communities. As a total of 8 local feasibility studies showed local acceptability for the KBS project to be within reach, so SKB took the opportunity in November 2000 to invite 3 communities to go a step further and host detailed site investigations where the focus of concern would be on geological suitability (SOU 2002, Elam and Sundqvist 2007: 47). These communities were Oskarshamn, Östhammar and Tierp. The latter municipality borders on the Forsmark reactor site. Several local feasibility studies had not been completed in November 2000, when SKB's choice of sites for site investigations was announced. The feasibility study in Tierp was a case in point and the municipality ended up withdrawing from the siting process as they felt SKB were cutting corners and showing insufficient respect for local democratic process (Elam and Sundqvist 2007: 47). As a consequence only two detailed site investigations were initiated in the two communities which had already been identified as the most logical sites for geological disposal of nuclear waste in Sweden in 1976. The door to a new era of Swedish nuclear industrial park development was opened.

Feasibility studies in Oskarshamn and Östhammar can be said to have played a vital role in fabricating both communities as local stakeholders in Swedish nuclear waste management. Prior to these studies they resembled more nuclear communities of fate with little voice and influence over the localisation and development of nuclear activities in the locality.

Oskarshamn were the first to recognize the mutual hostage situation that had arisen in the 1980s where the inability of the community to escape the nuclear industry was matched by an emergent situation where the industry itself had little locational room for manoeuvre if it wanted to carry on developing its activities. Historically, the 'local acceptability' of nuclear activities had never been a matter of public discussion. It had been nothing to publicly talk about or negotiate over. But then Oskarshamn and Östhammar started to recognize the combined strengths and weaknesses of their position as the locations responsible for generating and hosting the nuclear wastes that no other communities were willing to house. Their historical collusion and co-operation with nuclear industry offered them a position of strength and significant bargaining power (Elam and Sundqvist 2007: 41). Oskarshamn more than Östhammar discovered itself as, not only a nuclear community in itself, but also *for* itself during the feasibility study period in the late 1990s. Oskarshamn became a community eager to take a greater proportion of its nuclear fate into its own hands.

During the site investigation phase of the siting of a KBS 3 repository, Oskarshamn and Östhammar faced new difficulties in maintaining their identities as active stakeholders in Swedish nuclear waste management. Site investigations have implied the collection of large amounts of technical and geological data to be used in the formulation of the safety analysis – SR-Site – supporting the SKB's application to build a geological repository in Forsmark. In parallel with this work, two local environmental impact assessment processes have been carried on in Oskarshamn and Östhammar in accordance with the Swedish Environmental Code. According to this code it is the developer who is responsible for co-ordinating the EIA process. SKB have taken advantage of this situation to limit the scale and scope of the EIA process by firstly dividing it into 2 relatively separate and parallel community-based processes (Elam and Sundqvist 2009, Soneryd 2007). In both locations SKB have used EIA meetings to firstly inform local community representatives of the progress being made in the geological site investigations. The public mobilized has been firstly the public who would be directly affected by the construction and development of a repository in both locations. So those living closest to a planned repository have been encouraged by SKB to make their voices heard and demand further investigations to be carried out on such issues as noise pollution during the construction phase; the need for new infrastructural investments; the potential socio-economic spin-offs of construction and so on (SKB 2004, 2005). Problematically for SKB a legitimate environmental impact statement must address such issues as alternative methods for the final disposal of spent fuel including the so-called zero alternative where no development takes place (i.e. where an extended period of interim storage in CLAB is recognized as an option). Furthermore the EIS must discuss alternative sites and why one or two sites are preferred over others. As far as SKB is concerned these are past issues which are no longer in need of renewed discussion. Both the KBS 1 and the KBS 3 designs received governmental approval as absolutely safe or sufficiently safe methods for the geological disposal of nuclear waste in the 1980s and the siting process commencing in 1980 has been a long journey which has reached its natural conclusion in Oskarshamn and Östhammar (SKB 2006).

Given this situation the Swedish National Council for Nuclear Waste have since 2007 made significant efforts to repair the EIA process for the siting of a KBS-3 repository in Oskarshamn or Östhammar. Moving this process partly out of the two communities, the council have organised a series of 'transparency forums' and public hearings in Stockholm addressing such issues as a bifurcated decision-making process for nuclear waste management in respect of two framing laws; deep boreholes as an alternative geological disposal method to the KBS 3 concept; how to interpret the term 'best available technology' in relation to the case of Swedish nuclear waste management (KASAM/Kärnavfallsrådet 2007, 2011). In similar fashion to the role played by municipality of Oskarshamn during the feasibility study phase in the 1990s, so the Swedish National Council for Nuclear Waste is currently attempting to repair the legitimacy of the EIA process advancing the geological disposal of Sweden's nuclear waste according to the KBS 3 method in Östhammar and Oskarshamn.

In June 2009 SKB announced its intention to apply for a license to build a final repository for Sweden's spent nuclear fuel on the Forsmark reactor site in Östhammar (SKB 2009a). The final choice between Oskarshamn and Östhammar was presented as decided on firstly geological grounds. Having cultivated identities as active stakeholders in the siting process for a KBS 3 repository since the mid-1990s both communities had grown concerned about ending up 'the loser' in what had become a competition to host an internationally-renowned and celebrated solution to the nuclear waste problem. In response to this situation, SKB signed an Added Value Agreement (Mervärdesavtal) with both communities in 2009 just before announcing its choice of Östhammar (SKB 2009b). According to this agreement SKB and the owners of Sweden's nuclear reactors pledge to invest an additional 220 million € in Oskarshamn and Östhammar during the construction phase of a KBS-3 repository. Of this amount 75% shall be invested in the 'loser' community of Oskarshamn, and 25% in the 'winner' community Östhammar. The money is to be spent firstly on infrastructural and educational initiatives. In relation to these arrangements the continuing combined importance of both Östhammar and Oskarshamn for Swedish and even European nuclear waste management should not be underestimated. Rather than winner and loser, Östhammar and Oskarshamn can be seen as hosting together the KBS project with its vital components distributed between them. If Östhammar is to host the spent fuel repository, Oskarshamn will still host a new encapsulation plant where the spent fuel in CLAB is sealed in copper canisters prior to transport to Östhammar. Oskarshamn will also host the new canister factory producing the copper canisters themselves. If it currently remains unlikely that a geological repository in Östhammar will end up hosting waste from other countries, it appears as good as guaranteed that Oskarshamn can continue developing as a centre for research and development work in the construction of a European technology platform for the geological disposal of nuclear waste led by SKB and Finnish Posiva.

1.4 NGOs participating in the environmental impact assessment process in relation to the KBS project

There are various NGO's from the Swedish civil society engaged in the nuclear waste issue and they consist mainly of various environmental organisations. The most prominent umbrella NGO is called *The Swedish NGO Office for Nuclear Waste Review* (*Miljöorganisationernas kärnavfallsgranskning*, or MKG) (www.mkg.se). MKG is a cooperation between five other NGO's, these are: Fältbiologerna, Naturskyddsföreningen i Kalmar län, Naturskyddsföreningen Uppsala län, Oss - Opinionsgruppen för säker slutförvaring i Östhammar och Naturskyddsföreningen. MKG represented about 180 000 members in 2008, of which about 170 000 comes from Naturkyddsföreningen (Statskontoret 2008, p. 27). Today, MKG represents about 191 000 members (acquired via correspondence with MKG (20 September 2011). The aim of MKG is:

> …. to achieve the implementation of the environmentally best long-term option for the management of radioactive waste for both public health and the environment. MKG does not advocate any particular method or site, but wants the best base of information so that the environmental courts can make their decisions about where and how Sweden's nuclear waste shall be disposed. It is vital that alternative methods and sites that might be better options with respect to long-term environmental and health impacts, are fully evaluated. Being part of the environmental movement, MKG works toward long-term sustainability for both humankind and the environment. (MKG 2011)

MKG is one of four NGO's that is financed by the Nuclear Waste Fund (financed since 2005) to participate in the environmental impact assessment process in respect of the Swedish Environmental Code. MKG is generally very critical of how SKB is managing the issue of nuclear waste. They make a number of claims about SKB. MKG claim that SKB is not transparent enough about their research (MKG and Naturskyddsföreningen 2011, p. 13), and they are accused of ignoring criticism. Johan Swahn argues that:

> We in MKG have been critical of parts of this process, that we have not been able to gain access to the necessary documents from SKB among other things. We are critical of the chosen place and methods used. But it is up to the environmental court and SSM to evaluate it.
> (quoted in Schön and Goldstick 2011, May 11, p. 1)

Similarly, Kenneth Gunnarsson from Oss - *Opinionsgruppen för säker slutförvaring i Östhammar*, says:

> The value of a reciprocal or common deliberation process is completely missing in the Swedish case. It is the nuclear companies that decide everything from start to end. So, given this statement, I want you to ask yourselves: Why call for public participation, with transparency, and freedom of information, if nothing of our ideas are allowed to influence the process?
> (Schön and Goldstick 2011, p. 1)

On one occasion MKG goes on to claim that research conducted in the *Äspö-laboratory* has more or less deliberately produced false results or records in order to verify that their methods are solid (especially about the copper corrosion (MKG and Naturskyddsföreningen 2011). This statement was born out by a report that the Swedish Radiations Safety Authority (Strålsäkterhetsmyndigheten, or SSM) conducted. In 2010, SSM hired independent reviewers to do a quality assurance review of SKB's research in Äspö and found indeed that there were some serious issues concerning SKB's research. The authors of the review write:

> During the quality review of the selected projects, several QA-related [Quality Assurance] issues of different degree of severity were noted by the reviewers. The most significant finding was that SKB has

> chosen to present only selected real-time corrosion monitoring data in TR-09-20 [see SKB (2009b). *Miniature Canister Corrosion Experiment – Results of Operations* May 2008. SKB Report TR-09-20. SKB, Stockholm, Sweden]. This was surprising and SSM expect that SKB will analyse the reason for this thoroughly. The reviewers also made other observations which can be grouped as transparency related e.g. significant delays in reporting, lack of uncertainty evaluation for experimental data and too limited access to progress reports from research suppliers. Transparency and full accessibility of primary data is essential for upcoming licensing activities. SSM therefore encourage SKB to address the concerns in this review and provide a plan for improved transparency of field testing activities. (Baldwin and Hicks 2010, preface)

MKG uses the findings in this report as well as their experience from previous interaction with SKB as evidence of SKB being biased and unscientific (MKG and Naturskyddsföreningen 2011, p. 13). In the SSM report however, the external reviewers write that "…it must be emphasized that this quality assurance review only covers limited aspects of two ongoing field experiments and the results should not be generalised. Other quality assurance reviews of SKB has not resulted in any severe comments, it can therefore not be excluded that the deficiencies reported here is of singular occurrence" (Baldwin and Hicks 2010, preface).

Nevertheless, with reference to this criticism as well as to what independent university research have shown regarding the problems with premature copper erosion, MKG argues that copper corrosion will likely occur much faster than what SKB's research has shown (some estimates claim that erosion will occur as soon as 100 years after deposited) (MKG and Naturskyddsföreningen 2011, p. 6). Therefore, MKG argue that SKB ought not to be so narrowly focused on the KBS-3 method; they should probe more carefully other alternative methods that may not have been researched sufficiently (e.g. *deep boreholes*) (MKG and Naturskyddsföreningen 2011, p. 7).

Another issue that MKG focuses on is the site for the final repository. They question whether it is wise to place the repository at a coastal site, near ground water reserves, directly beside open sea. The area around Forsmark is a geological tectonic zone (MKG 2011; MKG and Naturskyddsföreningen 2011, p. 11). Even if this area has not been very active, for example in terms of earthquakes, it might become active in the future. Accordingly, MKG wants the final repository relocated to another site.

MKG is the largest NGO when it comes to Swedish environmental movement against nuclear energy, but there are other smaller national NGO's that have taken great interest in the Swedish management of nuclear waste, for obvious reasons: some of these are *Friends of the Earth Sweden* (Miljöförbundet Jordens Vänner) and Folkkampanjen mot kärnkraft-kärnvapen (www.folkkampanjen.se) They have in turn formed an association called *The Swedish Environmental Movement's Nuclear Waste Secretariat* (Miljörörelsens kärnavfallssekretariat, or Milkas). Milkas represented about 3000 members in 2008 (Statskontoret 2008, p. 28), today about 4000 members (acquired via correspondence with Milkas, 20 September 2011). Milkas is largely financed by the Swedish Nuclear Waste Fund. The purpose of the association is:

> ... to follow and critically scrutinize all projects dealing with management of highly radioactive waste, and to work for the best long-term and environmentally sound management method. (Milkas 2011)

They share a lot with MKG's criticisms regarding the Swedish case of nuclear waste management. Milkas "…basic understanding is that the so called KBS-3 method does not fulfill those criteria that one must expect of a final repository for nuclear waste …" (Lars-Olov Höglund 2009, p. 2). Moreover, Milkas claim, similar to MKG, that SKB is not transparent with regard to its research procedures and seldomly responds to criticism, "It is our experience that we are allowed to pose question but they are rarely responded to. The report of the proceedings, from the meetings with SKB, is very biased. Critical comments and questions are just left out…" (Hultén, Mörner and Törnqvist 2010, p. 5). Milkas even claim that SKB deliberately uses its position and power to silence criticism. Accordingly, the conflict between the anti-nuclear movement and SKB is deep.

Similar to MKG, Milkas wants SKB to evaluate alternative methods for deposing of nuclear waste. MKG favors "deep boreholes" whereas Milkas thinks it is indeed a viable option but believes that the Dry Rock Deposit method should also be tested – a method proposed by, for example, some researchers at the institute at Paleogeophysics and Geodynamics, at the University of Stockholm (Milkas 2007; Mörner 2005; Mörner 2008).

Sveriges Energiföreningars Riks Organisation (SERO) is the third NGO that receives financial support from the Swedish Nuclear Fund. They had about 2000 members in 2008 (Statskontoret 2008, p. 28), today about 2500 members (acquired via correspondence with SERO, 20 September 2011). SERO's main focus is to encourage extensive investments in renewable energy:

> SERO is a Swedish non-governmental central organization for regional and special organisations engaged in renewable energy. The main purpose for SERO is in different ways to support and work for a rapid expansion of renewable energy sources in Sweden. At present the main issues are to convince Swedish authorities to create a long term support system which efficiently increases the investments and the expansion of renewable energy in Sweden and eliminates the obstacles in present laws and frameworks for renewable energy power stations (SERO 2012)

Even if SERO gets support from the Swedish Nuclear Fund, they do not highlight much about the nuclear issue. The organization has received some criticism from the Government's Survey Support (Statskontoret) for not being active enough about raising issues at SKB's general meetings. It is written in their report that "Milkas and MKG have thus submitted notes to almost all public meetings 2005-2007. SERO has conversely submitted no notes yet received financial means 2006-2007 to attend these meetings" (Statskontoret 2008, p. 52).

There is also an NGO that is pro-nuclear energy, namely, *Miljövänner för kärnkraft*. This NGO has the following aim:

> Miljövänner för Kärnkraft is a politically and economically independent non-profit association. It was formed 1988 by some environmentalist that had become tired of a biased anti-nuclear energy propaganda. The association wants to give objective facts instead of biased ones based on fear and prejudice; facts that

consider health, environment and the economy, where energy produced via nuclear technology is judged upon on the same terms as energy produced from other technological sources. (MFK 2010)

Miljövänner för Kärnkraft represented about 1000 members in 2008 (acquired via correspondence with Miljövänner för kärnkraft, 20 September 2011). It received some financial support from the Swedish Nuclear Fund in 2006, but has not been supported by the Swedish Nuclear Fund since (Statskontoret 2008, p. 28). This is so because they have not met the condition of representing at least 2000 members which would make them eligible for financial support (Statskontoret 2008, p. 28).

Some anti-nuclear energy NGOs have accused Miljövänner för känrnkraft for being a lobby organisation and that they are financially supported by the nuclear industry. Folkkampanjen mot kärnkraft-kärnvapen, writes in its magazine that, "Miljövänner för kärnkraft which is financed by the nucear energy industry." (Miljömagasinet 2011, p. 10). In a newspaper article by Göteborgs posten, it is claimed that Miljövänner för känrnkraft is a "Lobby group founded 1988 employed by the nuclear energy industry, by scientists within the field and other…" (Olsson 2 April, 2011). Miljövänner för känrnkraft deny any such accusations, they argue on their website that:

MFK's (Miljövänner för känrnkraft) independence can be shown by its very limited budget that is entirely based on membership fees, and nothing else. Members of the board receive no payment, their work is from unpaid leisure time. Most of the members lack associations to the industry. They have simply realized that it is not possible to save the environment and welfare without nuclear energy. They are simply utilizing their democratic right and so giving their support for an important cause.

A NGO that confirms that they are supported by the nuclear industry is *the Swedish Nuclear Society* (Sveriges kärntekniska sällskap) which is a branch of the *European Nuclear society*. It is both financed by the industry and key members of their committee consist of persons from the nuclear industry. Thus they do not get any financial support from the Swedish Nuclear Fund. Sveriges Kärntekniska Sällskap is "…an association of people with an interest for promoting nuclear technology for peaceful use." (Sveriges Kärntekniska Sällskap 2011).

The table below summarizes the extent of financial support that the different NGO's received between 2005-2008. MKG gets about sixty percent of all the support disbursed, and Milkas about thirty percent. Whereas SERO gets about five percent (Statskontoret 2008, p. 27). The figures are still the same today.

Receiver	**2005**	**2006**	**2007**	**2008**
MKG	1 950 000	1 925 000	1 925 000	1 925 000
Milkas	1 000 000	1 000 000	925 000	925 000
SERO	-	75 000	150 000	150 000
MFK	50 000	-	-	-
Total	**3 000 000**	**3 000 000**	**3 000 000**	**3 000 000**

Table 1: Granted financial support to non-profit associations in SEK (Statskontoret 2008, p. 27).

2 TWO PROMINENT REMAINING SOCIO-TECHNICAL CHALLENGES FOR IMPLEMENTING GEOLOGICAL DISPOSAL

2.1 Upholding a privileging of political geography over physical geology in the siting of geological disposal

As mentioned earlier the 1977 Nuclear Power Stipulation Act can be seen as having posed the original framing socio-technical challenge for Swedish nuclear waste management. It established a ‘trial of strength’ between pro- and anti-nuclear forces in Sweden by challenging the nuclear industry to demonstrate the existence of a solution to the nuclear waste problem. Interestingly, the Swedish nuclear industry altered the terms of this challenge from the outset. While the emphasis of the Stipulation Act was on the challenge of demonstrating *how* and *where* radioactive *waste* can be finally stored with absolute safety, SKBF becoming SKB defined the goal of their activities as demonstrating ‘nuclear fuel safety’ (KBS = kärnbränslesäkerhet). So while the Stipulation Act emphasized the ‘back-end’ of nuclear fuel cycles, the KBS project has always referred more broadly to demonstrating the safety of the nuclear fuel cycle in Sweden incorporating geological disposal plans for spent fuel.

But what does it mean to be dedicated to demonstrating 100,000 years of nuclear safety in advance of its realisation? Even if/when a deep geological repository for high-level nuclear waste and/or spent nuclear fuel is actually commissioned in Sweden, or anywhere else in the world, it will still remain uncertain and undetermined if this repository constitutes a real permanent solution to the nuclear waste problem. At best, it will serve as a further resource for elaborating upon, and providing ‘confirmation’ of, the safety case upon which it is founded. At worst, it will serve to demonstrate the unreality of this safety case. Therefore, implementing geological disposal approximates a never-ending story where the widely promoted goal of ‘passive safety’ will not coincide with a situation where long-term safety has actually been realized, but one where widespread confidence has been established that no further human intervention is necessary to realize it. Thus, in an important sense successfully implementing the geological disposal of radioactive waste is about ‘colonizing the future’ and about winning confidence in abilities to eliminate and defuse the uncertainties of the future through rational action in the present (cf Reith 2004: 384). Implementing the geological disposal of nuclear waste is about collapsing 100,000 years into the present: demonstrating the future as equivalent to an endlessly extended present of controlled nuclear safety.

To steadily build and maintain confidence in any programme of geological disposal it will remain important to provide evidence of growing human and non-human involvement and commitment to its realisation. Geological repositories have been awarded iconic significance in the development of nuclear waste management, but their ability to translate the future into an extended present of nuclear safety will always remain dependent upon the strength of the relations underlying and maintaining them. Even in reasonably advanced stages of development, geological repositories and the safety cases underlying them will remain precarious constructs. For example, Yucca Mountain in the US is one of the most studied pieces of geology in the world after approximately US$9 billion were spent preparing it to become a national repository for spent nuclear fuel and high-level radioactive waste. However, due primarily to local opposition to the development, the project was cancelled by the new Obama administration in 2009 leading directly to the loss of 900 jobs connected to its realisation.

In the Swedish case, similar local opposition to that experienced in the state of Nevada has been overcome through a tactical withdrawal into those communities already hosting nuclear activities as the locations where the long-term acceptability of geological disposal plans can be most easily cultivated and won. While in the Yucca Mountain case there was a failure to wed local acceptability to a unique geological formation, in Sweden, the KBS project has continued to survive by privileging the search for local acceptability of geological disposal over the search for ideal/unique geological conditions. The search for appropriate geology for final geological disposal has been literally kept within the territorial bounds of a socially and politically engineered local acceptability. After 1986 no test drillings were carried out in the siting process for a KBS 3 repository before the political feasibility of locating such a repository in Oskarshamn, Östhammar and a handful of other communities had been thoroughly investigated. The social and political safety for nuclear industry of developing a KBS 3 repository in either Oskarshamn or Östhammar was also something that could be carefully gauged through the experience of commissioning not only reactors, but also other nuclear waste facilities in these two communities. The establishment in Oskarshamn of CLAB in 1985 and a dress rehearsal repository (the Äspö laboratory) in 1995 proceeded without undue controversy. In similar fashion, a geological repository for low- and intermediate level nuclear waste has lived a fairly anonymous existence in Östhammar since 1988. Therefore, when SKB announced its choice of sites for detailed site investigations for a KBS repository in 2000, existing experiences from Oskarshamn and Östhammar corresponded to a convincing political safety case in support of the decision.

So in recognition of the relative political and technical durability of the KBS project in Sweden compared to other programmes of geological disposal elsewhere, a remaining - or rather continuing - socio-technical challenge in the Swedish case is to successfully uphold and defend the privileging of political geography over physical geology upon which the siting process of a KBS 3 repository has been founded. Privileging political geography over physical geology has coincided with the relative liberation of the geological disposal of nuclear waste from geology in Sweden. Geology still matters greatly in Swedish nuclear waste management but not beyond the Swedish nuclear industry's own backyard. Forty years of nuclear activity in two locations in Sweden has been accepted as strongly qualifying them to participate in the siting process for a geological repository offering 100,000 years of radiation protection.

The relative liberation of the geological disposal of radioactive waste from geology in Sweden has proceeded in a number of steps. The first of these coincided with the government approval that was granted to KBS 1 in 1979-80. After further geological investigations in support of the safety case for KBS 1 had been demanded in 1978, a panel of geological experts recruited by the Swedish Nuclear Power Inspectorate (SKI) concluded in 1979 that they remained unable to provide guarantees of safety due to a continuing lack of sufficient knowledge and research. Despite this, SKI went ahead and recommended that government accept KBS 1 as a demonstration of absolute safety as the geological barrier had to be viewed in relation to the other engineered barriers the qualities of which were better known and capable of reducing the demands made on the geological barrier (Sundqvist 2002: 91, Anshelm 2006: 93). While geology was then privileged anew in the siting process for a KBS repository after the national referendum in 1980, its importance was progressively toned down again after 1986 when local protests had led to the postponement of a national programme of test drillings. In SKB's 1986 FUD report, it was argued that limited geological search had already demonstrated that many sites in Sweden existed for a KBS 3 repository (SKB 1986: 86). At the same time it was proposed to build a new hard rock laboratory in Oskarshamn specially dedicated to investigating how less than ideal bedrock conditions could be compensated for by excellence in the engineering design of a repository (SKB 1986: 35-37). Thus, the turn to a voluntary siting process for a KBS 3 repository in 1992 was a new socio-technical turn as it added both new political and engineering components to the KBS project. A turn away from a geology-led siting process to one founded on a principle of local acceptability placed new demands on engineering know-how as the KBS 3 method had to be rendered less vulnerable to the vagaries of geological circumstance in order to facilitate a siting process focussing on politically opportune locations.

In connection with the choice of Oskarshamn and Östhammar for site investigations after 2000, a debate arose over the issue of whether or not a combination of coastal and inland sites should be considered for geological disposal plans. For geo-hydrological reasons an exclusive focus on the coastal sites of Oskarshamn and Östhammar was brought into question (Holmstrand et al 2002). Of relevance was also that a neighbouring inland community to Oskarshamn which had also hosted a feasibility study expressed a willingness to host a site investigation but was rejected by SKB. Both SKI and SSI demanded that SKB pay more attention to the coast versus inland issue in their research programme, but SKB succeeded in marginalizing the issue and maintaining an exclusive focus on Oskarshamn and Östhammar for detailed geological investigation. However, upholding a privileging of political geography over physical geology in the siting of a geological repository places very high demands on the quality and reputation of the other barriers incorporated in the repository system. If the credibility of one or several of the engineered barriers is seriously bought into question then the very foundations of the safety case are destabilized. In this context it is interesting to note the debate that has arisen recently concerning the issue of copper corrosion in oxygen-free environments. Copper canisters lie at the heart of KBS 3 concept. The costliness of copper, compared to stainless steel for example, has been defended due to its greater integrity for radiation protection. The geological environment surrounding the copper canisters will be practically oxygen-free and the KBS-3 method is premised upon the idea that copper cannot corrode in such an environment. However, a group of researchers at the Royal College of Technology in Stockholm have now claimed to have demonstrated otherwise. Initial evidence from researchers involved was produced already in 1986 (Hultqvist 1986), but difficulties were experienced in replicating the results of this research. However, in 2007 new evidence was provided through a publication in *Electrochemical and Solid-State Letters* (Szakalos, Hultqvist and Wikmark 2007). Among the more dramatic claims being made by Szakalos and colleagues is that copper will corrode 1000 times faster than assumed in SKB's safety case (Kärnavfallsrådet 2009). Since the publication of the 2007 article SKB have made claims to have refuted the new findings presented through their own research and Swedish National Council for Nuclear Waste have sought to mediate in the controversy by organizing an international expert hearing on the matter in November 2009. Subsequently, the chairman of the Council has made an official statement in response to questions posed by the Swedish Minister of the Environment playing down the risks of copper corrosion (Carlsson and Forsling 2011). The controversy remains far from settled however and new research has been commissioned to investigate matters further.

Interesting questions arising out of the copper issue are: how has the growing controversy possibly influenced SKB's preference for Östhammar over Oskarshamn? Given the geological conditions in both locations could the risk for copper corrosion be presumed higher in one of the two locations? Is the copper corrosion issue breathing new life in the coast versus inland debate? The critical scientists highlighting the copper corrosion issue suggest that the KBS 3 method needs to be improved by coating copper with an extra layer of tin or gold(!), while MKG claim the method is more seriously undermined. If copper has been one of the vital components out of which the relative liberation of the KBS project from geology has been constructed, it is interesting to ask how far the potential corrosiveness of this component is serving to open up the 'how' and 'where' questions of Swedish nuclear waste management once again.

2.2 The challenge of financing Swedish nuclear waste management

The current system for financing the Swedish KBS project dates back to the late 1970s. In convergence with the general debate about the future of Swedish nuclear energy at that time, political negotiations took place regarding how to finance the management of nuclear waste (Kjellman 2001). Many questions needed to be settled regarding Swedish nuclear energy, not least how a system should be constructed for financing the management of nuclear waste. This has been done and then reformed through a series of official reports and government proposals. The foundation for the financing system can be found in the first major official report on the Swedish nuclear energy program, the so called AKA-report (SOU 1976:30).

There were two central questions related to financing that the report set out to answer: the first was whether the nuclear energy industry should carry the full financial responsibility of the management of nuclear waste, even after they stop production; the second question was about how these financial means should be deposited and managed, that is, should these means be deposited internally (each producer keeping a fund within its balance sheet: this had been the praxis earlier (Söderberg 2005:83)) or externally (deposited by the state), as well as, what kind of financial investment opportunities (and thus risk) should one allow for.

In brief, the investigators came to the conclusions that the industry should indeed carry the full financial responsibility and that the deposited financial means should be internally managed (SOU 1976:30). Each nuclear company should pay a fee relative to how much nuclear energy it produced. The number 0,5 öre/kWh was mentioned by the investigators as a reasonable fee.

Nevertheless, the government at that time could not agree on a unified energy policy and take a definite stand on the various suggestions in the AKA-report. Partly because of disagreement on nuclear policy, this government resigned in October 1978. A new government took office and shortly after that a government bill (prop. 1978/79:39) was passed on "reduced taxation of financial means deposited for future management of nuclear waste". This means that all financial means deposited to management of nuclear waste are completely exempted from tax. These means should be deposited internally (the numbers 0,8 öre/kWh was estimated to be a reasonable fee to deposit), as the AKA-report suggested. This meant however that the state did not have much control over the amount deposited. All other larger decisions were put on hold until a new official report was completed, which was in year 1980 (SOU 1980:14).

This report focused on similar issues that the AKA-report focused on, but with special attention on the financing of the management of nuclear waste. The suggestions of the 1980 report were similar to the AKA-report. The financial means should be managed internally and the industry should be held fully accountable for the costs of nuclear waste. The state's role was to supervise that this was done properly. An additional suggestion of the 1980 report was that the nuclear companies should present additional financial guarantees to reduce the risk that the state will need to play the role of a payer of the last resort. It is indeed the industry that has the full financial responsibility, but the state assumes supreme responsibility if the companies for some reason fail to do so (Proposition 1980/81:90, p. 319). The government reconfirmed its position to hold the producers fully financially responsible, much according to the AKA-report, but they did not follow the investigators recommendation to keep the finances internally managed. It was now decided that the financial means should be managed by a state agency, the Swedish National Debt Office (Riksgälden), the finances were now transferred to an interest based deposit at the Swedish Central Bank – by this time the nuclear companies had saved about 2 230 million Swedish Kronor deposited internally (Söderberg 2005:83, p. 26).

In 23 March 1980 a referendum was held about the future of nuclear production in Sweden. The outcome was to shut down all nuclear plants by 2010. This was a major reason for abandoning the internally managed system (SOU 1994:107, p. 80). One can read in the government bill (Proposition 1980/81:90, p. 610), 'Given the results of the referendum on the nuclear issue the parliament has decided that nuclear energy will not be used after year 2010…in this situation, to claim that the nuclear companies should manage financial means till the year 2060 is directly inappropriate'. The management of these means was now to be regulated by the so-called *financing law* (finansieringslagen) (Svensk författningssamling 1981:669), which was somewhat modified 1992 with no principle changes though (Svensk författningssamling 1992:1537).

In May 1993 the government appointed investigators to analyze whether the financing system could be improved further, this resulted in the third larger report about the financing system of the management of nuclear waste (SOU 1994:107). One of the central questions was whether one could increase the return on the financial means of accumulated fees. These means had been deposited in an account at the Swedish Central bank with no active or strategic portfolio management. The account yielded a certain interest each year, but this was eroded by inflation. The Swedish real rate of interest (equals the nominal rate of interest minus inflation) has fluctuated and has even reached negative values during the twentieth century, see Figure 1 (Lagerwall 2005).

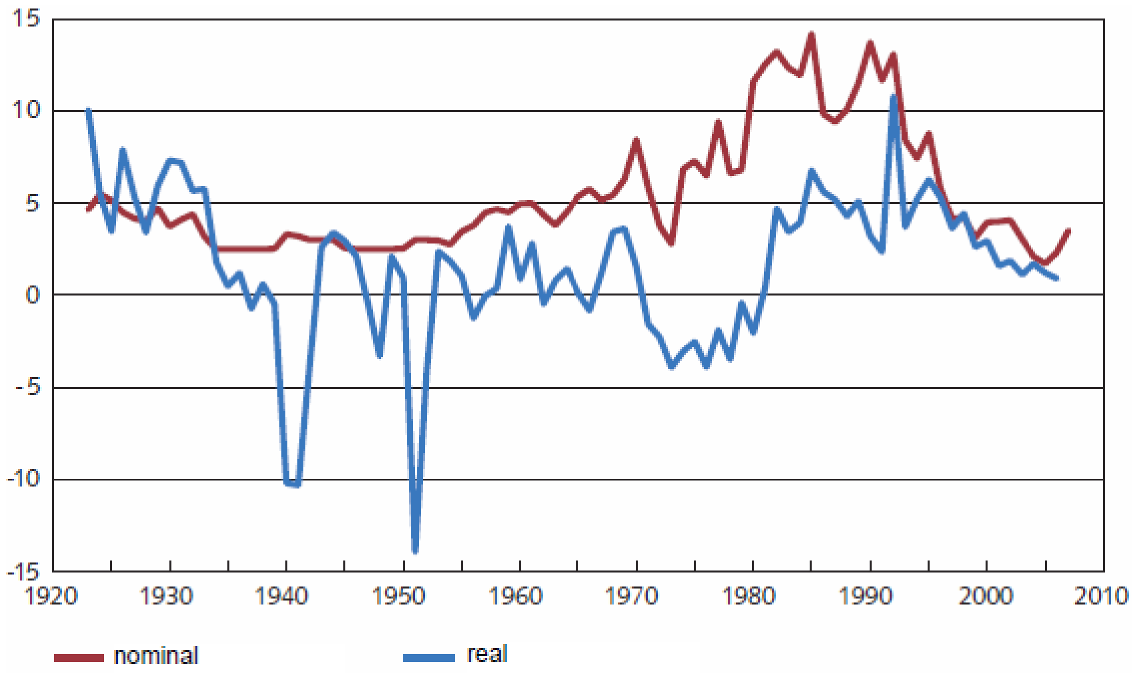

Figure 1: Nominal and real interest rate in Sweden, historical figure (Lagerwall 2005, p. 6; cf. SOU 1994:107, p. 105).

As discussed in the 1994 report (SOU 1994:107), inflation is one of the largest threats to projects of this magnitude where both large savings and high uncertainty is involved. The following are some of the questions that the investigators needed to deal with: How large will the future rate of inflation be and thus the real rate of interest? What size of the return can one expect to get on the saved financial means over 50 years? The investigators argued that these questions are of very complex nature and thus a financing system based on "guessing" the right rate of real return will be very unstable, which the existing developed system involved (SOU 1994:107, pp. 11-15). The financing system was therefore overhauled by the government in 1994 (Proposition 1995/96:83). There were two main changes made. The first was to ensure a higher return on the accumulated capital, for that purpose a new government agency was created called the Swedish Nuclear Waste Fund (www.karnavfallsfonden.se). This agency was given a higher degree of freedom to strategically place the accumulated means in different financial products, though restricted to bond placement (mainly state issued and mortgage based security bonds). The second change sought to ensure two kinds of guarantees. The first guarantee (called "finansieringsbelopp") was designed to ensure that a minimum of fees are paid by the companies for each reactor's lifecycle, set to 40 years (SKB 2010, p. 6). It is basically a guarantee against premature close down of a reactor. The size of the guarantee decreases for each year that the companies pays fees. The second guarantee (called "kompletteringsbelopp": this guarantee is today estimated based on a statistical method called *Successive principle*, see SKB, 2010) ensures that there is enough money to cover not only planned activities (research, building facilities, etc.) but also unexpected events (e.g. delays) (Kjellman 2001, p. 50; SOU 1994:107).

In 2004 yet another official report was written on the distribution of financial responsibility between not only the state and the nuclear energy industry, but also each individual company in the industry (SOU 2004:125). The report starts by writing 'The point of departure for the financing of the management of nuclear waste is that the nuclear energy producers – not the tax payers – shall cover the cost. The current regulations are incomplete in this respect' (SOU 2004:125, p. 9). Firstly, one of the main conclusions is that the guarantees designed in 1994 were not enough to cover the financial risk that the state is taking. Basically, the investigators recommended enlarged financial responsibility for the industry (more transparency in terms of how the fees are calculated, and clearer regulation). Secondly, the report pointed at the problem that there is no shared financial responsibility between the nuclear companies regulated in law. Each company pays a certain amount to the Nuclear Waste Fund but means are deposited on different accounts; one account for each company, see Figure 2. This means that if one company stops paying to the fund for whatever reason, the other companies does not have any juridical responsibility to cover that deficit. The state will have to cover that. Moreover, if there will be a surplus in one company account and a deficit in another, the company with a surplus is entitled to a refund even if the state has to cover the deficit on the other account (SOU 2004:125, p. 68). This is not reasonable, the report argues, and suggest modified regulation. Not much happened, it seems, with respect to the main issues discussed in this report.

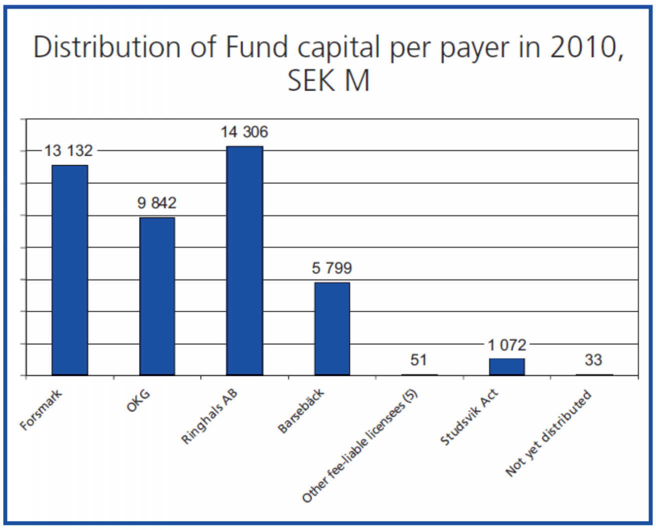

Figure 2 (Nuclear Waste Fund 2010, p. 7)

It was however not until further official reports (SOU 2006:43; SOU 2009:88) that the government proposed (Proposition 2009/10:173) that the claim for damages, but only related to accidents, should be increased. This proposition it seems aims at not only a minor modification of the regulation regarding financial responsibility but also to plan for a generation shift of the current reactors. It is written 'One of the Inquiry's main tasks has been to propose amendments to the Nuclear Activities Act and the Environmental Code that will make it possible to gradually replace existing nuclear power reactors with new nuclear power reactors.' (SOU 2009:88, p. 33). One such proposed change is that the industry should be held *boundlessly financially responsible*. Even if this will not be the case in event of an accident due to the limited finances of a company, this law has a symbolic value, the investigators argued (SOU 2009:88, p. 27).

In summary, the Swedish financing system of the management of nuclear waste has gone through many changes since its founding in the late 1970s. As the system stands today, it is the industry, in practice SKB, which calculates its total costs which are then submitted to the state, represented by the Swedish Radiation Safety Authority (SSM). The latest report is called *Plan 2010* (SKB 2010). The costs refer to all costs related to research, pulling down of the nuclear plants, building and closing the final repository. The next report is expected to be published 2013; a new report every third year (previously SKB was required to issue a report every year). SSM reviews SKB's calculations and proposes a fee to the government. It is then the government that decides on the size of the fee as well as disbursement from the Nuclear Waste Fund (Nuclear Waste Fund 2010, p. 5). The Nuclear Waste Fund has a responsibility to actively increase the return of the accumulated capital as well as to disburse means back to SKB and other organisations that are involved in supervising the Swedish nuclear waste management program. The Swedish financing system is today regulated by the financing law (Svensk författningssamling 2006:647; Svensk författningssamling 2008:715); on Studvikslagen, see e.g. (SOU 2004:125, p. 164).

Hence, there are several economic challenges associated with the financing of Swedish nuclear waste management. *A first economic challenge* is the challenge of estimating the size of the cost for managing the Swedish nuclear waste. As mentioned, it is SKB that approximates the total cost in its so called *Plan-reports*. The costs are estimated or based on a so-called *reference-scenario*. This scenario entails the following assumptions, all based on the KBS-3 method: (1) most reactors will be used for 50 years; (2) this will generate nuclear waste equivalent to about 6000 copper canisters; (3) most reactors will thus be pulled down between the years 2025-2032 (at the earliest 2020) (SKB 2010, p. 19); (4) start building the final repository about 2020; (5) the final repository will be closed sometime around 2050 (cf. SOU 2004:125, p. 9). This will require about 92 billion SEK. This amount only covers SKB's activities; it does not include other costs such as for the involvement of government officials, juridical processes, and costs for involving NGOs. The total cost is also subject to adjustment depending on new research, development, changing economic factors. See Figure 3 for SKB's own time and cost estimations. There are of course many sources of uncertainty that challenge SKB's estimations and so the Swedish financing system. One can ask several questions.

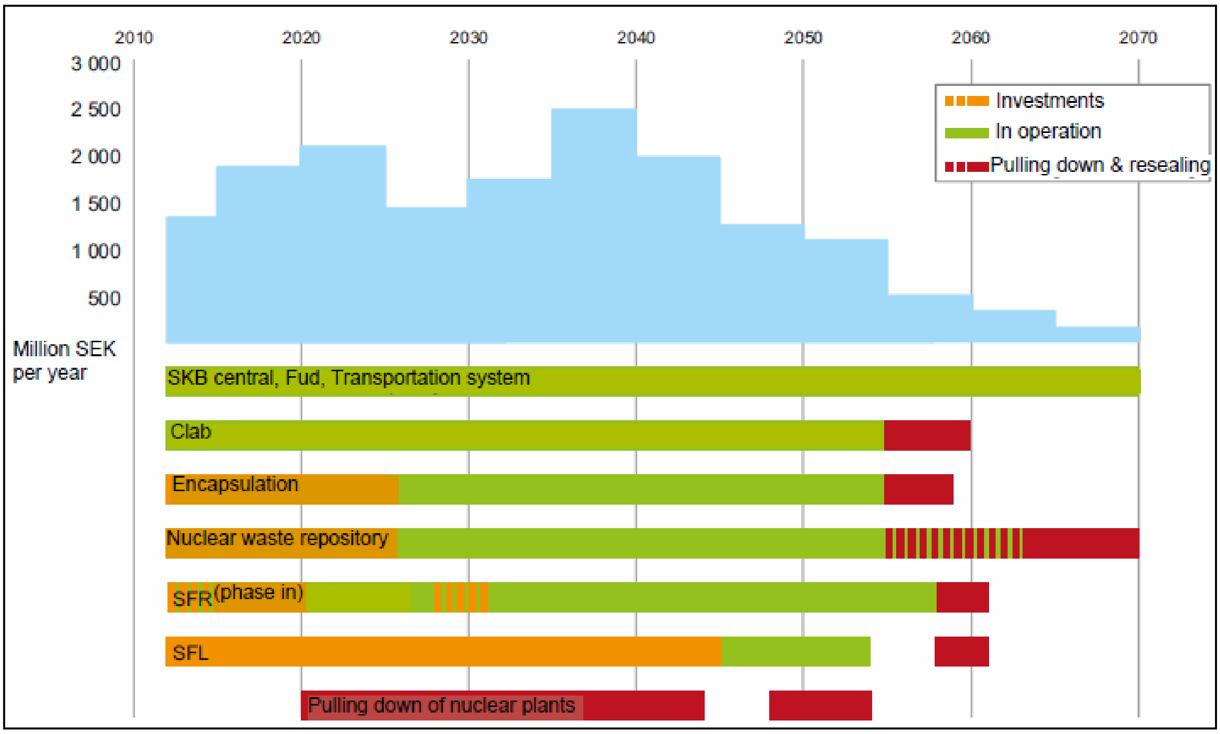

Figure 3 Remaining costs, excluding increment for unexpected events and risk, distributed over time for respective facilities, given in January 2010 price levels (SKB 2010, p. 51)

The second economic challenge points at the most obvious question, namely, is the total cost reasonable and what is the risk for budget overrun? According to Magnus Westlind, previously head of the nuclear waste department at *Statens kärnfraftsinspektion* (SKI is a predecessor to SSM) as declared it seems as though SKB is heavily underestimating the cost compared to other countries (KASAM 2005, p. 6). Research on project cost estimation has shown that most projects experience budget overrun (Flyvbjerg 2004:125; KASAM 2005;

Segerlod 2004:125). An extreme example of a budget overrun is the building of a pipeline between the oilrig in Prudhoe Bay in North Alaska and the harbour Valdez in South Alaska. The original costs was estimated to 863 million US dollars in 1969 but ended up costing about 9 300 million US dollars when the pipeline was finished in 1977 (Segerlod 2004:125, p. 99) – an overrun by about 1000 percent. On average, most overruns for large infrastructure projects (rail, bridges, tunnels, roads etc.) are between 20-45 percent (Flyvbjerg 2004:125). In 2009, it was reported that the Finish project to build a new nuclear plant in Olkiluoto is now up to double the original estimated price (cf. Greenpeace 2007; Ihrfelt 2009, 12 March). This question requires improved scrutiny procedures by organisations as SSM as well as international comparisons of similar projects for use as a sounding board (KASAM 2005, p. 8).

There are several factors that correlate with budget overrun, but most specifically time and if the project has been done before. The longer the time span the project is active the more likely the project will have a budget overrun; the same is true for a project that has never been attempted before. Both these factors play against current estimates of the financing of Swedish nuclear waste management. There is currently no government decision on when to actually pull down the nuclear power plants. In fact, one can read in the latest governmental energy policy declaration 'Swedish energy production stands on two pillars –water and nuclear energy....nuclear energy will therefore be an important part of the Swedish energy production for the foreseeable future' (Regeringskansliet 2009, 5 February, p. 3), and that '...permission will be given to gradually replace current reactors when they have reached an economic obsoleteness' (Regeringskansliet 2009, 5 February, p. 4). Accordingly, a budget overrun is highly probable it seems since SKB is calculating with respect to its reference scenario (ultimately closing the final repository sometime during the 2050s) and the current government is planning for nuclear energy production for the foreseeable future. It seems therefore reasonable to ask, not if, but how large will the overrun be.

One thing is clear however which is the fact that if all reactors would have been closed down by 2010 – as was decided after the referendum in 1980 – there would only be about half of the financial means available in the Nuclear Waste Fund that SKB estimates the project will cost, see Figure 4.[1] The figure below illustrates the growth of the fund from its establishment. There is accordingly about 44 billion SEK deposited in the fund. SKB has used about 15,6 billion between 1995-2011; to reiterate, the total capital need is approximated to be about 92 billion SEK (SKB 2010, p. 35; these figures were confirmed by SSM representative via email correspondence, October 6-8, 2011). The total means available in the Fund has been doing somewhat better than expected, it has beaten the average bound index by 0.9 percent per year since 1996; the real rate of return has been about 5.2 percent per year since 1996 (Nuclear Waste Fund 2010, p. 4). It is assumed that the real rate of

[1] It should be noticed that SKB does not discuss the issue of financing related to the final repository in the about one thousand long report or application, *SR-Site*, just submitted to the court for review (SKB 2011). The term "economic" is mentioned 14 times (excluding bibliography), finance or financing 0 times, and cost 3 times. Accordingly, no proper account is given in this report about the economic feasibility of this project. The *Plan reports* seems to be the only place where such accounts are given, see e.g. the latest SKB (2010).

return on the Fund capital should cover a large part of the future cost (KASAM 2005, p. 4). The return has been about 38,5 billion SEK, in payment via fees about 30,5 billion SEK and disbursement about 24,7 billion SEK (Nuclear Waste Fund 2010, p. 6). The size of the return is especially important since no fees can be claimed on a reactor that has been taken out of service (SOU 2004:125, p. 42) and since the real rate of the fees has been steadily decreasing (from about1.6 öre/kWh in 1982 to 0,3 öre/kWh 2005), largely due to inflation (SOU 2004:125, p. 38). But as the investigators in the 1994 official report argue expected real rate of interest was unusually high during the 80s and 90s and was expected to be lower at the beginning of the twenty-first century (cf. Lagerwall 2005; SOU 1994:107). The government just increased the nominal fee rate for the period 2012-2014 from the current rate 1öre/kWh to 2,2öre/kWh (Miljödepartementet 2011). SSM suggested 3öre/kWh, which was heavily criticized by representatives of the industry (see e.g. Billfalk et al. 2011). But still Inflation is accordingly a major challenge; let us call it *the third economic challenge*.

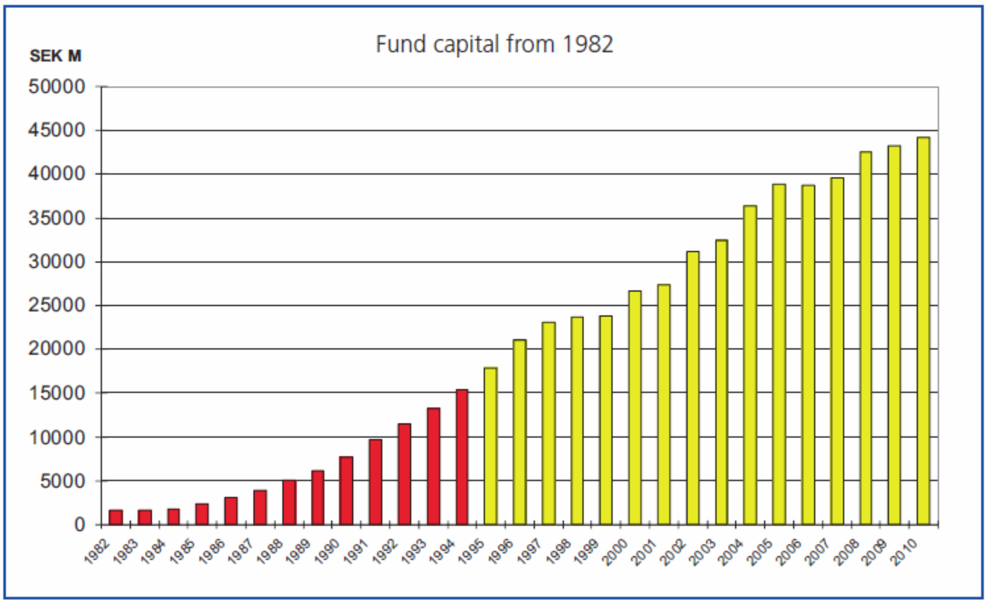

Figure 4 (Nuclear Waste Fund 2010, p. 4).

Now, given that there is not enough means in the Fund, that no fees can be claimed when a reactor is taken out of service, and given that the nuclear industry is held responsible to cover the cost of the management of nuclear waste, there is accordingly a clear economic incentive for the state to keep the reactors running until enough financial means have been collected to cover at least the major parts of the costs. If the government would have carried through the shutdown of all reactors in 2010, it would have had to cover the deficit with alternative state funds (funds about equal to Sweden's military budget for 2012 or its expenses on education for the same year) (Regeringskansliet 2012). No such budget item exists in the government's balance sheet or on its savings account. To reiterate, the current financing system builds on the idea that the industry should be fully accountable for the cost of the management of nuclear waste and the state should supervise the system, but the state (meaning tax-payers) will be forced to pay if the industry fails to carry this financial burden for whatever reason. This means at the same time that the industry has an economic incentive to underestimate its costs, both as a unified actor (towards the state) and as individual actors (towards each other as individual companies: this is the problem of mismatching), (SOU 2004:125, p. 50). There are of course financial guarantees constructed to guard against such behaviour but it is unclear if they are enough as the 2004 official report indicated (SOU 2004:125). It is indeed not clear where the state responsibility starts and industry responsibility ends in a case of insolvency (KASAM 2005, p. 8). It is, moreover assumed, that the Nuclear Waste Fund will only pay for about 50 years of SKB activity based on the KBS-3 method. There is thus no cost to cover for reversibility, active surveillance, or other maintenance costs, after closure or beyond these 50 years (Bråkenhielm 2005:83). The total cost and so the size of the fees is solely approximated with respect to the KBS-3 method; there are no financial means for implementing other methods that might be more expensive but ultimately deemed safer. There is, as it seems now, a lock-in into the KBS-3 method. This leads to *the fourth economic challenge*, namely, will the nuclear industry be able to generate enough means to cover all the costs involved?

Because of this uncertainty the state is led into a somewhat paradoxical situation: economically speaking, on the one hand, it seems reasonable to expect that the state will keep the reactors running, even replace obsolete ones, in order to claim fees and gradually fill the Fund; on the other hand, the longer the state keeps the reactors running the greater the risk is for budget overrun. But the greater the risk is for budget overrun, the longer the state will keep the reactors running.

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