



The Swedish National Council for Nuclear Waste's
Review of SKB's RD&D Programme 2019

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*The Swedish National Council
for Nuclear Waste*

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**The Swedish National Council
for Nuclear Waste**
(M 1992:A)

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To the minister and head of the Ministry of the Environment

This review from the Swedish National Council for Nuclear Waste (M 1992:A Swedish National Council for Nuclear Waste) concerns the Council's assessment of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) *RD&D Programme 2019. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste*. The Swedish National Council for Nuclear Waste is an interdisciplinary scientific committee tasked with advising the Government on issues of spent nuclear fuel, nuclear waste and the decommissioning of nuclear facilities. According to the Government's terms of reference¹, the Swedish National Council for Nuclear Waste shall submit a report on its independent assessment of the measures presented in SKB's RD&D programmes. As previously, Johanna Swedin, scientific secretary at the Swedish National Council for Nuclear Waste, has served as the project manager for the review.

This report is endorsed by all members and experts in the Swedish National Council for Nuclear Waste.

Stockholm, June 2020

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¹ M 1992:A Swedish National Council for Nuclear Waste, Dir. 2018:18.

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1 Introduction

The Swedish National Council for Nuclear Waste hereby submits the results of its review of SKB's (Swedish Nuclear Fuel and Waste Management Co's) *RD&D Programme 2019. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste.*

Chapter 1 Section 1.1 contains a summary of the Council's recommendations to the Government based on its review. Section 1.2 presents the points of departure for the Council's review. Section 1.3 highlights the importance of comprehensiveness, openness and transparency in the RD&D process, in order to ensure, among other things, that a final repository for spent nuclear fuel will be as safe as possible.

The two following chapters contain the results of the Council's review of the RD&D Programme 2019. Chapter 2 includes the Council's overall assessments and viewpoints. Chapter 3 contains specific comments to different sections in the present RD&D programme. These chapters also include a number of proposed measures for SKB.

In Chapter 4, the Council presents its views on future RD&D programmes. The Council reiterates the importance of interdisciplinary research for complex projects carried out over a long period of time. Finally, the Council argues for the continued need for an open RD&D process for both licensed and non-licensed activities (see Section 4.2 and 4.3).

1.1 Recommendations to the Government

The Swedish National Council for Nuclear Waste finds that SKB has improved its presentations in several sections of the RD&D Programme 2019 compared with the RD&D Programme 2016. At the same time, the Council notes on several occasions that SKB has not

implemented the measures proposed in the Council's previous review (SOU 2017:42)¹. The present RD&D programme contains several sections that require clarification and research that needs to be initiated to show that the research and development activities permit safe decommissioning and final disposal.

The Swedish National Council for Nuclear Waste recommends the Government to urge SKB to carry out the following measures in connection with the continued research activities:

- to continue to work on making the RD&D programme more comprehensive and to be more open about its activities (see Section 1.3 and 4.2 of this review). The RD&D programmes should provide a holistic perspective of the development of activities both in a repository and between different repositories and provide intradisciplinary depth and interdisciplinary breadth. For example, the Council emphasises that future RD&D programmes should describe the connections between research areas that will depend on and influence each other, and thereby also the final safety assessment (see Section 2.4 of this review).
- to remedy the deficiencies described by the Swedish National Council for Nuclear Waste in this review (Chapter 2 and 3), and to do so no later than in the RD&D Programme 2022, even if the Government should grant a licence for an activity. In future RD&D programmes, it is of particular importance that research is initiated and presented in the sections where the Council in its comments to RD&D Programme Chapters 9, 10 and 11 has identified a lack of research in the RD&D Programme 2019 (see Section 3.2 of this review).
- to also report the following research and development areas in future RD&D Programmes:
 - model and calculation tools and how the safety assessment can be optimised in a long-term perspective (see Section 3.1 of this review concerning RD&D Programme Section 5.4).

¹ Swedish National Council for Nuclear Waste. 2017. SOU 2017:62 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Management Co's (SKB's) RD&D Programme 2016*.

- a programme for efficient interaction between operational activities and continued research and technology development if a licence is obtained for a final repository for spent nuclear fuel (see Section 2.6 of this review).
- interdisciplinary research where social science research is integrated with the natural science programme (see Section 4.1 of this review).

Furthermore, the Council recommends the Government:

- to instruct the Swedish Radiation Safety Authority (SSM) to, in collaboration with SKB, draw up a national and long-term competence management programme within areas relating to the decommissioning of nuclear facilities and safe management and disposal of nuclear waste and spent nuclear fuel (see Section 3.1 of this review concerning RD&D Programme Section 5.5).²
- to ensure that research, development and demonstration (RD&D) is presented in the RD&D programmes in the future, for both non-licensed activities and licensed activities (see Section 1.3 and Section 4.2 of this review).

1.2 Points of departure for the Swedish National Council for Nuclear Waste's review

The Council's role and mission

The Swedish National Council for Nuclear Waste is tasked with reviewing the RD&D programmes, irrespective of the stage at which SKB is in the various licensing processes, and based on the information found in the RD&D programmes.

According to its terms of reference, the Swedish National Council for Nuclear Waste shall conduct an independent review from both an intradisciplinary and an interdisciplinary perspective and within the framework of its competence. The Council members

² Read more in Chapter 2 of the Council's latest state-of-the-art report. Swedish National Council for Nuclear Waste. 2020. SOU 2020:9 *Kunskapsläget på kärnavfallsområdet 2020. Steg för steg. Var står vi? Vart går vi?* ("Nuclear Waste State-of-the-Art Report 2020. Step by step. Where do we stand? Where are we going?").

represent competence from natural sciences, social sciences and the humanities, and in the work with the present programme the Council – partly with regard to its current composition with two vacancies – has focused its review on the following chapters: 3, 4, 5, 8, 9, 10, 11 and 12. Sufficiently detailed information is lacking in certain parts, which has made it more difficult to carry out the review. The Council's priority with respect to the RD&D Programme 2019 is above all the issue of final disposal of spent nuclear fuel.

Points of departure regarding content

When it comes to the management and disposal of nuclear waste, including the process of the RD&D programmes, the Council finds that there is reason to once again emphasise the general requirements on comprehensiveness, transparency and openness.³ In its decision to approve the RD&D Programme 2016, the Government stipulated that SKB should:

...consider how the RD&D programme can better contribute to openness and transparency in how the work with research, development and demonstration of methods for management and final disposal of nuclear waste is being conducted.⁴

The Swedish National Council for Nuclear Waste is of the opinion that it is SKB's responsibility to present a comprehensive research programme, and to be open and transparent in the planning and reporting of its research, development and demonstration. All for the purpose of contributing to increased safety in the different final repositories. These points of departure are further discussed in Section 1.3.

Other important points of departure for the Council's review are the safety assessment perspectives, validation of models used, the relation to research and development in other countries, the need for contingency planning (in case of national and global crises), ethical issues such as the responsibility for future generations, that the work is carried out in a specific societal context and that the nuclear waste issue not only concerns natural science and technical issues.

³ The requirements on an RD&D programme to be "comprehensive" and "allow openness and transparency" etc. are stated in: Gov. Bill 1983/84:60 with a proposal for new legislation in the field of nuclear energy, pp. 40 ff. and pp. 92 f.

⁴ *Government decision on the RD&D Programme 2016.*

1.3 Comprehensiveness, openness and transparency

There is no final repository for spent nuclear fuel in operation in the world, neither according to the KBS-3 method, nor any other method.⁵ A final repository according to the KBS-3 concept is not a fully developed method at the time of licensing; it will undergo a stepwise review regarding its compliance with the requirements in the Nuclear Activities Act during development and construction.⁶ Furthermore, the work after a licence from the Government is granted up to final closure is planned to continue at least 70 years into the future.

Therefore, it is reasonable and desirable from a societal perspective to have comprehensive and open RD&D programmes, which provide opportunities for insight into the research, development and demonstration required. This will also be the case when an activity has been granted a licence, up until final closure. This facilitates for other actors to review the RD&D programmes and increases the possibilities to supply knowledge that may improve the long-term safety of the final repositories.

The following describes the Council's general view of what a comprehensive and open RD&D programme is, and how it can contribute to transparency and safety.

1.3.1 Comprehensiveness

The requirement for comprehensiveness entails that all research and development tasks of importance for long-term safety are sufficiently reported and well executed. This means that the consequences from a comprehensive perspective need to be explored.

The opinion of the Swedish National Council for Nuclear Waste concerning the comprehensiveness of the RD&D programmes can be summarised in the following points:

⁵ Finland is the only country in the world that has started to build a final repository for spent nuclear fuel, but no spent nuclear fuel has been disposed of and the final repository is planned to be operated for about 100 years. Read more at: www.posiva.fi/en (visited 2020-06-01).

⁶ SKB is to produce updated safety analysis reports etc. that must be approved by SSM in a so-called stepwise review process. For example, SKB must take site-specific information into account and determine detailed design solutions.

- The RD&D programmes should include all parts of the final repository projects,⁷ and thus also include the activities that have obtained a licence (see Section 4.2 of this review).
- The Council provided important guidelines for a comprehensive research programme in SOU 2017:42. A programme should (1) clearly describe and justify the planned research, (2) explain why a certain method has been chosen, (3) elucidate the results achieved and present them in relation to the research being conducted within other organisations and institutions, both nationally and internationally, (4) justify the choice of collaboration partners and clearly describe how the collaboration takes place, and (5) define the scope of different research programmes with the aid of budgets and time frames.⁸
- Comprehensiveness also entails a presentation of research and development that concerns the whole process chain for management and disposal of radioactive waste, from interim storage to final disposal, and what is required for safe and efficient decommissioning and dismantling of nuclear facilities.⁹ Both intradisciplinary depth and interdisciplinary breadth is needed.
- The requirement for comprehensiveness means that different research activities should be integrated. This applies above all to the different research projects concerning the rock and engineered barriers (see Section 2.4 of this review).

1.3.2 Openness

As regards the RD&D process, the Council uses openness as a generic term to denote availability, clarity and comprehensibility in the programme's content. The RD&D programme is an important means for SKB to promote openness in its activities:

⁷ Compare the Act (1984:3) on Nuclear Activities (the Nuclear Activities Act) Section 12, The programme shall contain an overview of all measures that may be necessary and specify in detail the measures that are intended to be implemented within at least six years.

⁸ Swedish National Council for Nuclear Waste. SOU 2017:62 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2016*.

⁹ Gov. Bill 1983/84:60, p. 92.

- In the RD&D Programme 2019, SKB writes that research results should be correct, traceable, reproducible and relevant for SKB's mission: "The fundamental principle is that SKB's research results will be published in the open literature to facilitate external review."¹⁰
- It is important that research results are reported as soon as possible after completing a research project. This also applies to results from long-term experiments that are particularly important for verifying long-term safety.
- SKB should be open with its internal processes for research and technology development as far as possible, and these must be comprehensible and well-documented, including the approach for funding the research and the conditions for the same (see Section 2.2 of this review).

This openness is the basis for providing transparency for reviewing bodies and enabling them to fulfil their democratic role as reviewers of SKB's activities.

1.3.3 Transparency

Transparency and participation can be described as external actors' response to SKB's openness:

- A comprehensive and open RD&D programme provides the Government, municipalities, researchers, SSM, the Swedish National Council for Nuclear Waste, civil society, interested organisations and the general public with transparency into SKB's overall activities.
- Transparency and participation is one of the most important opportunities to contribute to confidence in SKB's activities and choices, by giving other actors the opportunity to independently assess the relevance and credibility of the planned research and development. Such confidence is important in order to strengthen the trust between actors in society.

¹⁰ SKB. *RD&D Programme 2019*, p. 105.

- Transparency is *at present* not only promoted through the RD&D programmes. SSM has extensive insight by for instance requesting supplements to SKB's application. The concerned municipalities have an ongoing dialogue with SKB, and the Swedish National Council for Nuclear Waste is provided a broader insight into SKB's research and development through seminars and special meetings. The RD&D programmes and their review will continue to play an important formal role, since it is unclear what participation and transparency will look like in the future (see Chapter 4.2 of this review).

1.3.4 Comprehensiveness, openness and transparency – for the sake of safety

SKB's openness provides an opportunity for transparency towards several actors and ultimately contributes to the long-term safety of the final repositories. The comments from different reviewing bodies and the responses from SKB contribute to improving SKB's research and development activities.¹¹ The reviewing bodies from different sectors of society can highlight perspectives and issues that are important for the execution of the projects and, not least, raise issues of relevance for society in general (see also Section 4.1 of this review).

SKB has been preparing RD&D programmes since 1986 and during all those years they have been reviewed by relevant stakeholders and approved by the Government. This formal process of review and response keeps issues alive and creates a democratic process focused on the safety of SKB's final repositories. Furthermore, this process contributes to a documentation for future generations of the critical issues raised by different actors in society. This creates a social memory of importance for future generations relating to the radioactive waste.¹²

¹¹ SKB. *RD&D Programme 2019*, p. 104.

¹² Compare RD&D Programme Section 4.12.1 *Preservation of information and knowledge through generations* in Section 3.1 of this review.

2 General assessments and comments on the RD&D Programme 2019

This chapter contains comments that are intended to make the RD&D programmes more comprehensive (see Section 1.3.1). The Swedish National Council for Nuclear Waste's comments in Sections 2.1 and 2.2 concern such improvements in the RD&D Programme 2019 that will contribute to improved transparency for reviewing bodies. The comments in Section 2.3 concern a broader perspective in the research programmes by monitoring of international technology development and research. The comments in Sections 2.4 and 2.5 concern clarity and openness and how the proposed research and development are related to and contribute to increased safety. Section 2.6 deals with the issue of interaction between operational activities and the continued research and technology development.

2.1 Scope of different research programmes (with respect to budgets and time frames)

In its comments to the RD&D Programme 2016, the Swedish National Council for Nuclear Waste emphasised that many of the research plans described there are difficult to assess in terms of their potential to provide the necessary knowledge. This is partly due to the absence of a budget and more exact time frames. This also applies to the RD&D Programme 2019. It is rarely clear for how long a project has funding, whether it is intended to be carried out in the coming RD&D period or over a period of time which covers several RD&D programmes. Nor is there information regarding the resources

to be allocated, which makes it difficult to assess whether the objectives are realistic.

In the SKB report *Plan 2019*, there is information about the calculation of costs for all measures necessary to manage and dispose of the nuclear fuel used in the reactors and other radioactive residual products, and to decommission and dismantle the nuclear power plants. Table 4–4 presents estimates for the overall cost of the RD&D Programme 2019 and the RD&D Programme 2022 amounting to SEK 234 and 262 million, respectively.¹

It would be valuable to know how large a fraction of these amounts that will fund/is planned to fund projects to be carried out by universities and institutes of technology, since these activities will be of importance for long-term competence management.

Proposed measures: In future RD&D programmes, SKB should more clearly describe the research programmes' objectives, organisation and resources, as well as their time frames.

2.2 A clearer description of processes and partners

One of the Council's comments on the RD&D Programme 2016 was that SKB needed to better justify the choice of collaboration partners and clearly describe how the collaboration takes place. Improvements have been made in the RD&D Programme 2019,² but the Swedish National Council for Nuclear Waste finds that the descriptions in general require more and clearer accounts of projects, collaborations, participants and actors.

Several sections of the RD&D Programme 2019 lack descriptions of both the premises and conditions for research projects, and the strategies for choosing who will carry out the tasks. It is important that these sections are expanded to allow insight and review, since they form the basis for transparency and quality assurance.

The Swedish National Council for Nuclear Waste especially wants to point out the importance of announcing SKB's planned future research projects publicly and in open competition so that the re-

¹ SKB. 2019. *Plan 2019 Costs from and including 2021 for the radioactive residual products from nuclear power. Basis for fees and guarantees for the period 2021–2023.*

² There are some attempts in the RD&D Programme 2019, for instance in Section 5.1.3 where examples of the origin of different research tasks are given or in Section 5.5.4 concerning international collaboration.

search groups with the best expertise and the best potential in other respects will carry out the research. Open publication of the research results in peer-reviewed scientific journals should, to a greater extent, be a distinct part of the project prerequisites.

The Council finds that the description of processes defined as SKB internal in the RD&D Programme 2019 should be clearer, for example what competence is represented in SKB's research council and what participation is possible in SKB's technology development process. There are no descriptions of the actors and stakeholders that could participate in the different work processes and in the planned activities. It is important that these processes are opened up to greater transparency as well.

Proposed measures: Future RD&D programmes should contain descriptions of both the premises and conditions for research projects, and the strategies for choosing who will carry out the tasks. At least some of the research projects should be announced publicly and in open competition.

SKB should describe its internal processes more clearly in the future. If this is not possible, SKB should explain why the activities and plans described cannot be opened for other participants.

2.3 Presentation of the research and technology development front

In all research, it is very important to monitor the literature in order to quickly get information on new results. The scientific citations in the RD&D Programme 2019, Part II, Waste and final disposal, describing the current and planned research, often refer to studies that are closely related to SKB or the company's collaboration partners. However, the number of citations to other researchers are remarkably few. SKB has a large network thanks to its extensive involvement in EU projects and research commissioned from universities and institutes of technology, but it is important to refer to the scientific development outside this framework as well.

Proposed measures: In future RD&D programmes, SKB should more comprehensively present the research and technology development front within the areas that are related to the KBS-3 method, in order to provide a more complete picture of the research field.

2.4 Clearer links between different research areas

In the RD&D Programme 2019, the different research areas in Part II, Waste and final disposal, are described in an intradisciplinary manner, which is valuable and necessary. There are, however, research areas that are clearly dependent on each other in a final repository. The Swedish National Council for Nuclear Waste believes that it is important to connect research areas that will depend on and influence each other and thereby also the final safety assessment. One such example when it comes to a final repository for spent nuclear fuel is the connection between copper corrosion and the properties of the bentonite barrier at different degrees of water saturation and erosion. This also applies to the modelling of different aspects related to the bedrock, and how newly acquired information from one type of modelling is integrated with other types of modelling.

Proposed measures: In future RD&D programmes, SKB should make connections between research areas that depend on and influence one another, and thereby also the final safety assessment.

2.5 The need for a comprehensive presentation of the research's importance for safety

At several places in the current research and development Programme 2019, it is emphasised that the crucial criterion for the relevance of the research is its contribution to optimising the safety of the final repositories. In the introduction to Chapter 5 in the RD&D programme, for example, SKB writes that the research goals are to:

...provide an adequate basis for the continued technology development and planning that is needed in order to achieve efficient and optimised solutions that simultaneously provide safety both during operation and after closure of SKB's final repositories.³

Against this background, it would be useful to get a general description of the way in which previously conducted research has contributed to the safety of the final repositories during operation and after closure, and how research during the coming six-year period is expected to optimise the safety of the final repositories.

³ SKB. *RD&D Programme 2019*, 5.1.1 "Research goals", p. 103.

Proposed measures: In future RD&D programmes, SKB should include a section that describes in a general way how the completed and planned research contributed or will contribute to the safety of above all a final repository for spent nuclear fuel, in the short and long term.

2.6 Interaction between research, technology development and operational activities

Provided that SKB's application for a final repository for spent nuclear fuel is granted a licence, a design phase of at least 70 years will follow. During this period, research and technology development will continue. Research and development concerning the different barriers that together will contain the radiation and the radioactive material from the spent nuclear fuel is particularly important. The operational activities will provide new experience and knowledge. It is important that these activities interact with research and development in an efficient manner. A prerequisite for this interaction is that knowledge and experience are passed on from experienced expertise and administration to new employees in the activities. International experience shows that specific programmes for this interaction between experienced and new employees in the activities may successfully contribute to optimising the ability of similar large-scale and long-term projects to meet safety requirements.

Proposed measures: Provided that SKB is granted a licence to commence the construction of a final repository for spent nuclear fuel, the Council believes that SKB should design and present a programme for efficient interaction between operational activities and the continued research and technology development.⁴ This research programme should also take into account the significance of knowledge transfer from previous employees to newly recruited personnel in the activities.

⁴ Note that there is an attempt for this in SKB's RD&D Programme 2010, Section 8.4.4 "Work methodology during construction and commissioning".

3 Specific comments on the RD&D Programme 2019

Chapter 3 discusses specific viewpoints consisting of comments and proposed measures related to specific issues. The chapter's subheadings in essence follow the RD&D programme's three parts and sections.

3.1 Comments on RD&D Programme Part I, Activities and plan of action

Comments on RD&D Programme Section 3.4, Plan of action for spent nuclear fuel

This section of the RD&D programme contains a description of the stepwise review process, but only covers about a decade during which a final repository for spent nuclear fuel is constructed and commissioned. There is only a sentence or so mentioning that so-called standard operation will start in parallel with the construction of the repository, which will continue for several decades. During this period, continued research and development is required.

Proposed measures: The RD&D Programme 2022 should emphasise that research, development and demonstration will be needed during standard operation and up until final closure.¹

¹ Read more in Swedish National Council for Nuclear Waste. 2020. SOU 2020:9 *Kunskapsläget på kärnavfallsområdet 2020* ("Nuclear Waste State-of-the-Art Report 2020"). See Chapter 3 concerning the fact that a final repository for spent nuclear fuel is a project that cannot be compared with the construction and operation of a nuclear power plant, when it comes to the stepwise review process and the phases thereafter.

Comments on RD&D Programme Section 3.7 Alternative strategies in case of changed conditions

As in previous RD&D programmes, this section covers the consequences for the entire final disposal process of (1) a shortening or extension of the operating times of the nuclear power reactors and (2) the time of commissioning of the various planned final repositories, and (3) continued research and development of the concept horizontal deposition (KBS-3H).

The Council has no objections to SKB's assessments in the section in question but considers that there is a need for a discussion of flexibility and best available technique. How will SKB follow up research and absorb research results from international research during a period of at least 70 years? It is likely that research over time will result in both improved techniques, new materials, new knowledge, and new findings, which in turn will set new standards that may differ from those in place today. This could concern new concepts, but also modifications and improvements of the KBS-3 concept. Already, similar concepts are being developed in several other countries.

Furthermore, there is no review of other and more extensive societal changes and their possible consequences for the final disposal process. This includes global, national, or local circumstances that could – temporarily or more permanently – impede SKB's activities. At the time of writing this, the spread of the pandemic covid-19 is ongoing, and we do not know what the consequences will be for human beings and the world economy in the end. If comparable or more extensive crises occur during the construction and operation of a final repository for spent nuclear fuel, the consequences are difficult to foresee. It could entail a more extended delay due to the fact that necessary material is not available or that part of the work force is diminished. National and global circumstances could lead to such serious consequences that a final repository is abandoned without having completed the disposal of all the spent nuclear fuel.

Proposed measures: The Council maintains its position from the statement on the RD&D Programme 2016 that future RD&D programmes should contain more detailed descriptions of possible alternative strategies in case of changed conditions and the flexibility available in terms of technology development.

Furthermore, in the next RD&D programme, SKB should include a more general review of contingency measures in the event of national and global crises.²

Comments on RD&D Programme Section 4.10 Monitoring during construction and operation

We find it positive that the RD&D Programme 2019 contains a separate section on monitoring, and the description is a good approach in several respects. But no description is provided of how different stakeholders can be involved in the design of a monitoring programme. This is of particular importance, not least in view of the fact that monitoring processes and their design are often mentioned as an area where there may be great public interest in participation.³ Transparency in the monitoring programme during the construction and operation of a final repository for spent nuclear fuel can contribute to increased confidence in SKB's work.

Furthermore, SKB emphasises that all monitoring during construction and operation should be concluded and evaluated prior to closure; monitoring after closure is not an alternative, since it may affect the barriers. If the Government decides on permissibility, that means that the KBS-3 method is considered safe and that monitoring after closure is superfluous. Nevertheless, the Council believes that monitoring after closure could provide better prospects for future generations to make well-founded decisions in case any measures should need to be taken.

Proposed measures: In the RD&D Programme 2022, SKB should present plans for a research programme on monitoring.

SKB should present plans for participation, how external stakeholders can be involved in a monitoring programme during construction and operation in the most suitable way.⁴

Moreover, SKB should follow the technology development of monitoring systems impartially during the long design phase and wait to make a final decision on monitoring after closure.

² This could for example constitute a research and development area based on the discussion of interdisciplinary research in Section 4.1 of this review.

³ Compare the EU project Modern2020: www.modern2020.eu/ (visited 2020-06-01).

⁴ This could for example constitute a research and development area based on the discussion of interdisciplinary research in Section 4.1 of this review.

Comments on RD&D Programme Section 4.12 Other areas

4.12.1 Preservation of information and knowledge through generations

SKB states that a long time remains before well-developed systems for information preservation are needed and that the expectations and methods will develop and change during this time. Despite finding these assessments partially reasonable, the Swedish National Council for Nuclear Waste is of the opinion that the work with information preservation should start early in a process with the purpose of planning, constructing and operating a final repository. Otherwise there is a risk that the information and knowledge needed are not saved, not preserved in the right way, or insufficiently processed. This is difficult to rectify later in the process.⁵

It is also difficult to solve the issue of how information preservation will be carried out over the long span of time during which a final repository for spent nuclear fuel should be safe. It is therefore important to start research and development in time to find the combination of technical, institutional and cultural measures that is needed. Furthermore, there will be a need for several parallel strategies.

Proposed measures: The Council stands firm behind its proposal from 2016 that SKB must start working on developing strategies for information and knowledge preservation by producing a coherent scientific report on the state of knowledge and the research needs in the area.⁶

Moreover, SKB should make connections to the section fuel information, to describe more precisely which fuel information is intended to be preserved, and how this information will be produced.⁷

These reports should be presented at the latest in the RD&D Programme 2022.

⁵ This is an important conclusion from the working group organised by the OECD/NEA, *Preservation of Records, Knowledge and Memory Across Generations (RK&M)*, in which SKB has participated actively.

⁶ This could for example constitute a research and development area based on the discussion of interdisciplinary research in Section 4.1 of this review.

⁷ See also the measures proposed for RD&D Programme Chapter 8 in Section 3.2.1 of this review.

4.12.2 Other methods for final disposal

The Swedish National Council for Nuclear Waste shares SKB's assessment that the company should continue to monitor other methods for final disposal without conducting a research programme under its own auspices.

Proposed measures: SKB should not only follow, but also report on the development of other methods in the future. This should be carried out in future RD&D programmes.

Comments on RD&D Programme Section 5.4 Work tools

In its plan of action for developing work tools, SKB writes that the model and calculation tools will be maintained and upgraded continuously alongside the general development of computers and operative systems. SKB is also carrying out development to optimise some of the commercial tools for the safety assessments and to continuously develop its own calculation tools. The Swedish National Council for Nuclear Waste wants to stress the importance of carrying out the development of model and calculation tools in pace with the rapid progress within computer technology, artificial intelligence, and modelling. Model and calculation tools are of fundamental importance for many of the research areas covered by the RD&D Programme 2019, for example analyses of the properties of the different barriers, and for the safety assessment in general. Validation of model and calculation tools is central for the reliability and applicability of the information obtained. Strategies and methods for this need to be presented.

Proposed measures: In future RD&D programmes, SKB should describe the connection between obtained modelling and simulation results and the validation that has been and is planned to be carried out. Advance planning is required if long-term experiments are planned or required as the validation method.

In the RD&D Programme 2022, SKB should describe the plans for how to optimise the safety assessment in a long-term perspective.

The Council believes that model and calculation tools should be presented as a separate research and development area in future RD&D programmes.

Comments on RD&D Programme Section 5.5 Resources and expertise

In the RD&D Programme 2019, SKB has described how the company intends to solve short- and long-term competence management issues, which was proposed by the Swedish National Council for Nuclear Waste in its review of the RD&D Programme 2016. Furthermore, the Government's decision to approve the RD&D Programme 2016 came with the condition that:

Future RD&D programmes shall contain a description of how competence development and competence management are to be ensured in a time perspective of 50–100 years.⁸

In 2018, SSM published a study on behalf of the Government regarding national competence in nuclear technology, nuclear safety and radiation protection,⁹ and the Swedish National Council for Nuclear Waste's state-of-the-art report for 2020¹⁰ contains a chapter that describes the situation in seven European countries, including Sweden. These two reports describe both the national and the international situation as alarming and challenging. One of the conclusions drawn by the Swedish National Council for Nuclear Waste is that Sweden needs a national programme to secure the long-term supply of competence, which includes a long-term goal regarding research programmes in nuclear technology, radiation safety and radiation protection. The programme will ensure access to education for studies at universities and institutes of technology in these disciplines at the undergraduate and the graduate level. The Swedish National Council for Nuclear Waste believes that it is essential to evaluate SKB's proposals in the RD&D Programme Section 5.5 on the basis of these two reports.

SKB states that its goal is to have personnel of its own with competence to manage and lead the work with research, development and operation of the system for management of radioactive waste and spent nuclear fuel. SKB's starting point is that society is responsible for the basic education of for example civil engineers and

⁸ Government decision on the RD&D Programme 2016.

⁹ SSM. 2018. *Grunden för en långsiktig kompetensförsörjning inom strålsäkerhetsområdet* ("The basis for long-term competence management in the field of radiation safety").

¹⁰ Swedish National Council for Nuclear Waste. SOU 2020:9 *Kunskapsläget på kärnavfallsområdet 2020* ("Nuclear Waste State-of-the-Art Report 2020"), Chapter 2.

for maintaining basic competence in relevant areas, but that the industry will need to make specific efforts as well.

In the RD&D Programme 2019, SKB describes how the company has conducted research and development in close collaboration with universities and institutes of technology and that SKB-funded research projects have contributed to about a hundred PhD researchers in areas that have been essential for the development of the KBS-3 method.

Proposed measures: In future RD&D programmes, SKB should describe its collaboration with universities and institutes of technology in terms of research funding and PhD positions, and other efforts to secure the short and long-term need for competence. This is important if SKB is to be able to manage and lead the work with research, development and operation of the system for management of radioactive waste and spent nuclear fuel.

Moreover, future RD&D programmes should contain a description of how competence development and competence management are to be ensured in a time perspective of 50–100 years.

3.2 Comments on RD&D Programme Part II, Waste and final disposal

3.2.1 Comments on RD&D Programme Chapter 8: Spent nuclear fuel

The description of knowledge requisites and the research planned in relation to the final disposal of spent nuclear fuel is much better and more clearly described in the RD&D Programme 2019 than previously. In general, there is a broader focus on the spent nuclear fuel. In the following, we give some proposals for areas where the Council finds that the planned research should be strengthened in relation to the description in the RD&D Programme 2019. Since there are similar viewpoints related to several sections, the comments on Chapter 8 are presented as a whole.¹¹

In terms of content, the description of the sections in the chapter is similar to that from previous years in several respects. The differ-

¹¹ The sections in the RD&D Programme 2019 Chapter 8 described here are: 8.3 “Non-regular fuels and fuel integrity”; 8.4 “Fuel characterisation, decay heat and radiation”; 8.5 “Fuel information and encapsulation optimisation”; 8.6 “Criticality”; 8.7 “Safeguards”.

ence is that in the RD&D Programme 2019, SKB provides a more detailed description of non-regular fuels (8.3), which regarding composition or design significantly deviate from the bulk of the spent nuclear fuel that has been in focus in previous RD&D programmes.

General comments on the current situation

The presentations of the current situation are of a descriptive character, which is not necessarily wrong. But there is no specification of which research issues have been studied and answered or are currently being studied, and which research issues have arisen as a result of previous research.

SKB should also improve the references to scientific publications of the work performed. Of Sections 8.3–8.7, only Section 8.5 contains references in the description of the current situation, and in that case, there are two references.

General comments on the research programmes

To a greater extent than in previous RD&D programmes, SKB refers to completed research, projects, collaborations and certain results in the programme section. But the link between previous research and the programme is unclear. What questions have been answered by previous research programmes, what questions remain and what new questions have emerged?

Furthermore, the descriptions of the purposes, approaches and methods of the research programmes are inadequate and leave many questions. Examples are found in Section 8.4–8.7, where SKB mentions several times that different methods will be developed and that studies will be conducted, but nothing is written of how this will take place or what actually will be done. An example is Section 8.7, in which SKB writes that a monitoring station will be developed, without describing what the purpose of such a monitoring station is, or which measurement techniques will be used.

As already mentioned, there are very few references to published results, and there are no references to scientific publications (or any other type) in the programme descriptions in Section 8.3–8.7.

As regards who conducts the research, it is often unclear whether the planned research will be carried out by SKB internally or by external partners, and in that case, whether they are already contracted or if the project will be announced at a later stage.

In some cases, it is also unclear whether the research programme really will only extend three years into the future, or if the time horizon is longer than that.

Specific comments on the research programmes

Some sections (8.3–8.5) explicitly mention SKB’s work with collecting, quality assuring and storing information in databases. Section 8.5 refers to the work with preservation of information for the future. There is, however, no specification of what information SKB intends to store and preserve for the future, nor any justification for the position taken.

As concerns SKB’s activities within nuclear safeguards, they are described primarily in Section 8.7 but also in other places in the RD&D Programme 2019. In addition to the general deficiencies already mentioned, in this area it is especially difficult to understand what information about the content of nuclear material in facilities and the transportation system (and the content of nuclear material in legacy waste) SKB intends to quantify, store and preserve, and how this will be done. SKB states that a regulatory framework is being prepared and writes that international collaboration is under way in order to: “...contribute to the development of principles and methods for safeguards in these new types of facilities”.¹² The Council understands that under such conditions, it is difficult to describe how something is to function in the end. Nevertheless, SKB should be able to present its position and the principles on the basis of which the company works, in order to make the picture clearer for an external party.

Proposed measures: There are both general and specific improvements that SKB should incorporate in the RD&D Programme 2022. In general, SKB should make more detailed reference to scientific publications in the Section on fuel, describe specific research issues, and specify and justify the choice of methods, approaches and partners.

¹² SKB. *RD&D Programme 2019*, p. 40.

In the specific case of information preservation, the Swedish National Council for Nuclear Waste believes it to be important that SKB describes its current activities, research needs and plans in the sections on fuel 8.3–8.7. SKB should also specify what (type of) information is considered to be relevant to include in the future storage of information, or how this will be determined.¹³

When it comes to safeguards, SKB should as clearly as possible describe how the company plans to report its content of nuclear material. Will the report be presented, for example, by nuclide, by element or in any other way, and will the content be calculated or estimated based on some type of measurement and in that case with which method? It is also important to know if other information that can be considered relevant for safeguards, but is not directly related to the nuclear material, will also be preserved (for example fuel parameters and irradiation history).

Such a report would make it possible for an external party to better assess the research and development activities pursued by SKB, but would also clarify the current state of knowledge, both at SKB and in the field internationally. This is central both for training and research institutions in the surrounding society, and for students and new graduates within the industry and in nearby fields.

3.2.2 Comments on RD&D Programme Chapter 9: Canister for spent nuclear fuel

The description of ongoing and planned research on the stability and integrity of the copper canister over the long periods of time required in a safe final repository for at least 100 000 years is generally well described in the RD&D Programme 2019. *In the following, we will describe those parts in the research on the copper canister that we believe need to be strengthened or initiated.* The Council makes a special note of some research that is not reported in the RD&D Programme 2019 under the heading *Missing in the RD&D Programme 2019*. The description below is divided into issues concerning A) the copper canister shell, and B) the copper canister's cast iron insert.

¹³ Compare with the proposed measures in Section 3.1 of this review concerning RD&D Programme Section 4.12.1 *Preservation of information and knowledge through generations*.

A) The copper canister shell

Comments on RD&D Programme Section 9.1 Corrosion

RD&D Programme Section 9.1.1 Sulphide corrosion

There is still no well-documented mechanism for stress corrosion cracking in oxidising conditions in the presence of nitrite, ammonium and acetate ions (transgranular cracking), or in reducing conditions in a sulphidic, oxygen-free environment (intergranular cracking). Therefore, it is positive that SKB is continuing the accumulation of knowledge concerning the corrosion processes and the formation of special passive films of copper sulphide or copper oxide in order to understand the causes of stress corrosion cracking.

A better understanding is required of how the copper canister's original surface film of copper(I)oxide (Cu_2O) is transformed to a copper(I)sulphide film (Cu_2S). Copper(I)sulphide can be passivating and can thereby cause localised corrosion and stress corrosion cracking. It is thus important to understand passivity and the properties of the sulphide film, and the conditions for localised corrosion. It is also important that SKB continues this research.

Proposed measures: The results of the research on sulphide corrosion processes should be presented in the RD&D Programme 2022, together with the measures that need to be adopted to reduce the risk of localised corrosion and stress corrosion cracking under repository conditions.

RD&D Programme Section 9.1.4 Radiation-induced corrosion

Corrosion of copper in water increases under gamma irradiation during the first 300 years by radiolysis and the formation of new forms of copper oxide on the copper surface as well as uptake of hydrogen in the copper. It is positive that research is continuing for investigating the reaction mechanisms in groundwater environments including ions such as chloride, sulphide and carbonate. The described research programme on radiation-induced corrosion is brief, and there is no mention of how the research will be conducted. The Swedish National Council for Nuclear Waste has on several occasions explained the need for a better understanding of the effects of

gamma radiation on corrosion and the possible hydrogen uptake in copper.

Proposed measures: Obtained research results in the groundwater environment and planned research should be presented in the RD&D Programme 2022.

RD&D Programme Section 9.1.5 Stress corrosion cracking

To be able to rule out stress corrosion cracking, the mechanisms that cause transgranular stress corrosion cracking must be understood on a detailed level. SKB uses threshold values from short laboratory experiments that may be unreliable.

Proposed measures: SKB needs to study the mechanism of transgranular stress corrosion cracking in oxidising environments through extended experiments during a longer time so as to understand how reliable these threshold values really are in relation to stress corrosion cracking. This should be presented in the RD&D Programme 2022.

Comments on RD&D Programme Section 9.2 Canister material properties

RD&D Programme Section 9.2.1 Creep of copper

There is no validated creep model based on the exact mechanism for how the integrity of the copper shell can be maintained under different loads.

To be able to develop the modelling of creep and the evaluation of the canister's strength, it is necessary to improve the mechanistic understanding of how phosphorus content in copper can give rise to both improved mechanical properties and improved creep properties. The Swedish National Council for Nuclear Waste shares SKB's view that there is a need for deeper understanding of how the quantities of phosphorus, sulphur, oxygen and hydrogen affect the material properties of copper in order to be able to determine the limits for these elements in the copper canister.

Proposed measures: In the RD&D Programme 2022, SKB should specify the limits of phosphorus, sulphur, oxygen and hydrogen in the copper that will be used in the copper canisters.

RD&D Programme Section 9.2.2 Hydrogen embrittlement

It is positive that SKB is continuing to study the role of hydrogen in different mechanisms for copper corrosion and creep, and how the hydrogen content affects the material properties of copper.

Proposed measures: In the RD&D Programme 2022, SKB should describe how the hydrogen content may affect the integrity of the copper canister under repository conditions.

Comments on RD&D Programme Section 9.4 Manufacturing, inspection and testing*RD&D Programme Section 9.4.1 Design and processing of copper components*

The Swedish National Council for Nuclear Waste shares the opinion that the creep properties of copper in welds are not sufficiently characterised, and that studies of the effects of cold working and multi-axial stress states need to be improved.

Proposed measures: Obtained research results and planned research should be presented in the RD&D Programme 2022.

RD&D Programme Section 9.4.3 Welding

The Swedish National Council for Nuclear Waste shares SKB's view that thorough investigation of oxide streaks in the weld metal is important in order to qualify the welding process and guarantee the mechanical properties of the weld and the integrity of the canister in the long term.

Proposed measures: In the RD&D Programme 2022, SKB should present a validated method for welding the lid on the copper canister.

B) The copper canister's cast iron insert**Missing in the RD&D Programme 2019**

The knowledge of cast iron's ability to absorb hydrogen and how this affects its mechanical properties is deficient. No such research is mentioned in the RD&D Programme 2019.

Proposed measures: SKB needs to initiate research on cast iron's ability to absorb hydrogen, how hydrogen uptake affects the mechanical properties of cast iron, and to define limits for the permissible quantity of hydrogen in cast iron. This should be presented in the RD&D Programme 2022.

Missing in the RD&D Programme 2019

According to the current recommendation, 600 grams of water are allowed in a sealed copper canister. Water can cause anaerobic (oxygen-free) corrosion of iron and the formation of hydrogen gas. Since hydrogen uptake in cast iron is suspected to degrade its mechanical properties (see above), it is important to set a limit for the amount of water that can be accepted in a sealed copper canister.

Proposed measures: SKB should consider what the maximum amount of water is that can be accepted in a sealed copper canister without adversely affecting the mechanical properties of the cast iron insert and possibly of the copper itself. In the RD&D Programme 2022, SKB should update the maximum amount of water that can be accepted in a sealed copper canister.

Comments on RD&D Programme Section 9.2 Canister material properties

RD&D Programme Section 9.2.3 Radiation effects on copper and nodular cast iron

The amount of copper in the cast iron insert affects its mechanical properties, particularly under gamma and neutron radiation. It is therefore important to conduct additional experiments where the mechanical properties under gamma and neutron irradiation of cast iron with different copper contents are studied.

Proposed measures: SKB should further verify the toughness and plastic properties of the cast iron insert with new experiments by characterising the radiation damage in the cast iron, so as to be able to formulate requirements on the maximum permissible copper content in the cast iron insert. The results of these proposed experiments should be presented in the RD&D Programme 2022. This

research is completed according to the programme in the RD&D Programme 2019.

Comments on RD&D Programme Section 9.4 Manufacturing, inspection and testing

RD&D Programme Section 9.4.2 Casting of the canister insert

The cast iron insert's critical defect size is small, putting high demands on the manufacturing and methods for quality control, which are still preliminary. SKB intends to relax the requirements on the canister's mechanical properties and the permissible defect size in different parts of the cast iron insert. By gaining a better understanding of the relationship between casting parameters and the material's microstructure and mechanical properties such as elongation at break and fracture toughness, reasonable limits can be determined. The Swedish National Council for Nuclear Waste believes that lower requirements on the cast iron insert's defect size must take into account all embrittlement mechanisms of nodular cast iron that can cause changes in the material properties over long periods of time in order to guarantee long-term safety.

Proposed measures: In the RD&D Programme 2022, SKB should report how much the tolerance of the mechanical properties has decreased as a result of the possibly lowered requirements.

The Swedish National Council for Nuclear Waste has previously stated that the embrittlement mechanisms of nodular cast iron have not been sufficiently studied, and that SKB needs to take static and dynamic strain ageing (blue brittleness) into account. This type of mechanical weakness can negatively affect the insert's mechanical properties in the long term. SKB has proposed (Table 9–1)¹⁴ an experiment plan for a study of nodular cast iron's dynamic strain ageing (DSA). The Swedish National Council for Nuclear Waste believes that the specified experiment plan does not meet sufficient scientific requirements to provide a mechanistic understanding of the process and its effects under repository conditions.

Proposed measures: In order to define the process window for DSA, SKB needs to modify the experiment plan so that it includes

¹⁴ SKB. *RD&D Programme 2019*, p. 204.

more experiments in the temperature range 25–200°C, and a much wider experiment range of draw rates should be used. This should be presented in the RD&D Programme 2022.

3.2.3 Comments on RD&D Programme Chapter 10: Cementitious materials

The ongoing and planned research on cementitious materials and their application in final repository conditions is well described and relevant. Some comments on improvements are nevertheless presented below.

Missing in the RD&D Programme 2019

In its review of the RD&D Programme 2016, the Swedish National Council for Nuclear Waste called for a more extensive report in the RD&D Programme 2019 on the complexation between relevant actinide ions and potential complexing agents in additives in cement or the decay products of these. Unfortunately, this research is not mentioned in the RD&D Programme 2019. The Council's opinion regarding this research area also applies to the research presented in Section 8.1 in the RD&D Programme 2019.

Proposed measures: The research on relevant actinide ions' complexation/adsorption to the cement surfaces of different concretes must be described in greater detail, since strong adsorption can delay a leakage of actinides from a final repository considerably and thereby serve as a chemical barrier in the final repository. SKB should include this research area in a dedicated section in the RD&D Programme 2022, where the state of knowledge and ongoing and planned research are presented.

3.2.4 Comments on RD&D Programme Chapter 11: Clay barriers and closure

The ongoing and planned research on clay barriers and closure is well described in the RD&D Programme 2019. Some comments on improvements are nevertheless presented below.

Missing in the RD&D Programme 2019

When the spent nuclear fuel in the copper canister emits ionising radiation (gamma radiation) to the environment, it will affect the properties of the bentonite buffer (radiolysis of pore water, radiolysis products, and radiation-induced changes of the montmorillonite). How this affects the properties of the bentonite buffer must be clarified.

Proposed measures: Obtained research results and planned research should be presented in the RD&D Programme 2022.

Missing in the RD&D Programme 2019

The water chemistry that the copper canister is exposed to when it comes into contact with groundwater in equilibrium with bentonite under gamma radiation could significantly affect the corrosion of the copper canister. More knowledge in this area is therefore important.

Proposed measures: Obtained research results and planned research should be presented in the RD&D Programme 2022.

Comments on RD&D Programme Section 11.1 Bentonite evolution after installation until saturation

RD&D Programme Section 11.1.1 Gas phase composition during the unsaturated period

Transport of gases, mainly hydrogen sulphide, to the copper canister and what protection the bentonite barrier provides in this respect are important to understand in order to be able to model the risk of copper corrosion in a final repository for spent nuclear fuel. Therefore, the Swedish National Council for Nuclear Waste takes a positive view of the fact that research of mainly hydrogen sulphide transport is being initiated, and that the transport of hydrogen sulphide in bentonite with different degrees of saturation is being studied systematically.

Proposed measures: In the RD&D Programme 2022, SKB should present these results, and describe different scenarios for how corrosion of the copper canister is affected by incomplete water saturation and erosion of the bentonite barrier.

RD&D Programme Section 11.1.6 Microbial sulphide formation under unsaturated conditions

Since the time to water saturation of the bentonite can be very long, it is possible that any microbial activity could generate considerable quantities of hydrogen sulphide in the gas phase. Sulphide compounds are the most important cause of corrosion of the copper canister.¹⁵ The sulphide content in the environment therefore affects the extent of copper corrosion.¹⁶ The area is new and there is not sufficient data or knowledge to be able to model copper corrosion adequately in different scenarios.

Proposed measures: Research in this area needs to be initiated and reported in the RD&D Programme 2022.

3.2.5 Comments to Chapter 12: Bedrock

The research efforts that relate to the bedrock are well justified and often clearly described. They include modelling and measurements in analogous materials and focus on improved process understanding. There are often references to results obtained from previous relevant studies, and the vague descriptions that were generally occurring in the RD&D Programme 2016¹⁷ (e.g. “properties”, “behaviour”, “changes” and “other development”) are used sparsely, which increases the readability and the understanding of what is meant. Chapter 12 in the RD&D Programme 2019 is, however, somewhat unevenly written, and it is not always clear how newfound information from a certain model or calculation tool will be integrated into others where there is direct or indirect interaction. In the descriptions of the current situation, it is generally evident which partners SKB has collaborated with, but in the future programmes, it is rather an exception.

¹⁵ See Chapter 9 in the *RD&D Programme 2019*.

¹⁶ Becker et al. 2020. *Sulphide-induced stress corrosion cracking and hydrogen absorption in copper exposed to sulphide and chloride containing deoxygenated water at 90°C*. Research report 2020:01. Swedish Radiation Safety Authority.

¹⁷ See Chapter 11 Rock in the *RD&D Programme 2016*.

Comments on RD&D Programme Section 12.1 Characterisation and modelling of rock properties

The research programme intends to compare analytical and numerical models with in-situ and/or laboratory experiments. Several of the models are dependent on each other, which means that the measurement errors that for instance occur in the Discrete Fracture Network (DFN) models are propagated further to the other models that are important for the description of the rock's barrier capacity. As boundary conditions in the models, there are rock stress models, which have been updated recently and will be revised during the construction phase. Error propagation in the models have been addressed in the RD&D Programme 2019, but not how this uncertainty will be handled and evaluated.

Proposed measures: The RD&D Programme 2022 should describe how measurement errors and uncertainties in the DFN models and the updates of the rock stress models affect the models that reflect properties related to rock mechanics, hydrogeology, hydrogeochemistry and transport, and how the results of these models can or will be validated (see also 12.2.3, 12.3.4 below).

Comments on RD&D Programme Section 12.2 Seismic impact on repository safety

The purpose of seismic monitoring and studies of late- to post-glacial faults is to gain a better understanding of glacially induced earthquakes and their connection to present-day seismicity, with the goal of reducing the uncertainties in analyses of the frequency, magnitude, and location of earthquakes in both the short and long perspective.

RD&D Programme Section 12.2.1 Seismic monitoring

The permanent seismic stations in Sweden belong to and are managed by the Swedish National Seismic Network (SNSN). They are located relatively evenly in terms of geography, with the exception of Norrland's inland, which has very few stations. In order to permit long-term monitoring and to improve the earthquake location determination, which in turn allows more reliable magnitude calculations,

seismic data must be collected continuously over a long period of time from a large number of geographically evenly distributed stations.

Proposed measures: SNSN has an agreement with SKB that expires in 2021. It is of great importance that SKB signs a new long-term agreement with SNSN. In addition, a local, stationary seismic network should be installed with good margin to the planned start of construction of a final repository for spent nuclear fuel.

RD&D Programme Section 12.2.2 Investigations of glacially induced faults

Continuing the investigations of suspected late- to post-glacial faults in Norrland and the proposed field studies in Uppland is strongly recommended, since they have a bearing on the understanding of the post-glacial evolution in the Forsmark area. It is, however, not evident how the geological structures will be modelled, if and in that case which bedrock data will be collected, what quaternary geological field methods will be applied or whether data from the nearby seabed will be included.

Proposed measures: Both structural geological data from the bedrock and data from the seabed outside the coast should be included in the study, and it should be clear what quaternary geological field methods will be applied. The programme should also include studies, in and around the area where the final repository is planned (the candidate area) in Forsmark, of major and minor deformation zones and their relation to each other, as suggested by the Council as a measure for the RD&D Programme 2016. This should be presented in the RD&D Programme 2022.

RD&D Programme Section 12.2.3 Modelling of seismic impact on the final repository

A better understanding of the occurrence and character of glacially induced faults will likely contribute to decreasing the uncertainties in the models of seismic impact on a final repository. It is not clear, however, if and how the results from the seismic activity modelling will be used in other models of the rock's mechanical, hydrogeolog-

ical and thermal properties, or in modelling related to the discrete fracture network.

Proposed measures: It should be clear how new data and new results from different modelling are integrated (see also proposed measures for 12.1 above).

Comments on RD&D Programme Section 12.3 Groundwater flow, groundwater chemistry and transport of solutes

RD&D Programme Section 12.3.1 Development of calculation tools for groundwater flow and transport of solutes

Different calculation tools for water transport, which are developed for various but partially overlapping types of water transport environments, will be further developed and linked to DFN (see 12.1 above). These results will be compared with each other and any differences will be explained in a scientifically sound manner, but it is not clear how the models are linked to field data and site-specific issues.

Proposed measures: The RD&D Programme 2022 should describe how the models that are based on the developed calculation tools can be verified and how they are or can be adapted to site-specific issues.

RD&D Programme Section 12.3.2 Processes affecting the hydrochemical environment

Degradation of organic matter in low-level and intermediate-level waste and microbial processes in a final repository for spent nuclear fuel have been studied within the framework of an EU-funded project (Mind). This and other studies have shown that microbial activity only occurs in the presence of nitrate and at a pH above 10. It is unclear whether this result refers to microbial activity in general in the repository or to specific environments.

Proposed measures: The RD&D Programme 2022 should clarify whether these boundary conditions (the presence of nitrate and a pH above 10) apply to all microbial activity that may occur in a final repository for spent nuclear fuel.

RD&D Programme Section 12.3.3 Transport properties and processes affecting solute transport in the bedrock

The transport properties of the rock with respect to fluids and gases and dissolved particles, and the mechanisms that govern the transport have a bearing on the function of the rock as a barrier and thereby on long-term safety. Matrix diffusion and sorption are important processes that affect the transport of solutes. Modelling tools for these processes have been developed and will continue during the RD&D period. Apart from matrix diffusion and sorption, reactions that cause dissolution and precipitation of minerals are also important for the transport of solutes and must therefore be taken into account in the models.

New measurements of site-specific materials will be carried out with the purpose of reducing the uncertainties in transport parameters. Sorption data for radionuclides for which data are lacking will be determined and the goal is to estimate which parameters the uncertainties are related to (for example differences between laboratory and in-situ measurements). How the measurement results will be interpreted is not described, however, and the impression is that they will only be reported as variations in time and space rather than understanding the processes that govern the sorption mechanisms.

Proposed measures: It should be made clear in the RD&D Programme 2022 whether dissolution and precipitation of minerals will be included in the models of solute transport and how the results of the site-specific measurement programme intended to reduce uncertainties in transport parameters will be handled.

It should also be clear how sorption data from these measurements will be used to increase the process understanding of sorption mechanisms.

RD&D Programme Section 12.3.4 Climate effects on geosphere processes

In connection with glaciations and the formation and melting of permafrost, fracture opening, fracture propagation and shear along fractures may take place in the bedrock and thereby change its thermal-hydrogeological-mechanical (THM) properties. Site-specific THM models will be prepared that take into account the ice load, perma-

frost variations, the effects of freezing at different depths in the bedrock, in addition to DFN descriptions. It is unclear how and if this programme is linked to other modelling and the development of modelling tools.

Proposed measures: The RD&D Programme 2022 should clarify how the results of the site-specific models related to changes in the bedrock during a glacial cycle are integrated with other models concerning thermal-hydrogeological-mechanical rock properties and which DFN descriptions will be used (see 12.1, 12.2.3 above).

Comments to 12.4 Detailed site investigations and site descriptive modelling

RD&D Programme Section 12.4.3 Critical structures and volumes

According to results from earthquake modelling, the structures that are assessed as critical are considerably larger than what was reported in SR-Site, and they are therefore considered to be identified by traditional mapping methods. Critical structures may, however, occur in locations that are not exposed during the construction of a final repository for spent nuclear fuel. In a perspective of 100 000 years, fractures may form and propagate (see 12.1 above), and fractures that are dry during construction may become water-conducting. The models are associated with uncertainties, and therefore the precautionary principle should be applied and smaller fractures and structures should be taken into account as well.

Proposed measures: Traditional mapping methods should be supplemented with indirect geophysical methods, taking into account the limitations of these methods, in order to locate potentially hidden critical structures in the vicinity of deposition holes.

3.3 Comments on RD&D Programme Part III, Decommissioning of nuclear facilities

In the RD&D Programme 2019, SKB presents a general description of how the work with decommissioning of the nuclear facilities will be conducted. It is evident that Uniper and Vattenfall are planning the work, separately, based on their different conditions. In order to

allow for the whole process chain from decommissioning planning and final disposal to be carried out in the best possible way, coordination between the companies takes place simultaneously. SKB, on behalf of the nuclear power companies, is responsible for national coordination of the work. In the Council's opinion, however, the division of responsibilities between the licensees and SKB is not presented in a sufficiently transparent manner.

Proposed measures: SKB should describe the division of responsibility more clearly in future RD&D programmes. At the same time, it is still unclear when the work with the final repository for long-lived waste will begin and where it will be located. Against that background, the Swedish National Council for Nuclear Waste believes that there is a need for a clearer description of the logistics for management of the decommissioning waste, including transports.

Comments on RD&D Programme Section 15.4 Resources and competence

SKB states that the decommissioning of nuclear facilities will continue at least until the mid-2070s. It is valuable that SKB points out that there are challenges concerning competence during this period. Furthermore, decommissioning is planned to take place in three stages, and the need for decommissioning competence between stages will be limited. SKB writes that it is highly probable that the relevant competence will be available internationally throughout the Swedish decommissioning period. The Council has drawn a different conclusion in the State-of-the-Art Report 2020 and believes that it is unlikely that other European countries will have a surplus of trained personnel in the foreseeable future. The result is that it will probably not be possible to import or buy sufficient and relevant international specialist competence.¹⁸

Proposed measures: SKB should describe how the company will handle the challenges of multiple stages in the RD&D programmes in the future. A discussion is needed concerning the fact that it is not possible to guarantee that the relevant competence will be available internationally.

¹⁸ Swedish National Council for Nuclear Waste. 2020. *Kunskapsläget på kärnavfallsområdet 2020* ("Nuclear Waste State-of-the-Art Report 2020"), p. 20.

Furthermore, SKB should specify in more detail what competencies are considered relevant.

The Swedish National Council for Nuclear Waste recommends in this review that future RD&D programmes contain a description of how competence development and competence management is to be ensured in a time perspective of 50–100 years.¹⁹ This includes SKB's plans to ensure long-term competence management in the work with decommissioning and dismantling of the nuclear facilities.

Regarding decommissioning and dismantling – see the Council's proposed measures 2016

In its decision to approve the RD&D Programme 2016, the Government set out the following condition for the continued research and development programme:

The report shall include research and development regarding decommissioning, dismantling and demolition, and the management and final disposal of the residual products of nuclear power.²⁰

One conclusion drawn by the Council regarding decommissioning and dismantling, based on a study visit to Spain and Germany, is that other countries see a need for research in this area. In the State-of-the-Art Report 2020, the Council writes that it should be noted that all countries in a study explicitly state the need for further research on the decommissioning of nuclear facilities and management of the residual products from these.²¹ The Council finds that this type of research is not prioritised in SKB's RD&D programme. The Swedish National Council for Nuclear Waste maintains its opinion from the review SOU 2017:42 that SKB should more clearly justify the company's view that this is more a matter of adapting technology than carrying out basic research, not least considering how little experience there is in Sweden today when it comes to decommissioning.

Proposed measures: At the latest in the RD&D Programme 2022, a more detailed description of the international experience of decom-

¹⁹ See Section 3.1 of this review concerning RD&D Programme Section 5.5 "Resources and expertise".

²⁰ *Government decision on the RD&D Programme 2016.*

²¹ Swedish National Council for Nuclear Waste. 2020. Kunskapsläget på kärnavfallsområdet 2020 ("Nuclear Waste State-of-the-Art Report 2020"), p. 22.

missioning and dismantling of nuclear facilities should be provided. This concerns research, but also development and demonstration efforts.²²

The Swedish National Council for Nuclear Waste believes that the research, development and demonstration concerning decommissioning and demolition should be presented in the RD&D programmes also in the future, so that they are comprehensive and describe the whole process chain.²³

²² The RD&D Programme Sections 15.3 “National and international coordination” and 19.1.9 “International development work” mention international groups and a collaboration with the Spanish Enresa. But only the existence of such a collaboration is mentioned, nothing about what it involves.

²³ Gov. Bill 1983/84:60.

4 Future RD&D programmes

In this concluding chapter, the Council deals with issues concerning future RD&D programmes. Previously in this review, the Council has proposed new areas that should be presented in the RD&D programmes in the future. In Section 4.1, the Council discusses the need for research areas with interdisciplinary research and development that should be presented in the RD&D programmes.

In this review, the Council has proposed a number of measures that should be reported in future RD&D programmes. The Council is of the opinion that even if an activity is granted a licence, it should be included in the RD&D programme. The Council argues for this in Section 4.2.

4.1 Interdisciplinary research areas should be included in future RD&D programmes

Looking at the bigger picture and both extending and broadening the perspective on a project that may take up to a century require interaction between several sciences.

Since the 1980s, there is a broad field of research called Science and Technology Studies (STS research), which is studying how society, politics and culture affect scientific research and technological innovation, and how these in turn affect society, politics and culture. STS research emphasises that actions and decisions take place by combinations of both “the social” (human actors, relationships, norms, groups, values, etc.), and “the technological” (technical equipment, calculations, tools, etc.).¹ STS researchers are of the opinion that the technological society needs to be more conscious of both the social

¹ Read more in InSOTEC. 2012. D1.2 *Socio-Technical Challenges to Implementing Geological Disposal: A Synthesis of Findings from 14 Countries*, p. 4.

consequences of its work and the underlying social assumptions and assessments that directly and indirectly affect the technical solutions. There is currently STS research in different areas at several universities and institutes of technology in Sweden, for example at Chalmers University of Technology, the University of Gothenburg², Linköping University and Uppsala University.

The Swedish National Council for Nuclear Waste, according to its terms of reference, has a broad scientific competence profile, including natural science, technology, social sciences and the humanities. Since 1992, the Council has worked based on the idea that an in-depth interdisciplinary perspective can contribute to making the management and disposal of spent nuclear fuel and nuclear waste better and safer for future generations.

A point of departure for continued work on interdisciplinary research in Sweden could be the EU project *International Socio-Technical Challenges for implementing geological disposal* (InSOTEC) that addressed issues concerning the implementation of geological final disposal from a STS perspective.³ The purpose of the project included identifying key socio-technical challenges when it comes to the management of spent nuclear fuel and high-level waste. These arise not least considering the long time span of the final repository projects, both regarding how long they should be safe and how long it takes to construct and operate them. InSOTEC believes that the need for long-term governance is one of the great challenges in constructing and operating these final repositories.

InSOTEC further believes that it is important to be aware of and bring into light the existing socio-technical challenges. To detect these challenges, more integrated, interdisciplinary research and development is necessary (natural science, technology, social sciences and the humanities). One of the conclusions of the EU project is that a final repository project needs to maintain a capacity for flexibility and technological innovation. This means that the research programmes

² The University of Gothenburg has participated in several projects related to the field of nuclear waste, for example the EU projects InSOTEC (see footnote below) and Modern2020: www.modern2020.eu/ (visited 2020-06-01).

³ InSOTEC was a three-year research project in the seventh Euratom framework programme (FP7), 2011–2014. See: <https://sites.google.com/a/insotec.eu/insotec/home> (visited 2020-06-01). See for example the reports: D 4.1 *Addressing the Long-Term Management of High-level and Long-lived Nuclear Wastes as a Socio-Technical Problem: Insights from InSOTEC and Project Final report: summarising the main S&T results, key messages and potential impact and use and dissemination of foreground*.

are important and that they need to continue throughout the design phase for a final repository. No matter how “robust and stable” a concept may seem, there may be changes in society (also politically or financially), in the growing knowledge base or in the technology (e.g. development of the management of radioactive waste in other countries).

It is unlikely that such a long and complex project as a final repository for spent nuclear fuel or high-level waste will be able to follow a completely linear development. A classical project-based approach with a clear start and end point is maybe not possible in this situation. Different strategies are required for handling different uncertainties.⁴

Interdisciplinary research in Sweden

The Swedish National Council for Nuclear Waste has long emphasised that several of the changes that could warrant a far-reaching review of the execution of the nuclear waste programme in Sweden and SKB’s main time plan are connected with different types of societal changes.⁵ Focus is on the construction of a final repository for spent nuclear fuel, but it also applies to other waste management that will last for a long time.

The Council would have liked to see a discussion in the RD&D Programme 2019 regarding the specific problems that a construction time of at least 70 years entails. This includes several important issues, like securing access to both immediate and long-term competence, and the knowledge transfer between several generations of engineers and work management. It is not a question of “purely technical” issues whether SKB over the course of several generations can transform a theoretically reasonable safe final repository for spent nuclear fuel

⁴ See also Section 1.1 in the Swedish National Council for Nuclear Waste. 2018. SOU 2018:8 *Nuclear Waste State-of-the-Art Report 2018. Decision-making in the face of uncertainty.*

⁵ See for instance: Swedish National Council for Nuclear Waste; SOU 2017:62 *The Swedish National Council for Nuclear Waste’s Review of the Swedish Nuclear Fuel and Waste Management Co’s (SKB’s) RD&D Programme 2016*; SOU 2014:42 *The Swedish National Council for Nuclear Waste’s Review of the Swedish Nuclear Fuel and Waste Management Co’s (SKB’s) RD&D Programme 2013*; SOU 2011:50 *The Swedish National Council for Nuclear Waste’s Review of the Swedish Nuclear Fuel and Waste Management Co’s (SKB’s) RD&D Programme 2010*; SOU 2008:70 *Final Disposal of Nuclear Waste – The Swedish National Council for Nuclear Waste’s Review of the Swedish Nuclear Fuel and Waste Management Co’s (SKB’s) RD&D Programme 2007.*

into a final repository that is closed in reality and meets all the requirements in the safety assessment and the legislation.

During the period 2004–2010, SKB had a social science research programme that was presented in the RD&D programmes, but since then there have been no plans to continue with this activity. The Council found the approach to be good, but a great deficiency was that the programme was regarded as purely pertaining to social science, and therefore it was not linked to the technological/natural science research programme.⁶ That a site has been selected for the final repository, that an application has been submitted, or a licence has been granted, is, according to the Council, not reason enough to stop this type of research and development; on the contrary, it makes it even more relevant.

A few examples of research areas

The Swedish National Council for Nuclear Waste has in several previous reviews proposed research areas that should be described in the RD&D programmes.⁷ An example that the Council previously pointed to is organisational issues and safety culture. A point of departure for the continued work with this could be the safety culture forum with the nuclear power industry arranged by SSM and others concerning how national context and culture can affect safety. The report *Säkerhetskultur i ett nationellt perspektiv Sverige* (“Safety culture in a national perspective in Sweden”) identified Swedish so-called national attributes, one of which was self-satisfaction/national pride. The report states that self-confidence can be a good quality on the one hand, but that on the other hand, it may lead to self-satisfaction, which makes it more difficult to accept criticism. The report contains several proposals for areas to improve.⁸

⁶ See the Swedish National Council for Nuclear Waste’s reviews: SOU 2014:42; SOU 2011:50; SOU 2008:70.

⁷ For instance, research projects concerning financial, political and social external changes that may affect the execution of the final repository project and projects concerning information preservation. See also the proposed measures for RD&D Programme Section 3.7 “Alternative strategies in case of changed conditions” and 4.12.1 *Preservation of information and knowledge through generations*, both in Section 3.1 of this review.

⁸ The World Association of Nuclear Operators (WANO) and the OECD/Nuclear Energy Agency (NEA), along with the Swedish Radiation Safety Authority, have developed a concept called Country-Specific Safety Culture Forum, CSSCF. The report *Säkerhetskultur i ett natio-*

Another example of a research area may be to present the work with participation processes. A point of departure could be the report *Monitoring in Geological Disposal and Public Participation – A Stakeholder Guide* from the EU project Modern 2020, which covers both participation in general and participation with respect to monitoring.⁹ When it comes to participation, the issue of building and maintaining the relationship with the hosting municipality is of great importance as well.

Proposed measures: The Council repeats its opinion from previous reviews of RD&D programmes, that there are interdisciplinary areas linked to the nuclear waste area where research and development is needed. SKB should initiate research in interdisciplinary areas and describe them in future RD&D programmes.

The Council has previously pointed out that this interdisciplinary research and development does not always need to be conducted by SKB, but that the company should participate so that the connection to natural science issues related to the final repository project is made.

4.2 A comprehensive RD&D programme continues to be of great importance

There are several arguments as to why a future research programme should include all parts of the planned system for management and disposal of nuclear waste, also the parts that have been granted a license. The Council has expressed this view in its two most recent RD&D reviews.¹⁰ Furthermore, there are several arguments as to why this programme should continue to contribute to openness and transparency, see the Council's arguments for transparency in Section 1.3 of this review.

In the State-of-the-Art report 2020, the Council raises the issue of “the controllability and control of technology”.¹¹ The Council believes that a continued comprehensive RD&D programme can be a tool to contribute to both the controllability and control of SKB's

nellt perspektiv Sverige (“*Safety culture in a national perspective in Sweden*”) contains proposals for ways forward (see p. 43 ff.)

⁹ Meyermans, A. et al. 2019. D 5.2 *Monitoring in Geological Disposal and Public Participation – A Stakeholder Guide*.

¹⁰ The Council has also discussed this in their RD&D reviews SOU 2017:62 and SOU 2014:42.

¹¹ Swedish National Council for Nuclear Waste. 2020. Kunskapsläget på kärnavfallsområdet 2020 (“*Nuclear Waste State-of-the-Art Report 2020*”), p. 125.

activities, and thereby contribute to safer final repositories. It may contribute to quality assurance of the work.

Research and technology development needs for licensed activities

The main argument for a continued comprehensive RD&D programme with openness and transparency, also for the licensed parts of the activities, is the amount of research and development that will be required for the licensed parts as well. There are multiple examples of such areas, not least relating to a final repository for spent nuclear fuel.¹²

Furthermore, the RD&D programmes not only present basic research, but also development and demonstration, which will likely continue until the closure of a repository. Meeting the requirement on best available technique is relevant also for licensed activities.

Transparency in the RD&D programmes provides an opportunity for knowledge accumulation for a number of actors, which is particularly important for the concerned municipalities.¹³ An RD&D programme that describes research, technology development and demonstration for all activities makes it possible for external parties to get a holistic perspective. It is also important to get an overview of the different research areas in a repository.¹⁴ There is thus great value in providing perspectives on the different levels of the waste system.

¹² The work that is carried out during construction and operation of a final repository for spent nuclear fuel should be reported during the entire period until final closure. For instance, the parallel work with construction and operation provides information for the safety assessment, which in turn affects construction and operation. (What do the rock stresses look like? Are the models of the rock validated? How does the observational method actually work when tunnels are selected and prepared?); Measurement programmes/monitoring can provide information for the safety assessment and should be presented in future RD&D programmes. Long-term experiments in the repository environment (demonstration repository) can provide information that should be presented in future RD&D programmes; Strategies for information preservation need to be developed over time and should be presented in future RD&D programmes; A global external analysis should be made in future RD&D programmes; Research, development and demonstration of plugs, backfill and closure need to be presented in future RD&D programmes; There will also be unknown unknowns (uncertainties that we currently do not know exist).

¹³ See: Östhammar Municipality. 2019. *Remiss från Strålsäkerhetsmyndigheten gällande Svensk kärnbränslehantering AB:s Fud-program 2019* ("Referral from the Swedish Radiation Safety Authority regarding the Swedish Nuclear Fuel and Waste Management Co's RD&D Programme 2019"); County Administrative Board of Kalmar County. 2019. *Yttrande över remiss: Granskning av SKB:s Fud-program 2019* ("Statement on referral: Review of SKB's RD&D Programme 2019").

¹⁴ Compare the Council's opinion in Section 2.4 of this review regarding clearer connections between different research areas.

Regulatory control and transparency

If a licence has been granted for nuclear activities, the following regulatory control will take place on the basis of licence conditions and regulations within the framework of the granted licence. SSM writes that regulatory control:

...also applies to any conditions for carrying out the necessary research and development activities apart from those described in the Swedish Radiation Safety Authority's Regulations concerning Safety in Nuclear Facilities (SSMFS 2008:1).¹⁵

The Swedish National Council for Nuclear Waste fears that transparency and the holistic perspective will be lost if research that is conducted after a licence is granted is not presented in the RD&D programmes, but is instead a matter between only two parties, i.e. SKB and SSM. Therefore, the RD&D programmes should include both licensed activities and activities that have not yet received a licence. According to the Nuclear Activities Act Section 12, all measures that may be necessary are to be reported in general terms, while measures in the coming six years are to be reported in greater detail.

According to the Nuclear Activities Act, the programme shall be sent to the Government or the authority appointed by the Government to carry out the review and evaluation. In conjunction with the review and evaluation, conditions that are required for the continued research and development activities may be imposed.

It is possible that the presentation of the RD&D programmes will take place in partly new forms in the future. In order to maintain transparency and at the same time facilitate SSM's responsibility for licensed activities, a possibility would be to divide the RD&D programme into two parts in the future:

- one part that presents research, development and demonstration of the activities that has not yet been granted a licence. This part would still be reviewed by the Government.
- one part that presents research, development and demonstration of the activities that has a licence. This part would be reviewed by SSM, which may impose conditions for the continued research (within the framework of the licence).

¹⁵ SSM. 2020. *Granskning och utvärdering av Fud-program 2019* ("Review and evaluation of the RD&D Programme 2019"), p. 17.

This proposal permits participation, transparency and external review by reviewing bodies such as universities, institutes of technology, interested organisations, concerned municipalities et al. also for licensed activities. If the State is to take over the responsibility after closure of a final repository for spent nuclear fuel, it must have transparency throughout the course of the project, which is achieved by this proposal.

Continued transparency and openness without RD&D programmes?

If a final repository for spent nuclear fuel were not to be included in future RD&D programmes after all, it is important that research etc. proceeds and is described in a transparent manner in the future, in the stepwise review process and in standard operation with overall assessments and so on. In this case, the Government must impose very clear conditions to ensure this. Furthermore, the Government should request an integrated activity description and a global external analysis etc. at regular intervals so as to get the overall picture and permit transparency in the activities.

4.3 Concluding remarks

The inquiry on the Nuclear Activities Act in 2019 states: “that the responsibility for the comprehensive research and development work shall extend until a solution has been granted a licence under the Nuclear Activities Act” and: “that the continued research and development activities should focus on unresolved parts of the waste system.”¹⁶ The Council believes that there may be, or arise, unresolved problems even for a licensed activity, and especially wants to emphasise the requirements of the Nuclear Activities Act regarding the licensee’s responsibility:

...to describe the research and development required to be carried out in order to be able to solve the problems concerning safe management and final disposal according to the method that appears to be best with regard to safety and radiation protection.¹⁷

¹⁶ Kärntekniklagutredningen (Inquiry on the Nuclear Activities Act). 2019. *SOU 2019:16 Ny kärntekniklag – med förtydligat ansvar* (“New nuclear activities act – with clearer responsibilities”), p. 186.

¹⁷ Gov. Bill 1983/84:60, p. 92.

As mentioned in the preceding Section (4.2), from this point of view it is important that SKB continues to publish research and development programmes every three years, and that these programmes include both licensed activities and activities that have not yet been granted a licence. The Council is of the opinion that the legislation on these points should not be changed.

This assessment is linked to the Council's more general view of research and technology development. Research and development is an ongoing process, which not only provides new knowledge, but also gives rise to new questions. Previously accepted knowledge is reconsidered and new technical solutions are developed. An example is the ongoing research on cast iron's absorption of hydrogen with the associated embrittlement processes.¹⁸

The previous picture of natural science research as linear and continuous knowledge accumulation has been succeeded by another picture that emphasises periodic scientific paradigm shifts. On a smaller scale, research is characterised by regular reconsideration of methods and results. In view of this, there is a strong need for continued, unabated development and research after a licence has been granted. The principle of BAT is fundamental in the Environmental Code¹⁹ and a concept that is also focused on the future. At a seminar in 2010, Claes-Otto Wene (previous member of the Swedish National Council for Nuclear Waste) stated that: "The term best available technique opens up for looking at technology development".²⁰ There may be good reason to wait for technology if better technology is deemed to be within reach. At the same time, development requires a constantly ongoing activity with respect to technology. But – Wene continued – "waiting for new technology could be waiting for Godot." Another participant in the seminar (Lars Högberg, previously with the Swedish Nuclear Power Inspectorate) added:

To define technology based on the concept of best *available* technique is like shooting at a moving target. We can continue to develop for ages, but in the end we must decide on something that is good enough to be acceptable for dealing with an environmental problem...²¹

¹⁸ See Section 3.2.2 of this review under B) The copper canister's cast iron insert.

¹⁹ Swedish Environmental Code (1998:808).

²⁰ *Nyhetsblad från Kärnavfallsrådet 2010:4. Vad betyder egentligen bästa möjliga teknik?* ("Newsletter from the Swedish National Council for Nuclear Waste 2010:4. What is actually meant by best available technique?")

²¹ *Nyhetsblad från Kärnavfallsrådet 2010:4* ("Newsletter from the Swedish National Council for Nuclear Waste 2010:4"), p. 4.

The Council has on several occasions in this review emphasised the character of the final disposal process, which is not only research-dependent but also has the character of a long-term project, i.e. with “a century of challenges”. This means that special emphasis must be placed on the dynamic and unpredictable character of the research process. Science is a human activity and humans are fallible. This insight is best combined with openness and humility.

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Links visited 2020-06-01

www.modern2020.eu

www.posiva.se

<https://sites.google.com/a/insotec.eu/insotec/home>

Legislation, Government Bills and Ordinances

The Act (1984:3) on Nuclear Activities.

The Environmental Code (1998:808).

Prop. 1983/84:60 med förslag till ny lagstiftning på kärnenergiområdet. (Gov. Bill 1983/84:60 with a proposal for new legislation in the field of nuclear energy.)

SMFS 2008:1 the Swedish Radiation Safety Authority's Regulations concerning Safety in Nuclear Facilities.

Committee terms of reference 1992:72

Scientific committee tasked with investigating issues relating to nuclear waste, and the decommissioning and dismantling of nuclear facilities etc.

Decision at Government meeting of 27 May 1992. Head of the Ministry of Environment and Natural Resources, Minister Johansson

My proposal

I propose that a special scientific committee is appointed with the task of investigating issues relating to nuclear waste and the decommissioning and dismantling of nuclear facilities and of advising the Government and certain regulatory authorities in these matters.

Background

In the Government Bill 1991/92:99 regarding certain appropriation matters for the budget year 1992/93 and changes in the state organisation in the field of nuclear waste, the Government proposed that the National Board for Spent Nuclear Fuel be abolished as a separate authority and that its activities be transferred to the Swedish Nuclear Power Inspectorate. The Government Bill stated that the scientific council – KASAM – associated with the National Board for Spent Nuclear Fuel would be given a more independent position and be tied directly to the Ministry of the Environment and Natural

Resources as a committee instead of being administratively tied to an authority.

The Swedish Parliament (1991/92:NU22, rskr.226) has decided in favour of the Government's proposal for a changed state organisation in the field of nuclear waste.

Thus, a special scientific committee tasked with investigating issues relating to nuclear waste and the decommissioning and dismantling of nuclear facilities and advising the Government and certain regulatory authorities in these matters should be appointed.

Task

The committee should

- every three years, beginning in 1992, no later than 1 June, present in a special report its independent assessment of the state of knowledge in the field of nuclear waste
- no later than nine months after the point in time specified in Section 25 of the Ordinance (1984:14) on Nuclear Activities present its independent assessment of the programme for comprehensive research and development activities and other measures, which the holder of a licence to own and operate a nuclear reactor shall prepare or have prepared according to Section 12 of the Act (1984:3) on Nuclear Activities.

The committee should also give advice in matters related to nuclear waste to the Swedish Nuclear Power Inspectorate and the Swedish Radiation Protection Authority upon request.

If necessary and financially feasible, the committee should undertake field trips abroad to study facilities and activities in the field of nuclear waste, and arrange seminars concerning general issues in nuclear waste management.

The committee should comply with the Government's instructions to state committees and special investigators regarding the focus of its proposals (Dir. 1984:5) and the EU aspects of the committee's activities (Dir. 1988:41-43).

The committee should consist of a chairperson and at most ten other members. It should also be allowed to engage external expertise for special tasks, if necessary and financially feasible. Chairperson,

members, advisors, experts, secretaries and other assistants should be appointed for a fixed period of time.

The committee's task shall be considered to be completed when the Government has decided in the matter of an application for final disposal of spent nuclear fuel and high-level nuclear waste in Sweden.

Petition

With reference to the above, I petition the Government to authorise the head of the Ministry of the Environment and Natural Resources

- to appoint a special scientific committee – subject to the Committee Ordinance (1976:119) – with at most eleven members tasked with investigating issues relating to nuclear waste and the decommissioning and dismantling of nuclear facilities and advising the Government and certain regulatory authorities in these matters
- to appoint chairperson, members, advisors, experts, secretaries and other assistants.

Furthermore, I petition the Government to decide that the costs be charged to appropriations under the fourteenth title Commissions etc.

Decision

The Government concurs with the rapporteur's considerations and approves his petition.

Committee terms of reference 2009:31

Supplementary terms of reference for the Swedish National Council for Nuclear Waste (M 1992:A)

Decision at Government meeting of 8 April 2009

Summary

The Swedish National Council for Nuclear Waste was established through a decision at a Government meeting on 27 May 1992 (dir. 1992:72). The Council, hereinafter called the Swedish National Council for Nuclear Waste, shall investigate and shed light on issues relating to nuclear waste and the decommissioning and dismantling of nuclear facilities etc. and advice the Government in these matters. Aside from the Government, important target groups for the Swedish National Council for Nuclear Waste are concerned public authorities, the nuclear power industry, municipalities, interested organisations, and politicians and the mass media.

The Swedish National Council for Nuclear Waste shall have a broad scientific competence profile, including natural science, technology, social sciences and the humanities.

The Swedish National Council for Nuclear Waste's task should be considered to be completed when the Government has decided on a final repository for spent nuclear fuel and high-level nuclear waste in Sweden.

These terms of reference replace the terms of reference from 27 May 1992.

Task

The Swedish National Council for Nuclear Waste shall assess the Swedish Nuclear Fuel and Waste Management Co's research, development and demonstration programmes (RD&D programmes), applications and other reports of relevance for the final disposal of nuclear waste. The Swedish National Council for Nuclear Waste shall, no later than nine months after the Swedish Nuclear Fuel and Waste Management Co has submitted their RD&D programme in accordance with Section 12 of the Act (1984:3) on Nuclear Activities, present its independent assessment of the research and development activities and other measures described in the programme. The Council shall also monitor the work that is pursued regarding decommissioning and dismantling of nuclear facilities.

The Swedish National Council for Nuclear Waste shall, in February every year from 2010, submit a report on the work conducted in the previous year and its independent assessment of the state of the art in the field of nuclear waste.

The Swedish National Council for Nuclear Waste shall investigate and shed light on important issues in the field of nuclear waste, for example by hearings and seminars, and create the conditions for providing well-founded advice to the Government.

The Swedish National Council for Nuclear Waste shall follow the development of final disposal programmes for the management of nuclear waste and spent nuclear fuel in other countries. The Council should also follow and, if necessary, participate in international organisations' work on the nuclear waste issue.

These terms of reference replace the terms of reference from 27 May 1992 (dir. 1992:72).

Organisation

The Swedish National Council for Nuclear Waste shall consist of a chairperson and at most ten other members (of whom one acts as vice chairperson). The members shall have broad scientific competence in areas related to the nuclear waste issue. The Council can engage external expertise for special tasks when necessary and financially feasible. Chairperson, members, advisors, experts, secretaries and other assistants should be appointed for a fixed period of time.

Timetable

The Swedish National Council for Nuclear Waste's task should be considered to be completed when the Government has decided on a final repository for spent nuclear fuel and high-level nuclear waste in Sweden.

(Ministry of the Environment)

Committee terms of reference 2018:18

Supplementary terms of reference for the Swedish National Council for Nuclear Waste (M 1992:A)

Decision at Government meeting of 1 March 2018

Modification of task and timetable

The Swedish National Council for Nuclear Waste was established through a decision at a Government meeting on 27 May 1992 (dir. 1992:72), replaced by the supplementary terms of reference (2009:31).

The Swedish National Council for Nuclear Waste shall, starting in 2018, submit a report on the work conducted in previous years and its independent assessment of the state of the art in the field of nuclear waste every two years, instead of annually.

The Council's task is limited in time to 31 December 2022. Thereafter, the task can be extended by at most five years at a time.

These terms of reference replace the terms of reference from 08 April 2009.

Task

The Swedish National Council for Nuclear Waste shall investigate and shed light on issues relating to the management and final disposal of nuclear waste and spent nuclear fuel and the decommissioning and dismantling of nuclear facilities. The Council shall also advise the Government in these matters. Aside from the Government, impor-

tant target groups are concerned public authorities, the nuclear power industry, municipalities, interested organisations, politicians and the mass media.

The Swedish National Council for Nuclear Waste shall have a broad scientific competence profile, including natural science, technology, social sciences and the humanities.

The Swedish National Council for Nuclear Waste shall assess the Swedish Nuclear Fuel and Waste Management Co's research, development and demonstration programmes (RD&D programmes), applications and other reports of relevance for the final disposal of nuclear waste. The Swedish National Council for Nuclear Waste shall, no later than nine months after the Swedish Nuclear Fuel and Waste Management Co has submitted their RD&D programme in accordance with Section 12 of the Act (1984:3) on Nuclear Activities, present its independent assessment of the research and development activities and other measures described in the programme. The Council shall also monitor the work that is pursued regarding decommissioning and dismantling of nuclear facilities.

The Swedish National Council for Nuclear Waste shall, in February every two years from 2018, submit a report on the work conducted in the previous years and its independent assessment of the state of the art in the field of nuclear waste.

The Swedish National Council for Nuclear Waste shall investigate and shed light on important issues in the field of nuclear waste, for example by hearings and seminars, and create the conditions for providing well-founded advice to the Government.

The Swedish National Council for Nuclear Waste shall follow the development of final disposal programmes for the management of nuclear waste and spent nuclear fuel in other countries. The Council should also follow and, if necessary, participate in international organisations' work on the nuclear waste issue.

The task of the Swedish National Council for Nuclear Waste expires at 31 December 2022. Thereafter, the task can be extended by at most five years at a time.

Organisation

The Swedish National Council for Nuclear Waste shall consist of a chairperson and at most ten other members, of whom one acts as vice chairperson. The members shall have broad scientific competence in areas related to the nuclear waste issue. The Council can engage external expertise for special tasks when necessary and financially feasible. Chairperson, members, advisors, experts, secretaries and other assistants should be appointed for a fixed period of time.

(Ministry of the Environment and Energy)