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The Politics of High-Level Nuclear Waste Management in Sweden: Confined research versus Research in the Wild

Keywords: nuclear waste management, KBS, controversy, enactment, research in the wild, confined research

Abstract

In 2010, the Swedish nuclear energy industry is expected to announce a proposal for the final storage of high-level nuclear waste in bedrock. The underground storage concept is attracting increasing interest from other countries in Europe. Because of the nature of Swedish political culture, the development of the actual method for final disposal is commonly perceived as resting on consensus and democratic cooperation. However, this paper argues that the aforementioned disposal method instead represents the outcome of intense conflict between the nuclear energy industry and the anti-nuclear movement. Accordingly, any investigation of the technical and political solutions to controversial environmental problems should involve the study of lay people and social movements. The present study does so, employing theoretical notions from science and technology studies that allow the analysis to conceptualize actions and strategies (enactments) of the nuclear energy industry (confined research) and the anti-nuclear movement (research in the wild).

The Politics of High-Level Nuclear Waste Management in Sweden: Confined Research versus Research in the Wild

Introduction

In the era of concern about climate change, nuclear power is experiencing something of a renaissance world-wide. A serious problem attracting little attention in the current energy debate is that there still is no undisputed method for handling and storing high-level nuclear waste. In Sweden, a forerunner in nuclear power production and waste management, the advocacy of a new generation of nuclear reactors has grown recently among certain political parties, despite the 1980 referendum that led to the parliamentary decision to phase out nuclear power. This new development coincides with the presentation of a proposal from the Swedish nuclear energy industry concerning the construction of a final storage repository for high-level nuclear waste. In 2010, the Swedish government will decide whether or not the proposal meets the authorities' safety requirements (Anshelm, 2006). Since the decision is supposed to guarantee secure storage for 100,000 years, it is crucial to reconstruct and discuss the truth claims made in the debate on nuclear waste management, claims that have shifted over time. Taking these shifts into consideration, the historical knowledge provided will be indispensable to all decisions regarding the final storage of nuclear waste or construction of new nuclear reactors.

In 1976, the Swedish government passed a law requiring that a completely secure method for the final storage of spent nuclear fuel must be presented before permission would be granted to commission any new nuclear reactor - even one already constructed. The immediate

consequence was that the nuclear energy industry in Sweden made large investments in developing a highly advanced method for underground waste storage in Swedish bedrock. The project was called KBS (an acronym for ‘nuclear fuel safety’ in Swedish). The nuclear energy industry created a specific company, SKB that would guarantee safe nuclear waste management. The company presented three methods for doing this (KBS 1-3), all of which drew international attention. Among countries using nuclear energy, Sweden was regarded as having the greatest efforts to find a solution to the problem of the long-term storage of spent nuclear fuel. The Swedish approach was acknowledged as one of the most ambitious, technologically advanced, and trustworthy suggestions for final storage, and Sweden has been seen as in the vanguard in this area (Anshelm, 2006:78, 115, 163; Kantara, 2007). KBS 3 has recently been adopted by the UK as a reference repository concept for the disposal of spent nuclear fuel and has drawn considerable attention from the European Commission in its plans to develop a new sustainable nuclear energy technology platform for Europe (Elam and Sundqvist, 2009). Representatives of the nuclear energy industry have declared that the KBS 3 method, which stores the fuel in copper canisters 500 meters under in solid bedrock, is completely safe for more than the 100,000 years the spent fuel will be harmful to humans (Anshelm, 2006).

Aim, Methods, and Materials

Several studies have dealt with the politics of nuclear waste in Sweden. One of the most important is Göran Sundqvist’s *The Bedrock of Opinion* (2002), which analyses the development of the Swedish program for storing spent fuel from a science and technology studies (STS) perspective. This work focuses on the strategies developed by the nuclear

industry, the authorities and the Swedish Parliament for establishing objective scientific matters of fact. Specifically, Sundqvist presents and discusses the efforts of these actors to construct scientific and political legitimacy among the public to support the siting of a final nuclear waste storage site. An important scholarly paper is 'On the right track? Technology, geology and society in Swedish nuclear waste management' (Lidskog and Sundqvist, 2004), which explains how the Swedish nuclear industry has successfully implemented nuclear waste management policies, while Mark Elam and Göran Sundqvist in *Stakeholder Involvement in Swedish Nuclear Waste Management* (2007) analyze how the politically controversial issue of the final storage of spent nuclear fuel has become transformed into a *local* political issue, merely concerning the nuclear industry and two small Swedish municipalities.

Although the above literature highlights key aspects of the politics of nuclear waste in Sweden, it omits the contribution of lay people to configuring the controversy regarding the management of spent nuclear fuel. This research mainly focuses on the strategic actions of the nuclear energy industry, politicians and authorities with regard to the development of KBS 3. In contrast, the point of departure of this paper is the acknowledgement that technical and political solutions to controversial environmental problems cannot be fully examined without analyzing the influence exerted by lay people and social movements. Accordingly, this paper aims to analyze the Swedish concept of final nuclear waste storage, KBS 3, as a result of dynamic controversies between the Swedish anti-nuclear movement and the nuclear energy industry. We argue that the anti-nuclear movement contributed considerably to the development of KBS 3, and that the KBS 3 case provides us a better understanding of the management of environmental issues of great concern. In doing so, we aim to identify and discuss the development and configuration of various views of the configuration of nuclear

waste management in Sweden from the 1950s to the present. These standpoints refer to conflicts between the agendas of the nuclear energy industry (conventional science) and lay people (social movements). In the analysis, we will employ theoretical notions from the STS-field that will let us conceptualize and analyze the actions and strategies of the nuclear energy industry and the anti-nuclear movement.

However, we argue that the construction of ‘truths’ and values concerning spent nuclear fuel has not only rested upon the employment of ‘objective scientific matters of fact’, that is, risk-free objects comprising persistent, stubborn, non-mental entities defined by strict laws of causality, efficacy, profitability, and truth (Latour, 2004: 23). On the contrary and as we will show, nuclear waste management in Sweden is a product of complicated *matters of concern*, that is, complex political, cultural, ethical, geographical, and economic constructions, arguments, assumptions, reasoning, overlays, and forecasts (ibid. 23-24). In the framework of our analysis, nuclear waste management constitutes a technoscientific controversy with unclear boundaries but with specific involved parts (the nuclear energy industry and the anti-nuclear movement¹).

This paper analyzes the enactment of nuclear waste risks in the public debate/controversy by the nuclear industry and the anti-nuclear energy movement in Sweden. Moreover, we will show how the debate is informed by various views on nature and science. We are interested in the part of the debate articulated in printed documents. We agree with Ockwell and Rydin (2006: 381) that controversies between different knowledge holders can be understood fully by investigating the discursive bases of the various linkages. Such a methodological choice

¹ We are conscious of the fact that several other actors are involved in the controversy, such as local municipalities, the government, state authorities etc. Nevertheless, we make the methodological choice to focus our study on the investigation and analysis of the arguments and positions ranging from the nuclear energy industry and the anti-nuclear movement.

lets us monitor the argumentation and rhetoric of the anti-nuclear movement, which has mainly employed the strategy of writing discussion pieces for publication in the mass media and scientific journals and of publishing books and leaflets to articulate their standpoints, instead of launching costly major campaigns. In this way, SKB was forced to confront the anti-nuclear movement in the formation of public opinion and to participate openly in the debate in the media concerning nuclear waste management. The conflict/controversy is mainly articulated in the public debate.

Accordingly, our analysis will be based on a close reading of articles in newspapers and scientific journals, official reports, leaflets, and books. The material (embracing over 1200 documents) was collected through extensive searches of databases (Artikelsök, Presstext, Mediaarkivet, and Biblioteksstjänsts tidnings- and tidskriftsindex) covering all Swedish newspapers and the most important Swedish journals. Books and official reports published in the study period were also examined. Our method, comparative text analysis, entailed the close reading of every single text situated in the debate in order to identify central meanings and themes. The analysis of individual texts was undertaken using thematic coding technique that aimed to detect patterns in qualitative data. This approach to coding was inspired by the analytical procedures that have been developed by Strauss and Corbin (1990), but does not intend to be a grounded theory approach; instead this study uses the methods as ways of categorizing and identifying patterns. Specific questions stood out as central, while others were found to be peripheral or even absent. Since the texts were produced in a period of over five decades, it was possible to detect shifts in the arguments over time. More extensive empirical evidence than can be provided here to support certain interpretations can be found in the book *Bergsäkert eller våghalsigt?* (Anshelm, 2006). The next section of this paper

presents and discusses the theoretical concepts that advance our analysis of the empirical data. Our point of departure will be the work of Michel Callon on the increasing involvement of lay people in enacting technosciences.

Situating the case: Enacting Nuclear Waste Management

The end of World War II and the advent of the Cold War were marked by the establishment of a double divide: between ordinary citizens and their elected representatives, and between lay people and experts. Such a double separation precluded any overlap between sociopolitical issues and questions related to technology and science. This led to what Callon calls ‘confined research’, that is, research conducted by experts in milieus removed from the public sphere, for example, in confined worlds such as laboratories, architects’ offices, scientific committees, and private offices, protected from the prattle of lay people (Callon, 2003: 33-36). Nevertheless, the more technosciences became a key factor in Western societies, the less the exclusion of lay people from technoscientific processes could be accepted. Previously excluded groups strove to make the abovementioned separations progressively more illegitimate. Lay people refused experts’ monopoly on knowledge production and sought to intervene in research processes and technological development (ibid. 57). Consequently, the research community has become increasingly interested in investigating engagements and conflicts between accredited scientific knowledge and other forms of knowledge (Ockwell & Rydin, 2006: 380).

This paper focuses on how lay groups (e.g. the Swedish anti-nuclear movement) linked to or influenced by the production of scientific facts or technological artifacts (e.g. nuclear waste management) and the controversies these imply, seek to participate in configuring technical

solutions. Lay people may collectively participate in the relevant research either directly or indirectly. As we will show in analyzing the empirical material, concerned lay people, through their vigilant presence, motivate researchers to be more cautious or conscious, or lay groups may invite experts to practice vigilance on their behalf (cf. Callon, 2003: 47). Accordingly, we are interested in how the debate on nuclear waste management changes depending on the negotiability and participation (or lack of participation) of lay people in configuring various technoscientific practices. According to Callon (ibid. 57), a theoretical focus on lay participation implies a shift from traditional decision-making models: lay involvement delivers a preliminary blow to the traditional division between scientists and lay people. This is the process to which he refers to as *research in the wild*, whereby lay people take action and participate in producing scientific facts. To achieve this participation, lay people establish new practices, exploit existing knowledge, negotiate with other groups of researchers, and form new organizational configurations (Galis 2006: 40).

Callon and Rabeharisoa (2003: 62) define research in the wild as the process through which lay people accumulate and compare the experience of their members and build up a collective expertise as authentic as that of ‘experts or scientists’, even if it is different. In contrast to *confined research*, research in the wild does not claim or possess ‘scientific’ purity. Instead, it is confronted with compound, impure, polluted realities. How are lay people, such as the Swedish anti-nuclear movement, involved in research in the wild and what does that imply for the processes through which nuclear waste management is performed? The concept of research in the wild highlights the perspective that the management of technoscientific facts and artifacts does not have to follow the traditional route via the laboratory, which often implies a relatively passive role for the public sphere and a domination of scientists and

engineers (Galis, 2006: 40). After all, lay people possess expertise concerning their own needs, which is important knowledge for designing and implementing various technologies and which emerges from research in the wild.

The controversy we are to present is a dynamic process, that is, nuclear waste management is in a diachronic transition and reconfiguration. The knowledge and expertise on nuclear waste management is a constant process of blurring the boundaries between research in the wild and confined research. By this we mean that the trajectory that the controversy follows is largely unpredictable and depends on the nature and the degree of groups participating, alliances formed, technological solutions revealed or ruled out, and kinds of research explored (Callon, *et. al.*, 2009:26). In that sense, we argue that technoscientific controversies, such as nuclear waste management, are continually configured and reconfigured, they are recurrently ‘done and enacted’ (Mol, 1999: 77). Mol explains that to use expressions such as ‘scientists make’ or ‘research objects are constructed’ is clumsy, since these expressions imply that research material (e.g. nuclear waste) is assembled by sociological analysis, and then turned into an object that subsequently returns to the world all by itself. Instead, we need a concept/metaphor that stresses the specific ways a research object is handled, for example, in a debate. It is possible to say that in physical practices, research objects are *enacted* (Mol, 2002: 32-33). Matters of concern come into being with the practices (confined research versus research in the wild) in which they are implicated. The translation of technoscientific matters of concern (such as nuclear waste management) enact and are enacted by arguments (articles in newspapers), practices (methods for managing and storing nuclear waste), organizations (SKB, anti-nuclear energy groups), the content of the controversy, expert hegemony, and the involvement of lay people in technology development. We may talk nuclear waste

management but we cannot forget about repositories. This conceptual apparatus allows us to follow nuclear waste management as it was enacted in public debate by the nuclear energy industry (confined research) and opponents (research in the wild) in Sweden.

Risks and responsibility in transition

Between the 1950s and 1960s, the debate on risks and responsibility concerning nuclear waste was confined to scientific or political authorities. It was commonly understood that the Swedish nuclear industry, Atomenergi AB (Atomic Energy Ltd.), and state authorities shared the responsibility for nuclear waste management. If the topic was raised, nuclear physicists, reactor engineers, and politicians maintained that future technology would eliminate any waste handling problems. They insisted that, unlike other industries, the nuclear energy industry paid serious attention to questions of industrial waste in the planning phase, which guaranteed that there were no reasons to worry. Information leaflets from the nuclear energy industry did not even mention risks related to nuclear waste. In newspaper articles, nuclear physicists and reactor engineers predicted that people in the future would learn to live with and handle radiation, just as they had learned to live with and handle electricity (Westermarck, 1952; Brynielsson and Eklund, 1954; Svedberg, 1955a; Funke, 1956; AB Atomenergi, 1957). Communication specialists explained, popularized and reassured: there really was no risk (Callon, *et. al.*, 2009:14). Thus, in that period nuclear waste was enacted solely by scientific and political lobbies, as a risk-free matter of fact. Lay people still constituted outsiders who were unable to influence scientific/political configurations of nuclear waste. Nuclear waste management and the risks it implied were issues that exclusively concerned confined research.

In the early 1970s, conflict first emerged concerning the socio-political characteristics of risks associated with nuclear waste. Plans to open a reprocessing facility in Bohuslän in western Sweden drew protests. A local environmental movement was mobilized to prevent the building of what they called a 'plutonium factory'. It was argued that the facility would expose the local inhabitants to great risks and that plutonium produced during reprocessing was one of the most dangerous and long-lived poisons known (Jacobsson, 1969; Johansson, 1969). At the same time as the Bohuslän incident, Hannes Alfvén, a physicist awarded the Nobel Prize and familiar with the nuclear energy debate in the USA, wrote an open letter to the Swedish government pointing out that nuclear energy and especially nuclear waste involved enormous risks. He warned that mass production of nuclear waste could eventually poison the earth and jeopardize the future of humanity (Alfvén, 1972). This constituted a turning point in the debate, since it was the first time that nuclear waste management was enacted as a hazard to the public. Simultaneously, it was obvious that the nuclear waste issue not longer constituted an objective matter of fact, defined and enacted solely by participants in confined research. On the contrary, a local environmental movement and a well-established scientist who did not belong to SKB's confined research claimed the right to participate in resolving what they considered a controversial matter of concern, questioning scientific and political authority in the enactment of nuclear waste management.

Following the Bohuslän events, in spring 1970, a lengthy debate concerning the risks related to nuclear waste was initiated in the pages of *Dagens Nyheter*, the leading Swedish daily newspaper. On the one side were spokespeople for what some years later became the anti-nuclear movement, while on the other side stood representatives of the authorities responsible for radiation and of the nuclear energy industry. Suddenly, nuclear waste, which reactor

engineers and radiation experts still insisted was not a problem, had been enacted as an object of public controversy - an 'impure' matter of concern rather than a pure matter of fact. The intense discussion led to nuclear waste management being seen as the most urgent environmental issues in Sweden in 1972 (Gillberg, 1970; Lindell, 1970; Jugnell, 1970). Criticism that the risks had been neglected for years grew as the anti-nuclear movement increased its influence. In 1973, Parliament imposed a moratorium on commissioning new nuclear power plants until a reliable plan for nuclear waste management had been presented (Lindquist, 1997). Thus, in less than four years there had been a considerable reconfiguration of public discussion of the risks related to nuclear waste. The very same period marked the entrance of lay people, in the form of an anti-nuclear movement, into the debate on the enactment of nuclear waste.

It is symptomatic of this sudden change that the first state investigation into nuclear waste management began on 25 April 1973, just one month before the moratorium was imposed. In this investigation – in which representatives of confined research (e.g. nuclear physicists and radiation experts), representatives of the nuclear energy industry, and politicians with an optimistic view of nuclear energy played important roles – risks related to nuclear waste were discussed more seriously than ever before in Sweden (SOU, 1976). The environmental and anti-nuclear movements demanded that a detailed official plan for managing nuclear waste should be presented. The state investigation suggested that the waste should be encased in glass and stored in Swedish bedrock - a suggestion heavily criticized by the anti-nuclear movement (Lindeberg, 1976; Blomfeldt, 1976; Melander, 1976; Moberg, 1976). What was important about this investigation was its insistence on a completely new risk evaluation and on finding convincing methods for securing final storage. Risks related to nuclear waste were

no longer peripheral unquestionable matters of fact to be left to confined research - that is, scientists and engineers working on the assumption that people would learn to live with the risks. Instead, presenting a reliable storage method in advance became a prerequisite for the further development of nuclear energy in Sweden. The controversy regarding nuclear waste management had completely re-enacted the concept of 'risks'. Accordingly, the nuclear industry and reactor engineers had to change their risk evaluations as well. For the first time, the anti-nuclear movement did not simply oppose confined research and nuclear industry, but made concrete suggestions concerning safe storage methods. In that sense, lay people no longer constituted just a sceptical activist group but now sought to 'stick their noses' into science and technology.

Ultimately, the nuclear energy industry yielded to the pressure of the anti-nuclear movement and their advocates, though this was certainly not an unconditional capitulation. The first traces of research in the wild forced the industry to embark on an ambitious research project to develop secure methods for managing and storing nuclear waste. A special company, SKB, owned by the nuclear energy industry, was created for this purpose. Through SKB, the nuclear energy industry took full responsibility for its by-products and made large investments in research and technological development. Three possible suggestions for the final storage of nuclear waste were finally presented in proposals that became known as KBS 1-3, which focused on geological and technical aspects of storage. The proposals for final storage in the official report from the first state investigation were developed and refined by a cadre of contracted experts (Rosenberg, 1977; Thunell *et al.*, 1977; Mosesson, 1977). New proposals were circulated for comment nationally and internationally. Eventually, SKB presented a method for final storage of nuclear waste that was described as one of the most

advanced in the world. The company insisted that this method would ensure secure storage of nuclear waste (Bjurström, 1986; Bjurström, 1988; Falk 1995; Papp, 1995). However, the process to be followed for the final storage of nuclear waste did not entail the participation of the anti-nuclear movement, despite the fact, as we will show in the following section, that researchers in the wild were extremely critical of this final method. The design and application of technical methodology were still essentially confined to the margins of the nuclear energy industry (i.e., SKB).

However, detailed examination of the various alternatives, as well as the considerable money and research energy invested in the project, indicate that decision-makers in the nuclear energy industry in the 1970s and 1980s enacted risks differently from their predecessors. The risks posed by nuclear waste were taken much more seriously than before. Accordingly, the conflict between the nuclear energy industry and the anti-nuclear movement no longer concerned whether or not nuclear waste involved large risks. The conflicts now concentrated on whether these risks could be handled using methods developed solely by the nuclear energy industry or whether researchers in the wild could deliver serious criticism and discuss alternatives. In answering that question, the nuclear energy industry and the anti-nuclear movement, as well as their consulting geologists, engineers and radiation experts, came to completely different conclusions (Lindeberg, 1976; Mörner, 1978; Bjurström, 1986, 1988). This, however, constitute the first concrete dispute between research in the wild and confined research during the controversy regarding the storage of nuclear waste management in Sweden, a dispute that involved deconstructing objective matters of fact regarding nuclear waste and the enactment of impure matters of concern, that is, different perceptions and proposals regarding storing methods. How did the controversy escalate?

In the 1980s, SKB began test drilling in the Swedish bedrock. In several places, drilling was obstructed by lay people (local residents), who claimed responsibility for future generations and the environment. They, however, interpreted and acted on this responsibility in a way that differed completely from that of SKB. They did not act on responsibility by seeking methods for storing nuclear waste but by protecting their home districts from the radioactive contamination they feared could result from inappropriate and untested methods of underground storage. Accordingly, they completely opposed KBS 3 and all underground storage of nuclear waste. This responsibility was enacted by local resistance groups, which conducted research in the wild and mobilized counter-experts that questioned the claims of geologists and engineers contracted to SKB (Noresson, 1985). By the end of the 1980s, this resistance forced SKB to realize that the company could not take sole responsibility for nuclear waste storage; the company would have to allow local residents to share responsibility by involving them and winning their consent to any project. All attempts to force waste storage measures on people were doomed to fail since they led to serious conflicts (Arpi, 1990). Enrolling researchers in the wild became increasingly unavoidable as concerned lay people grew in number, formed alliances (e.g. local residents with counter-experts), and increasingly made themselves heard (cf. Callon, 2003: 54). Their voices helped re-enact not only risks related to nuclear waste management, but also how responsibility for this issue was articulated and manifested in the debate. Nuclear waste management was not longer an issue that concerned only confined experts and politicians, but the subject of contention between research in the wild and confined research that prompted new research efforts and critique.

Accordingly in 1992, SKB sent a letter to all 286 municipalities in Sweden asking whether they were interested in cooperating with investigations of local bedrock to find suitable sites

for a final repository for high-level nuclear waste. The technocratic model having failed, this letter was an invitation to municipalities and citizens to share the responsibility for managing nuclear waste. During this information campaign, SKB also pledged that the municipality selected as a repository would be guaranteed a considerable number of employment positions for many years to come. Once cooperation with two municipalities in northern Sweden, Malå and Storuman, had begun, SKB representatives argued that the responsibility for handling nuclear waste rested on the entire Swedish population. SKB was to enrol lay people in their project. All municipalities that might have suitable sites for a final repository had a moral obligation to contribute to solving the problem, since it was in the common interest to ensure that storage was as secure as possible (Thegerström, 1993). These arguments indicate that a considerable change had taken place. First, SKB did not base its campaign for enrolling Swedish communities simply on scientific matters of fact but employed other political, moral, and economic arguments. Second, SKB no longer saw itself as having sole responsibility for the storage of nuclear waste and for choosing sites on scientific grounds: SKB attempted to redistribute responsibility, that is, confined research no longer claimed a monopoly over scientific research and policy making. Instead it appealed, with varying results, to people's sense of responsibility for the common good. In the early 2000s, the company managed to persuade several municipalities to express their willingness to share this responsibility (Elam and Sundqvist, 2007).

Nevertheless, SKB's consensus making efforts and their attempt to include lay people in the enactment of responsibility was met with suspicion and resistance. Lay people and their advocates had learned to mistrust information provided by nuclear agencies, even when they seemed to be above suspicion technically and morally (cf. Callon *et. al.*, 2009:14). In the anti-

nuclear and the environmental movements, there was strong opposition to SKB's proposal for underground storage, KBS 3, and to how the company supported its views by presenting more-or-less tendentious and made-up scientific results as unquestionable matters of fact. The company's information campaigns were characterized as distorted, biased, and dishonest (Åhäll, 1986; Holmstrand, 1987). The distribution of responsibility was also deemed defective, as the opponents did not think that responsibility should rest with a private company owned by the nuclear energy industry, which would inevitably base its actions on principles that differed completely from those required to address serious environmental questions. The anti-nuclear movement argued that the state should take over responsibility for nuclear waste as soon as possible to enable public control of the process (Bildström, 1997). The government's response was to assert that it considered the distribution of responsibility to be appropriate and based on the sound principle that the producers of nuclear waste should take responsibility for dealing with it. Moreover, state authorities had input into the process and the government retained the right to approve or reject SKB's proposals for final storage. The government was thus satisfied that the process being followed was democratic (Larsson, 2000). The enactment of responsibility again raised the divide between lay people, politicians, and experts. The developing dynamics of the anti-nuclear movement, the Swedish government's approach, and the nuclear industry methods together led to the conflict. While the government and the nuclear industry considered SKB's suggestions appropriate, lay people representing the anti-nuclear movement opposed all forms of underground storage while struggling for an alternate method.

The controversial questions of risk and responsibility have been enacted in various ways since the 1970s, and opinions have oscillated between emphasizing locally defined and nationally

performed responsibility/risk. It currently appears that consensus has been reached, at least in some places, as the municipalities of Oskarshamn and Östhammar have decided to accept a final repository for nuclear waste within their boundaries (Elam and Sundqvist, 2007). Once SKB had come to an agreement with these two municipalities, it was hard for the national environmental movement to object to these municipal decisions on democratic grounds. Nevertheless, this does not imply political closure regarding nuclear waste management. On the contrary, and as we will show in the following section, the divide between the anti-nuclear movement and the nuclear energy industry remains.

The previous discussion of the change in interpretation of risks and responsibility, as articulated in public debate from 1950 to the present, indicates a radical re-enactment of nuclear waste management and reconfiguration of the implicated actors, enforced by the anti-nuclear movement and research in the wild. In the following, we will discuss how these processes were manifested in the context of nature and science. We will show how confined research, research in the wild, and their mutual antagonisms contributed to re-enacting the natural world, technoscientific knowledge, and the KBS project.

Re-enacting nature and science

In nuclear waste storage proposals of the 1950s – for example, depositing the waste in the oceans, burying it in Antarctic ice, or storing it in abandoned mines – reactor engineers, nuclear physicists, and radiation physicists (i.e., confined research) always described nature as stable and sustainable. It was assumed that the dilution or burial of radioactive waste would not affect a forgiving nature in any significant way. The oceans were huge and deep and the bedrock ancient and stable and neither would be affected by radioactive emissions

(Brynielsson and Eklund, 1954; Svedberg, 1955a; Sievert, 1956). In the 1970s, when specific proposals for constructing underground storage for nuclear waste in Sweden were presented, these proposals were still permeated with the notion of a sustainable and unchanging nature. It was taken for granted that bedrock would remain the same forever (SOU, 1976).

At the time, it was very unusual to question the statements of confined research concerning nuclear waste and its management, even though these statements were sometimes only speculations concerning future technology. Visions of deep-sea dumping, launching nuclear waste into space, and disposal in Antarctic ice masses went unquestioned. Dramatically revised scientific statements about the half-life of radioactive waste gave rise to no official expressions of doubt about the trustworthiness of the proclamations of nuclear and radiation physicists.

However, in the early 1970s, physicists such as Hannes Alfvén and Sten Lindeberg began to criticize the scientific reasoning of the authorities responsible for future nuclear waste management as well as the science underlying the first official report on nuclear waste. Confined research and its scientific authority were under attack. The aforementioned physicists made clear in public debate that the scientific statements underpinning the political decision-making were nothing but qualified interpretations moulded by political, economic, and technological interests, that is, impure matters of concern. Science was not politically neutral, and it was possible to formulate alternate scientific interpretations that were as trustworthy as the established ones (Blomfeldt, 1976; Lindeberg, 1976). Inspired by Alfvén, politicians in the Centre Party began to question the scientific statements of researchers in the nuclear energy industry (Rainer, 1973; Fälldin, 1976). The anti-nuclear movement and environmental organizations engaged their own scientific experts to conduct research in the

wild, to scrutinize the scientific statements and truth-claims articulated in government and SKB reports.

The hegemonic position of confined research was seriously deconstructed. Researchers in the wild - i.e., oppositional scientists, journalists, environmentalists, politicians, and concerned lay people - questioned matters of fact pronounced in the name of science by confined scientists because they interpreted these facts as expressions of political interest/concerns and thought that they exceeded what could be confirmed from a strictly scientific viewpoint (Lindeberg, 1976; Moberg, 1976; Westman, 1976). It was no longer possible to talk of nuclear waste management without at the same time saying something about what constituted a desirable society.

The same kind of antagonism between confined research and research in the wild was also evident in how nature was enacted. The emerging environmental and anti-nuclear movements took an entirely different view of nature from geologists and other natural scientists. They performed nature as vulnerable and eco-systems as damageable. Nature was not stable but variable, heterogeneous and somewhat unpredictable (Moberg, 1978; Mörner, 1978; Bergom-Larsson, 1979). Given such a view, the idea of burying nuclear waste in bedrock for over 100,000 years appeared clearly risky, even irresponsible.

Environmental organizations and critics of KBS enacted the Swedish bedrock as living and changeable. They enlisted the support of several geologists who testified that it had undergone several transformations, especially during the ice ages. Geology revealed traces of earthquakes, faults, fissure formation, and altered subsoil water flows. Thus, it would be impossible to predict the condition of bedrock for a period of 100,000 years, especially if the bedrock contained a nuclear waste repository that might affect both subsoil water flows and

fissures. Accordingly the anti-nuclear movement, Greenpeace, and several local resistance groups opposed all forms of underground storage of nuclear waste. They asserted that the concept that made it possible to ‘get rid of’ nuclear waste by burying it rested on the same view of nature that had caused earlier environmental disasters. The critic’s view of nature could not accept the construction of a facility intended to keep nuclear waste isolated from the biosphere for an almost incomprehensibly long period. They argued that dry deposit and storage at ground level were preferable, since the nuclear waste could then be kept under constant surveillance and its containment would not be dependent on the changeable and unpredictable natural environment. Several geologists publicly questioned the company’s geological assessments and local resistance groups refused to accept test drilling in their municipalities (Noresson, 1985; Mörner, 1988; Alfvén, 1988; Edberg, 1988; Gahrton, 1988). Critics of nuclear energy began to consider every scientific statement about the future management of nuclear waste as political. Awareness of scientific and technical weaknesses led to the re-enactment of the terms of the debate and the emergence of new inquiries and critiques (cf. Callon, *et. al.*, 2009: 15). KBS 1–3 and SKB technical reports were thoroughly reviewed and heavily criticized in every detail. Every single report was scrutinized by scientific counter-experts (researchers in the wild) who maintained that the nuclear energy industry was presenting energy policy in a scientific disguise (Lindeberg, 1978; Anér, 1978). In scientific disciplines such as geology, intense controversy arose between researchers working for SKB and researchers in the wild: the latter feared that the former were allowing geology to be used for purposes that could undermine its trustworthiness. Some critical researchers were part of the anti-nuclear movement and publicly denounced their colleagues for participating in KBS research (Mörner, 1978; Nilsson, 1978; Mörner, 1979; Sundqvist,

2002:150-171). Geologists spoke out against geologists, hydrologists against hydrologists, physicists against physicists, and engineers against engineers. There is no doubt that most researchers defended KBS and considered its proposals scientifically valid. However, the critical researchers received much public attention. Their accusations that SKB's reports were adjusted to suit the interests of the company undermined efforts to show that there was widespread scientific consensus concerning KBS. As a result, SKB was forced repeatedly to 'refine' KBS, to defend itself from the attacks of research in the wild.

The questioning of SKB's confined research into final nuclear waste storage continued in the 1980s. Callon explains that, in a similar case in France, concerned lay people did not engage personally in research in the wild; instead, they hired experts who, with their knowledge and research, contributed to broadening the research collective and the scientific critique (Callon, 2003: 46). Likewise, local lay groups and the anti-nuclear movement in Sweden engaged geologists, hydrologists, physicists, and engineers in opposing specific test drillings as well as underground storage in general. In Klipperås in southern Sweden, conflicts arose when the local resistance group did not believe that SKB's geologists were impartial and wanted to consult independent geologists. SKB did not want geologists other than their own to examine the cores from the test drillings, but the resistance group refused to accept this. In this way, SKB's confined research became closed research (*ibid.*). Parts of the cores were stolen and subjected to illegal geological examinations (Holmström, 1984). This incident illustrates the total lack of trust in SKB scientists on the part of local resistance groups.

This distrust was hardly reduced when KBS 3 was circulated for scientific comment in 1984. The anti-nuclear movement and several environmental organizations maintained that feedback from critical scientists and institutions had been removed and that only positive opinions had

been retained (Ringsberg, 1984; Eriksson, *et. al.*, 1986; Noresson, 1986). Critical remarks from researchers in the wild were also ignored, reinforcing the conviction in the anti-nuclear and environmental movements that the nuclear energy industry conducted unscientific research and that all further production of nuclear waste should be stopped immediately. The critical geological and technological experts taking sides with the environmental organizations questioned the assumptions on which SKB's construction of repositories and encasements were based, addressing such issues as hydrological conditions, fissures, firmness and corrosion (Eriksson *et. al.*, 1986; Åhäll, 1986; Holmstrand, 1987; Mörner, 1988; Holmstrand, 1990). SKB rejected these criticisms and pointed out that a massive body of international scientific expertise had declared that KBS 3 was secure (Bjurström, 1988). The opposing positions were thus rigidly fixed and accusations of unscientific behaviour were reciprocal.

As we showed earlier, SKB's position was that burial in massive bedrock would guarantee the secure storage of nuclear waste. Searching for the most suitable bedrock had accordingly been a priority. However, in the late 1980s SKB announced that it was possible to construct a final repository almost anywhere in Sweden and that the most important barrier preventing radiation from reaching the biosphere was not the bedrock but the copper encasement of the waste. According to SKB, the role of the bedrock was no longer to prevent radioactive waste reaching humans but to prevent humans reaching nuclear waste (Bjurström, 1989; Ahlström, 1989; SKB, 1992; Sundqvist, 2002:113-116). This assertion rendered moot the whole question of whether the bedrock was stable. The problem was no longer the sustainability of nature but the sustainability of technological construction. This reorientation enabled SKB to avoid awkward geological questions while allowing nuclear waste storage facilities to be

located wherever the political will to cooperate existed. The same reorientation occurred in the USA in 2000, when encasement rather than geological conditions was declared the most important factor in safe nuclear waste storage (Macfarlane, 2003:793). All of a sudden, SKB's rhetoric was based on a political argumentation (i.e., striving for cooperation with a municipality) rather than scientific matters of fact (i.e. geology).

This kind of reconfiguration produced an extraordinary result. Those who had earlier accused SKB (e.g., researchers in the wild and the anti-nuclear movement) of being undemocratic when it carried out geologically motivated test drillings to find the most suitable bedrock now accused it of neglecting geological and hydrological factors and of being prepared to base its choice of final storage site on the amount of political opposition the site would attract. SKB's critics maintained that the new focus on political acceptance rather than geological conditions made the company untrustworthy and dangerous (Holmstrand, 1990; Avfallskedjan, 2001). In the 1980s, when SKB had made great efforts to find the most suitable bedrock, critics in the anti-nuclear movement and local resistance groups had strongly opposed this on the basis that all underground storage of nuclear waste was unjustifiable. Now, however, organizations that had previously opposed underground storage brought up questions of the quality of the bedrock in relevant municipalities, discussed alternative sites on geological grounds, and accused SKB of neglecting geological and hydrological factors. In contrast to the 1980s, the anti-nuclear movement discussed geological and hydrological criteria in a positive way. Instead of simply condemning all underground storage, it pointed out that the most suitable geological formations were in inland areas with slow subsoil water flow (Holmstrand *et. al.*, 2002). Their intention was clearly to cast doubt on the coastal sites, Oskarshamn and

Östhammar, which SKB had chosen. Thus, even SKB's opponents reconfigured their positions, for example, by adopting scientific arguments regarding geology and hydrology.

This became more obvious in 2006 when KBS 3 was heavily criticized by the anti-nuclear movement and several environmental organizations for resting on obsolete technology. These organizations advocated developing a technology for the final storage of nuclear waste in 5000-meter deep drill-holes in bedrock. This method was presented as more sophisticated and secure than KBS 3; however, SKB was sceptical and stated that the method was untested (Lihnell Järnhöster *et. al.*, 2006). Thus, the argumentation of the anti-nuclear movement did not explicitly involve political means, while the resistance to underground storage was not a main principle any longer. The movement's new strategy was based solely on discussing technical and scientific matters in the same way as SKB had done for decades. In other words, at a time when agreement had been reached between SKB and two municipalities, concerned lay people and researchers in the wild aimed to present better technological alternatives instead of merely criticizing existing ones. By doing this, they exerted new pressure on KBS 3 and made it necessary for the authorities to investigate other alternatives than KBS 3. Whether or not the concerned lay people and their allies had changed their attitude towards underground storage is not easy to tell, since they had learned their lesson well and refrained from discussing political matters, confining themselves strictly to technological alternatives. From this point on, the anti-nuclear movement made politics using scientific means, while SKB made science using politics.

Still it was a case of one group's word against another's, and nothing indicated that this would change. The examined reconfigurations of nature and science as enacted in the controversy between confined research (SKB) and research in the wild (the anti-nuclear movements and

its allies) illustrate how interpretations claimed to be true, correct and reasonable can shift in relation to each other and to social and political circumstances. In some respects the opposing sides had switched positions, and had done so more than once.

Conclusions

Nuclear waste management does not constitute a matter of deciding on the basis of indisputable scientific facts (cf. Callon, *et. al.*, 2009: 16). Nuclear waste management is a matter of concern enacted in the conflicts, negotiations, and research of diverse groups of legitimized experts, lay people, ordinary citizens, and researchers in the wild. Both the critics and proponents of the Swedish KBS programme have been able to enact their own positions as scientifically grounded and their opponents' as politically distorted science. Scientific statements have been locally valid, negotiable, situated, and changeable, that is, local matters of concern. Despite repeated attempts, nobody has been able to enact their statements and goals as universally scientifically valid, as confined research had succeeded in doing in the 1950s and 1960s. The boundaries between nature, science and politics as well as between confined research and research in the wild have been completely scrambled (cf. Callon, *et. al.*, 2009: 26).

As shown, SKB was forced to develop and refine its technical proposal (KBS) in the face of mounting criticism from researchers in the wild and lay people. Such criticism gave birth to negotiations among the opposing factions, which frequently shifted from their original standpoints and often adopted the opponents' rhetoric and strategies. Therefore, we argue that KBS 3 was not a result of the Swedish political culture informed by principles of

corporativism and consensus making, as several researchers maintain, but rather a product of intense conflicts between SKB and the anti-nuclear movement. There is an ironic aspect in this: researchers in the wild, by successfully criticizing KBS, contributed to the refinement and development of the technical solution - underground storage - to the problem of spent nuclear fuel. Currently, the European Union considers this technical approach to be exemplary, while SKB presents it as a result of Swedish scientific research and engineering. We claim that this proposal would not have met such a positive reception, if the Swedish anti-nuclear movement and research in the wild had not exposed KBS to such meticulous criticism. As a result, researchers in the wild have unintentionally endorsed a technical solution that they, at the same time, have resisted.

The latter discussion indicates that in the issue of nuclear waste management, the anti-nuclear movement won a Pyrrhic victory: by thoroughly following and deconstructing KBS, researchers in the wild made the nuclear industry develop safer nuclear waste storage methods. Regarding nuclear waste management, the anti-nuclear movement had articulated two concrete goals: first, to make obligatory the development of a safer nuclear waste storage method and second, to prevent underground storage of spent nuclear fuel. By severely criticizing SKB's plans, they managed to fulfil their first goal, since SKB was forced to reconsider, develop, and refine their proposals for nuclear waste storage. Their second goal, however, was never accomplished, since their criticism contributed to the development of KBS and to its broad acceptance, even at an international level. Does this imply that SKB managed to enrol researchers in the wild in their own project of establishing KBS 3 as an unquestionable matter of fact?

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