

INTEGRATED REVIEW SERVICE FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT, DECOMMISSIONING AND REMEDICATION (ARTEMIS)

MISSION TO SWEDEN

Stockholm, Sweden

16-27 April 2023

DEPARTMENT OF NUCLEAR SAFETY AND SECURITY
DEPARTMENT OF NUCLEAR ENERGY



Integrated Review Service for Radioactive
Waste and Spent Fuel Management,
Decommissioning and Remediation

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REMEDICATION (ARTEMIS) MISSION
TO
SWEDEN**

Mission dates: *16-27 April 2023*
Location: *Stockholm, Sweden*
Organized by: *IAEA*

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IAEA-2023

The number of recommendations, suggestions and good practices is in no way a measure of the status of the national infrastructure for nuclear and radiation safety. Comparisons of such numbers between ARTEMIS reports from different countries should not be attempted.

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EXECUTIVE SUMMARY

At the request of the Government of Sweden, the International Atomic Energy Agency (IAEA) organized an Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS) peer review mission.

The objective of the ARTEMIS Peer Review Service is to provide independent expert opinion and advice on radioactive waste and spent fuel management, decommissioning, and remediation, based upon the IAEA safety standards and technical guidance, as well as good international practice. Sweden requested this ARTEMIS review to fulfil its obligations under Article 14.3 of the Council Directive 2011/70/Euratom of 19 July 2011, establishing a *Community Framework for the Responsible and Safe Management of Spent Fuel and Radioactive Waste*.

The review was performed by a team of eight senior international experts in the field of decommissioning and radioactive waste and spent fuel management, from multiple IAEA Member States, with IAEA staff providing coordination and administrative support.

This ARTEMIS mission was organized “back-to-back” with an Integrated Regulatory Review Service (IRRS) review mission, conducted from 14 to 25 November 2022. The conduct of the ARTEMIS mission and the preparation of the associated mission report have been carried out with due consideration of the IRRS mission. The ARTEMIS review was focused on the evaluation of the current Swedish national programme and national framework for executing the country’s obligations for safe and sustainable radioactive waste and spent fuel management as well as decommissioning of facilities. In developing the ARTEMIS mission report, the outcomes from the 2022 IRRS mission to Sweden were taken into account. The report takes advantage of the IRRS findings on the legal and regulatory oversight of activities, facilities and exposure situations in the field of radioactive waste and spent fuel management.

The ARTEMIS Review Team considered that Sweden has developed a nuclear programme that complies with the highest standards with regard to the safe management of the radioactive waste and spent nuclear fuel arising from nuclear power plant operations.

For this reason, the ARTEMIS Review Team highlighted that the commitment of Sweden to achieve safe disposal of the spent fuel in a deep geological disposal facility is commendable and identified a good practice related to the design of the KBS-3 concept for spent fuel disposal and developing it to a mature concept that has achieved wide acceptance and a governmental licence for the proposed disposal project.

The ARTEMIS Review Team however considered that improvements could be brought to some aspects of the national policy and strategies for waste management, particularly concerning non-nuclear radioactive waste. The ARTEMIS Review Team recommended to the government to supplement its policy and strategy with regard to the sustainable management of all non-nuclear radioactive waste and to ensure that safe management routes are made available for all radioactive waste, including disused sealed radioactive sources. In this perspective a need was identified to ensure that the responsibilities and obligations in respect of securing financial provisions allow for the sustainable management of all legacy waste and non-nuclear radioactive waste.

Concerning the timely fulfilment of the national policies and strategies for spent fuel and radioactive waste management, the ARTEMIS Review Team suggested that the *National Plan* for the responsible and safe handling of spent nuclear fuel and radioactive waste in Sweden

evolve so as to serve as an instrument to support and monitor their implementation. In addition, establishment of a national database such that records of all radioactive waste be further used to inform decision making on storage and disposal routes is considered a useful improvement by the ARTEMIS Review Team.

Finally, the benefit of strengthening the cooperation between stakeholders involved in achieving the safe management of radioactive waste was identified with regard to the development of long term disposal solutions for the long lived waste and competence building and maintenance. In this regard, the ARTEMIS Review Team suggested that the Swedish Radiation Safety Authority (SSM), should consider initiating a forum involving the Swedish Nuclear Fuel and Radioactive Waste Management Company (SKB) and waste owners for developing in a timely manner the preliminary conditions for the disposal of waste in the planned disposal facility for long lived low and intermediate level waste (SFL). As for competences, the ARTEMIS Review Team suggested that actions to improve coordination at the national level to strengthen and maintain the competence of all parties with responsibilities related to radioactive waste and spent fuel management be considered by the government.

The ARTEMIS Review Team commended the Swedish counterparts for the professionalism displayed by all staff and their involvement during the review process. Sweden is encouraged to make the review public and to take the findings of the review into account.

The ARTEMIS Review Team suggests that Sweden considers requesting a follow-up mission within the next four years to make sure the outcomes of the present review are appropriately implemented.

The IAEA issued a press release upon conclusion of the mission.

I. INTRODUCTION

On 17 January 2018, Sweden requested the IAEA to organize an Integrated Review Service for Radioactive Waste and Spent Nuclear Fuel Management, Decommissioning and Remediation Programmes (ARTEMIS). On 23 March 2020, the Swedish Radiation Safety Authority (SSM) requested the IAEA to organize the mission as a back-to-back review Integrated Regulatory Review Service (IRRS) and ARTEMIS missions, with the IRRS mission in late 2022 and the ARTEMIS mission in spring 2023.

Sweden's request for the ARTEMIS review is to satisfy its obligations under Article 14(3) of the Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community Framework for the Responsible and Safe Management of Spent Fuel and Radioactive Waste (hereinafter the *EU Waste Directive*).

The ARTEMIS review mission was carried out between 16-27 April 2023 following the IRRS mission which took place from 14-25 November 2022. The ARTEMIS review was led by the IAEA by the Department of Nuclear Safety and Security supported by the Department of Nuclear Energy.

The review was performed by a team of eight senior international experts in the field of decommissioning and radioactive waste and spent fuel management, from multiple IAEA Member States, with IAEA staff providing coordination and administrative support. A preparatory meeting with the ARTEMIS Review Team and the Swedish counterpart took place online on 14 October 2022. The Advanced Reference Material (ARM) was received and reviewed by the ARTEMIS Review Team in February of 2023. The ARTEMIS Review Team mission to evaluate the overall Swedish radioactive waste and spent fuel management programme took place between 16-27 April 2023.

II. OBJECTIVE AND SCOPE

The ARTEMIS Review Team evaluated the Swedish national programme and the national framework for executing the country's obligations for safe and sustainable radioactive waste and spent fuel management.

The outcomes from the 2022 IRRS mission to Sweden were taken into account as appropriate to avoid unnecessary duplication. This is in line with the Supplementary Guidelines on the Preparation and Conduct of IRRS-ARTEMIS back-to-back Missions, applicable, upon requests of the Member States, for situations when an IRRS mission is conducted before an ARTEMIS mission, with a maximum of six months between the two missions. These Supplementary Guidelines are not a substitute for the ARTEMIS Guidelines but supplement them with the specific provisions that need to be taken into account while conducting IRRS-ARTEMIS back-to-back missions.

III. BASIS FOR THE REVIEW

A) PREPARATORY WORK AND IAEA REVIEW TEAM

At the request of the Government of Sweden, an on-line preparatory meeting for the ARTEMIS Review mission was conducted on 14 of October 2022. The preparatory meeting was chaired by the appointed Team Leader, Mr François Besnus, the IAEA coordinator and deputy coordinator, Mr Gérard Bruno and Ms Rebecca Robbins respectively, and the team of National Counterparts led by Ms Åsa Zazzi from SSM, with participation of other representatives from SSM and the Swedish Nuclear Fuel and Waste Management Company (SKB).

During the preparatory meeting discussions focused on:

- the Terms of Reference for the ARTEMIS review of the Swedish Radioactive Waste and Spent Fuel Management programme; and
- the relevant detailed aspects for organization and conduct of the review.

IAEA staff presented the ARTEMIS principles, process and methodology. Mr Michael Egan (SSM) presented an overview of the Swedish context. This was followed by a discussion on the work plan for the implementation of the ARTEMIS review in Sweden.

Ms Åsa Zazzi was appointed as the National Counterpart for the ARTEMIS mission and designated IAEA point of contact.

In line with the discussions during the Preparatory Meeting and the Terms of Reference, Sweden provided IAEA with the Advance Reference Material (ARM) for the review at the beginning of February 2023.

B) REFERENCES FOR THE REVIEW

The articles of the *EU Waste Directive*, the draft guidelines for the ARTEMIS review service and the responses to the self-assessment questionnaire were used as references for the review together with the ARM and materials presented during the mission and associated discussions. The complete list of IAEA publications used as the basis for this review is provided in Appendix E.

C) CONDUCT OF THE REVIEW

The initial ARTEMIS Review Team meeting took place on Sunday, 16 April 2023 in Stockholm, directed by the ARTEMIS Team Leader Mr François Besnus, the ARTEMIS Team Coordinator Mr Gérard Bruno and the Deputy Team Coordinator, Ms Rebecca Robbins.

The National Counterpart Ms Åsa Zazzi was present at the initial ARTEMIS Review Team meeting, in accordance with the ARTEMIS guidelines, and presented logistical arrangements planned for the mission.

The ARTEMIS entrance meeting was held on Monday, 17 April 2023, with the participation of senior management and staff from the Ministry of Climate and Enterprise, SSM, SKB, AB Svafo, Cyclife Sweden AB, and Vattenfall AB. Opening remarks were made by Ms Charlotta Fred, Head Government Offices Chemical Division, Ms Nina Cromnier, Director General, SSM, Ms Jessica Palmqvist, Acting Managing Director, SKB, Mr Gérard Bruno, IAEA Team Coordinator and Mr François Besnus, ARTEMIS Review Team Leader, and the seven other members of the team of international experts.

During the ARTEMIS mission, a review was conducted for all review topics within the agreed scope with the objective of providing Swedish authorities with recommendations and suggestions for improvement and, where appropriate, identifying good practice.

A site visit of the Central Interim Storage Facility for Spent Nuclear Fuel, CLAB and of the Äspö Hard Rock Laboratory was organised by SKB on the 24th of April.

The ARTEMIS Review Team performed its review according to the mission programme given in Appendix B.

The ARTEMIS Exit Meeting was held on Thursday, 27 April 2023. A presentation of the results of the Review Mission was given by the ARTEMIS Review Team Leader Mr François Besnus. Opening remarks were made by Mr Daniel Westlén, State Secretary to the Minister for Climate and the Environment and Ms Nina Cromnier, Director General, SSM. Closing remarks were made on behalf of the IAEA by Ms Hildegard Vandenhove, Director of the Division of Radiation, Transport and Waste Safety, Department of Nuclear Safety and Security.

An IAEA press release was issued.

1. NATIONAL POLICY AND FRAMEWORK FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT

1.1. NATIONAL POLICY

Swedish position

In Sweden, spent fuel has been and continues to be generated from the operation of nuclear power plants (NPPs), with six reactors currently in operation and six permanently shut down. Much smaller amounts of spent fuel were also generated from research and other reactors operated in the past. Radioactive waste has been and is generated from the operation of NPPs and other nuclear facilities, and from the decommissioning of old facilities. Smaller amounts of radioactive waste are generated from industrial, medical and research facilities, and from the use of radioactive sealed sources in a wide range of activities.

The Swedish national policy for the management of spent fuel and radioactive waste derives from basic principles established by parliament largely during the 1980s, and subsequently reflected in various legal instruments, notably the following four basic principles:

1. The ‘polluter pays’: the expenses for management of spent fuel and radioactive waste should be met by the operators of the activities that have produced it;
2. Those who carry out activities with ionizing radiation and radioactive material have an obligation to ensure the safe management and disposal of spent fuel and radioactive waste from their activities;
3. The state has the ultimate responsibility for the safe management of spent fuel and radioactive waste generated within Sweden; and
4. Each country is responsible for the spent fuel and radioactive waste generated in that country. The disposal of spent fuel and radioactive waste from nuclear activities in another country is normally not permitted in Sweden, and disposal of Swedish spent fuel or radioactive waste in another country is also normally prohibited.

More specific principles, established internationally and/or derived from European Union directives are incorporated in the legal and regulatory framework and constitute national policy on radiation safety and environmental protection. These include the International Commission on Radiological Protection (ICRP) principles on justification, optimisation and dose limitation, the principles of sustainable development and ensuring a healthy environment for current and future generations, the knowledge principle, the precautionary principle and the use of best available technology (BAT). Provisions of the Environmental Code intended to promote sustainable development include overarching requirements regarding implementation of the waste management hierarchy¹ for wastes of all types, and the Radiation Protection Act requires that those who carry out an activity with ionizing radiation minimize the generation of radioactive waste. The principle of applying a graded approach, with due consideration to the scope and nature of the activity at hand, is incorporated in legislation on the licensing of nuclear activities and other activities involving radiation.

Reprocessing of spent nuclear fuel is not explicitly prohibited by Swedish legislation, but it has been a de facto policy since the 1980s to regard and to manage spent nuclear fuel as a waste. However, since spent fuel does not legally become waste according to the Act on Nuclear

¹ The term ‘waste management hierarchy’ refers to the controls by which the amount of waste in terms of volume and radioactivity are generally applied in the following order: reduce waste generation, reuse items as originally intended, recycle materials and, finally, consider disposal as waste. Reference: GSR-Part 5 para 4.6

Activities until it is emplaced in a disposal facility, the policy and strategy refer to the management of spent fuel and radioactive waste.

Swedish legislation distinguishes “nuclear waste” — broadly, radioactive waste originating in a nuclear facility — from other radioactive waste (non-nuclear waste). In general, similar principles apply to the management of all radioactive waste. However, whereas the Radiation Protection Act strictly covers all radioactive waste, specific provisions under the Act on Nuclear Activities concern only nuclear waste. ‘Historical radioactive waste’ is also a separate category, including nuclear and non-nuclear radioactive waste generated before 30 June 1991 by the state, industry, hospitals and other operators. A separate, non-profit private organization, AB Svafo, manages the majority of these wastes.

In practice, the national policy for the management of spent fuel and radioactive waste is:

- Direct disposal of spent nuclear fuel in a deep geological facility. Such fuel is currently wet stored in the central interim storage facility for spent nuclear fuel (Clab) at Oskarshamn, and will be encapsulated in a future facility, the integrated central interim storage facility and encapsulation plant (Clink), also at Oskarshamn, for disposal in the geological facility, based on the KBS-3 concept, to be constructed at Forsmark.
- Disposal of very short lived low level radioactive waste in shallow land burial facilities. Such facilities are currently operated at three of the NPP sites and a similar facility at the Studsvik Tech Park for other wastes is now closed.
- Disposal of other radioactive waste in underground repositories: short lived low and intermediate level waste in the existing SFR facility at Forsmark and long lived waste in a future deeper, much smaller, SFL facility.
- Clearance of waste for recycling or disposal in conventional facilities.

The de facto national policy is that management of all spent fuel and radioactive waste is ensured by waste generators or commercial actors providing services to waste generators. This is clearly established in the case of nuclear waste, where:

- The Swedish Nuclear Fuel and Waste Management Company (SKB), which is owned jointly by the NPP operators, provides spent fuel and radioactive waste management directly for those operators and for AB Svafo (also owned by the NPP operators) and, normally, indirectly to other waste generators. SKB also defines the overall plan for management of spent fuel and radioactive waste from the Swedish NPPs, which constitutes the large majority of the National Plan for the responsible and safe handling of spent nuclear fuel and radioactive waste in Sweden (hereinafter referred to as the *National Plan*) compiled by SSM.
- Cyclife Sweden AB provides commercial predisposal waste management services by which waste from other producers can meet requirements for acceptance by SKB for disposal.

ARTEMIS observation

The ARTEMIS Review Team considers that the de facto policy of relying upon producers of spent fuel and radioactive waste to provide for their safe management (either themselves, or by agreement with other producers), is a clear and direct application of the Polluter Pays Principle, and is effective in the case of spent fuel and radioactive waste from nuclear power plants, and in the case of other radioactive waste for which management solutions are established or relatively straightforward. The policy is commendable in reinforcing the primary responsibility of waste generators for the safe management of the waste they produce, and weakening of that principle should be avoided. However, the policy does not effectively provide for all situations

where the waste generator does not or cannot discharge their responsibility, i.e. it does not provide for the state to discharge its ultimate responsibility, either directly or by providing a mechanism to allow waste generators to discharge their responsibility. The ARTEMIS Review Team considers that the policy is incomplete in that it does not provide a contingency for cases in which the main approach fails to ensure that all radioactive waste is managed safely.

The ARTEMIS Review Team considers that the gap in the arrangements for safe management of all spent fuel and radioactive waste referred to here and in later sections of this report is a consequence of the de facto policy of relying upon commercial agreements between waste generators and managers. The scale of the problem is generally assumed to be ‘small’ (although not quantified), but in the ARTEMIS Review Team’s view it is nevertheless significant, both in itself and as a potential ‘weak link’ in the overall system. The ARTEMIS Review Team recognizes that it may be a difficult and delicate task to modify or supplement the existing policy without undermining or distorting a policy that has been and remains successful in providing safe solutions for the large majority of spent fuel and radioactive waste. The ARTEMIS Review Team therefore does not recommend any particular approach: a contingency might be provided through additional legal obligations, incentives (or indemnifications) or state action – or a combination of these – and might be a general addition to the policy or provide for measures only in defined ‘exceptional’ situations, but it should provide a reliable means of filling the gap without damaging the effectiveness of the existing policy.

Until this gap has been addressed, there must also be a concern about the possibility that radioactive waste or disused radioactive sources may be stored without adequate safety measures, especially if the owner is not a licensed holder. SSM may therefore need to consider means by which the safety of such materials can be assured through regulatory supervision or other measures. The ARTEMIS Review Team notes that Recommendation 15 from the 2022 IRRS Review of the Swedish regulatory system addresses this concern (assuming that it applies to all orphan sources).

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES

Observation: *The policy of relying upon generators of spent fuel and radioactive waste to provide for their safe management themselves, or by agreement with other generators, is effective in the case of the nuclear power plant operators. However, in the case of those responsible for other radioactive wastes, such as non-nuclear users of radiation or finders of orphan sources, the policy is effective only for radioactive waste or sources that can technically and economically be treated by Cyclife Sweden AB for disposal by SKB. For wastes for which this is not the case, there is no management route available at this time.*

(1)	<p>BASIS: GSR Part 5 Requirement 2 states that <i>“To ensure the effective management and control of radioactive waste, the government shall ensure that a national policy and a strategy for radioactive waste management are established. The policy and strategy shall be appropriate for the nature and the amount of the radioactive waste in the State, shall indicate the regulatory control required, and shall consider relevant societal factors. [...] The national policy and strategy shall form the basis for decision making with respect to the management of radioactive waste.”</i></p> <p>Para 3.5 states that <i>“The national policy on radioactive waste management has to set out the preferred options for radioactive waste management. It has to reflect national priorities and available resources and has to be based on knowledge of the waste to be managed (e.g. knowledge of the inventory and of waste streams) now and in the future. It has to assign responsibilities for various aspects of radioactive waste management, including regulatory overview.”</i></p> <p>Para. 1.3 in the Introduction to GSR Part 5 states that <i>“The [...] radioactive waste from all sources [...] needs to be managed safely over its entire lifetime, and there is, therefore, a need for the establishment of a national policy and strategy for the safe management of radioactive waste.”</i></p>
R1	<p>Recommendation: The Government should supplement its policy and strategy so that responsibilities and resources are allocated to ensure safe and sustainable management of all non-nuclear radioactive waste.</p>

1.2. LEGAL, REGULATORY AND ORGANISATIONAL FRAMEWORK

Swedish position

The primary legislation most relevant to the management of spent fuel and radioactive waste in Sweden comprises:

- The Act on Nuclear Activities, which defines the licensing requirements for the construction and operation of nuclear facilities and for handling or using nuclear materials (including nuclear waste).
- The Radiation Protection Act, which defines the requirements for protection of people and the environment and for radiological work from the harmful effects of radiation. The Act applies to radiation protection in general and, in this context, it includes provisions regarding worker's protection, radioactive waste management, and the protection of the general public and the environment that apply to both nuclear and 'non-nuclear' activities.
- The Act on Financing of the Management of Residual Products from Nuclear Activities which deals with the main financial aspects, and defines the responsibilities pertaining to the management and disposal of spent nuclear fuel as well as radioactive waste arising from the decommissioning of nuclear activities.
- The Environmental Code, which regulates general aspects of the environment and the possible impacts of "environmentally hazardous activities" (which include, but are not limited to, nuclear activities).

These Acts are supplemented by a number of ordinances and regulations, which contain more detailed provisions for particular aspects of the legal framework.

Operation of a nuclear facility can only be conducted in accordance with a licence issued under the Act on Nuclear Activities as well as with a licence issued under the Environmental Code. The Act and the Code are applied in parallel.

- SSM is the regulatory body for safety, security and safeguards in relation to all aspects of the management of spent fuel and radioactive waste related to their radioactive (and fissile) properties, primarily under the Acts listed above.
- The Land and Environment Court takes decisions in relation to assessing the compliance of licence applications under the Environmental Code, taking account of recommendations from SSM when the environmental hazards are due to ionizing radiation.
- The NPP operators are the main waste generators, generating essentially all of the spent fuel and the large majority of radioactive waste. AB Svafo (owned by three of the NPP operating companies) is not a waste generator as such, but is responsible for managing historical radioactive wastes and decommissioning historical nuclear research and development facilities. Cyclife Sweden AB is a commercial provider of radioactive waste treatment services, and takes over ownership from generators of non-nuclear waste that is destined for disposal. Studsvik Nuclear AB, Westinghouse Electric Sweden AB and Chalmers University of Technology handle nuclear and other radioactive materials from 'nuclear' sources, but are relatively minor waste generators (at least in terms of current operational waste volumes, although some of the materials they handle are high activity).

- Thousands of activities where ionising radiation is used in industrial, medical, educational and research facilities generate relatively small volumes of radioactive waste compared to the volumes generated within the nuclear fuel cycle. Radioactive waste will also arise from the European Spallation Source (ESS) accelerator facility, currently being commissioned at Lund in southern Sweden.
- SKB is the main organization for the management of spent fuel and radioactive waste, primarily of nuclear origin, but including other radioactive waste.
- Cyclife Sweden AB is the main supplier of commercial radioactive waste treatment, particularly to non-nuclear waste generators. Although Cyclife Sweden AB provides services for Swedish non-nuclear waste generators, its main business is waste treatment of nuclear waste or Swedish and international customers through incineration, melting and pyrolysis. The radioactive residues from these processes are returned to the waste owner.
- The Swedish National Debt Office and the Nuclear Waste Fund are public authorities with defined roles in relation to the financing of spent fuel and radioactive waste management.

Activities in the nuclear field are regulated both under the Act on Nuclear Activities and under the Environmental Code. To construct and operate nuclear facilities, licences under both Acts are required. While SSM will process applications under the Act on Nuclear Activities, the Land and Environment Court does the same for applications under the Environmental Code. Where appropriate, based on the views of both entities, the Government then will issue a licence under the Act on Nuclear Activities and an approval under the Environmental Code. The former incorporates relevant aspects relating to approval under the Radiation Protection Act and will typically include general conditions. Further specific conditions might subsequently be set by SSM. The approval under the Environmental Code is subject to approval or rejection by the affected municipality, and the Land and Environment Court will issue the licence under the Code, normally with associated conditions.

ARTEMIS observation

Overall, the ARTEMIS Review Team considers that Sweden has a comprehensive legal, regulatory and organizational framework for the safe management of spent fuel and radioactive waste (noting that the 2022 IRRS Review already reviewed the regulatory framework more generally). Interfaces between different legislation and different regulators (e.g. for radioactive waste that is also hazardous waste) appear generally to be well defined and managed effectively.

The ARTEMIS Review Team notes that important steps in the development of spent fuel and nuclear waste management require decisions of the government as well as regulatory decisions by SSM and decisions of the Land and Environment Court. As well as being required, Government decisions can provide valuable certainty about key steps in the long decision making processes associated with spent fuel and radioactive waste management, by defining ‘boundary conditions’ for further development (for example, the 2001 government decision linked to review of the RD&D programme that further development should be based on the KBS-3 concept, since no clearly better concept had been identified). The involvement of government can create a possibility of overlapping responsibilities or conflicting decisions, but this has not been reported to date, and there seems to be a good awareness of the need to avoid such cases. Typically the Land and Environment Court makes its decision and the Government takes account of that, as well as SSM’s recommendations as a statutory consultee, in reaching its decision on the permissibility of the application, possibly subject to conditions. SSM’s

licensing decisions typically follow the Government decision and are more focused on specific aspects arising from the Act on Nuclear Activities and the Radiation Protection Act, notably the adequacy of safety demonstrations, within the parameters set by the government's decision. The decisions to proceed with the development of the spent fuel disposal facility were unusual in that the Land and Environment Court effectively referred its final decision to the government in relation to questions about the corrosion of copper canisters, and the government finally decided, taking account of SSM's recommendations, that the issue could be considered resolved.

The ARTEMIS Review Team also notes that the regulatory processes relating to the Act on Nuclear Activities and Radiation Protection Act on the one hand and the Environmental Code on the other appears to have the potential to lead to situations in which there are different positions on safety issues from the two different perspectives. Again, experience to date suggests that this has not led to situations that cannot be resolved through the regulatory processes or by government decisions. However, the ARTEMIS Review Team notes that some of the particular safety considerations in relation to the management of spent fuel and radioactive waste, such as those relating to long term releases of radionuclides into the environment after disposal, can be considered particularly relevant in terms of the general environmental requirements of the Environmental Code as well as the more specific requirements of nuclear safety and radiation protection. Overlaps in responsibility might therefore be more likely to occur in relation to spent fuel and radioactive waste management than in other cases related to nuclear and radiation technologies. There might therefore be scope for additional guidance that could help to avoid such possible overlaps or clarify how they can be resolved.

The ARTEMIS Review Team considers that adequate provisions for the decommissioning of facilities have been taken by the government by putting in place an appropriate governmental, legal and regulatory framework for safety, with clearly assigned responsibilities and funding. This is covered by the Act on Nuclear Activities, the Radiation Protection Act, the financial Act, the Studsvik Act and the Environmental Impact Assessment Ordinance.

1.3. COMMUNICATION AND PUBLIC INFORMATION

Swedish position

Extensive communication and public information has long been and continues to be arranged by the NPP operators, especially locally around their sites, by SKB in relation to its activities (especially the spent fuel disposal programme), by the operators on the Studsvik Tech Park (Cyclife Sweden AB, AB Svafo and Studsvik Nuclear AB), and by SSM in relation to their responsibilities. Activities include general information provision (e.g. through web sites), local safety boards, annual public meetings, public hearings (in the context of licensing processes according to the Environmental Code) and more focused information campaigns.

ARTEMIS observation

The ARTEMIS Review Team agrees that arrangements for communication and public information related to spent fuel and radioactive waste management are extensive and inclusive in general, but especially in relation to the development of the spent fuel encapsulation and disposal facilities. The ARTEMIS Review Team notes that some activities seem to have been linked to specific 'projects' and to have been discontinued rather suddenly when a defined point

was reached in the project. A particular example is the dissolution of the local safety board at Barsebäck following the permanent shutdown of the reactors, a decision that suggests that it is not considered necessary during decommissioning activities at the Barsebäck site, which will continue for many more years.

2. NATIONAL STRATEGY FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT

2.1. SCOPE

Swedish position

The *National Plan* describes the policies, legal framework and strategies developed by Sweden in order to achieve a safe management of spent fuel and radioactive waste, from production to disposal. The National programme prescribed by Directive 2011/70/Euratom is included in the *National Plan*. The *National Plan* covers all types of waste and also gives insight into the management of naturally occurring radioactive material (NORM). The largest amounts of waste originate from the production of nuclear energy. The “polluter pays” principle applies to both nuclear and non-nuclear licensees. Strategic planning components include the system of environmental objectives (see Topic 1 on Policy and framework), the research development and demonstration (RD&D) programme and the financing system (see Topic 6 on Cost estimates and financing).

There are roughly two lines of strategy in the management of spent fuel and radioactive waste in Sweden:

- One for spent fuel and radioactive waste from NPPs.
- One for radioactive waste which is generated by other activities and industries than the production of nuclear energy.

The *National Plan* describes certain challenges in the management of spent fuel and radioactive waste in Sweden. An important challenge concerns the need for management and disposal solutions for some waste streams which are not accepted by SKB or Cyclife Sweden AB under the current policies. Other challenges concern financing the management of all of the historical waste.

Key actors in the management of spent fuel and radioactive waste²

Several organisations are responsible for the collection and management of spent fuel and radioactive waste in Sweden:

- SKB, which is jointly owned by owners and operators of NPPs, is responsible on behalf of its owners for the transport system for their spent fuel and radioactive waste and is responsible for preparing and building disposal facilities for different types of waste (see hereafter the paragraph on the strategy for NPPs);
- Studsvik Nuclear AB, which owns laboratories that provide services such as investigating nuclear materials including spent fuel and radioactive waste;
- AB Svafo, which is responsible for wastes arising from the decommissioning of reactor facilities built in the 50s and 60s, and which processes and stores historical waste, from both nuclear and non nuclear activities;
- Cyclife Sweden AB, which is owned by EDF and processes low and intermediate level waste, such as contaminated scrap metal and organic waste from the Swedish and international nuclear industry, as well as other radioactive waste from industries that are not related to nuclear energy;
- _____

² Primary waste generators also have a responsibility as actors for “waste management”, such as storing their own waste, and are not included in the list that follows.

- The Debt Office (see Topic 6 on Cost estimates and financing);
- The Nuclear Waste Fund (see Topic 6 on Cost estimates and financing).

Studsvik Nuclear AB, AB Svafo and Cyclife Sweden AB (as well as the nuclear fuel fabricator Westinghouse Electric Sweden AB) each have agreements with SKB concerning the disposal of wastes for which they are responsible. In the case of Studsvik Nuclear AB this includes an agreement for the disposal of certain fuel residues to the planned spent fuel repository.

Furthermore, licensed shallow land burial facilities and waste deposit sites play a role in the management of radioactive and cleared waste, respectively.

Strategy for nuclear power plants

Nuclear power plants have the legal obligation to collaborate in elaborating management solutions for the spent fuel and radioactive waste they produce. Spent fuel is not reprocessed and therefore is treated as waste. The licensees are responsible for the management of spent fuel and waste from their sites, for the decommissioning of their installations, and for management of shallow land burials for very low-level waste on three of the four NPP sites. They collaborate in the ownership and control of SKB. SKB also offers services to other licensees than NPPs (see hereafter paragraph on the strategy for other industries). SKB presents joint technical solutions for all NPPs for spent fuel and radioactive waste in the long term in the RD&D programme. SKB operates several facilities and services on behalf of the NPP licensees:

- The Central Interim Storage Facility for Spent Nuclear fuel (Clab);
- The disposal facility for short-lived low and intermediate level waste (SFR);
- The ship m/s Sigrid for the transport of spent fuel and radioactive waste.

In the RD&D programme, SKB has planned several facilities that will supplement the existing solutions and complete the overall management system for spent fuel and radioactive waste for NPPs:

- An encapsulation plant for spent fuel (Clink);
- A disposal facility for spent fuel ;
- A disposal facility for long-lived low and intermediate level waste (SFL).

As well as proposing and designing new facilities, the RD&D programme also includes the extension of the SFR, which is necessary to fit waste coming from the decommissioning of several NPPs which is already taking place.

The Swedish State has committed to bearing the ultimate responsibility in the exceptional case that a licensee would fail to fulfil its responsibilities in the disposal of their spent fuel and waste.

Strategy for other activities and industries

Other activities and industries that produce radioactive waste in Sweden include other nuclear facilities, medical facilities, research and other industries. Each licensee is responsible for the safe management of the waste on site, prior to disposal.

Other Swedish nuclear or non-nuclear waste generators make contract agreements with SKB or Cyclife Sweden AB on a commercial basis for processing and/or disposal. Neither SKB nor Cyclife Sweden AB has any legal obligation to accept waste other than as defined by such commercial contracts. In a limited number of cases, Cyclife Sweden AB stores waste for other parties without a contract for disposal; in such cases Cyclife Sweden AB will not assume ownership and associated legal responsibility for their management. Cyclife Sweden AB may also refuse to make agreements to accept waste for disposal where there is a commercial risk associated with taking responsibility for waste without having a defined disposal route.

Orphan sources are stored by the finder on their own site until a processing and a disposal solution have been found. When a processing and a disposal solution are available, the source will be managed by Cyclife Sweden AB. SSM can provide funding for the processing and disposal of orphan sources.

Clearance

SSM's regulations include procedures to clear materials. Cleared materials can be managed as conventional waste or be used without restrictions.

Transport

Transportation of spent fuel and radioactive waste from nuclear power plants takes place mainly by sea on ship m/s Sigrid which is owned by SKB.

Transportation of small volumes of waste from other installations than NPPs take place by road. The service is mainly provided by Cyclife Sweden AB, although there are other authorised carriers. Larger volumes can be transported by sea.

ARTEMIS observation

Although the *National Plan* covers all kinds of waste, it indicates that for some types of waste, there is no assured route from generation to disposal.

The management of waste in Sweden is well organised for NPP operators and owners, with clear defined responsibilities. However, for waste from other producers, in particular generators of nuclear waste which are not NPPs, and for non nuclear installations that generate radioactive waste, the route to disposal can be troublesome, as acceptance depends on the commercial criteria of Cyclife Sweden AB, which are linked to SKB's criteria for disposal, which in their turn are designed to accommodate waste and spent fuel from NPPs.

Examples of waste types for which there is currently no disposal route include radioactive wastes containing significant content of carbon-14, or some types of disused sealed radioactive sources or some waste containing NORM.

Orphan waste and orphan sources may have to stay with their finder for an indefinite period of time as there is no obligation for Cyclife Sweden AB to accept waste, which potentially could raise safety issues. As indicated in the *National Plan*, under the Radiation Protection Act, a party that finds and manages an orphan radiation source is also considered a holder and would therefore be responsible for its management, which may raise questions concerning radiation protection for some individuals. The ARTEMIS Review Team recalls that a recommendation on this issue has been formulated by IRRS (recommendation R15).

This gap in the arrangements for the safe management of some radioactive waste is a consequence of the de facto policy of relying solely upon commercial agreements between waste generators and managers which is very effective for nuclear waste and spent fuel but may show weaknesses for legacy and orphan waste as mentioned previously in chapter 1.1. Chapter 4.5 of the *National Plan* refers to challenges with regard to the management of certain types of waste, mainly from non nuclear installations. However, there is to date no adopted roadmap to come to a situation where there is an assured disposal route for every type of waste which is produced in the country.

Similar concerns can apply to new types of waste, such as future waste streams from ESS.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES

Observation: *The existing strategy relying upon generators of spent fuel and radioactive waste to provide for their safe management themselves, or by agreement with other generators, is effective in the case of the nuclear power plant operators. However, in the case of those responsible for other radioactive wastes, such as non-nuclear users of radiation or finders of orphan sources, the strategy is effective only for radioactive waste or disused sealed radioactive sources that can technically and economically be treated by Cyclife Sweden AB to make them suitable for disposal by SKB. For waste for which this is not the case, there is no management route available at this time. Under these conditions, some orphan sources have to stay with the finder until a solution is found. This can potentially raise safety issues.*

(1)	BASIS: SF-1 Principle 2, para 3.9 states that “[...] Government authorities have to provide for control over sources of radiation for which no other organization has responsibility, such as some natural sources, ‘orphan sources’ and radioactive residues from some past facilities and activities.”
(2)	BASIS: GSR Part 1 (Rev. 1) Requirement 9, para. 2.25 states that “Radiation risks may arise in situations other than in facilities and activities that are in compliance with regulatory control. [...] Where unacceptable radiation risks arise as a consequence of an accident, a discontinued practice, or inadequate control over a radioactive source or a natural source, the government shall designate the organizations to be responsible for making the necessary arrangements for the protection of workers, the public and the environment. [...]”
(3)	BASIS: GSR Part 1 (Rev. 1) Requirement 10 states that “The government shall make provision for [...] the safe management and disposal of radioactive waste arising from facilities and activities, and the safe management of spent fuel.”
(4)	BASIS: GSR Part 1 (Rev. 1) Requirement 10 para. 2.30 states that “Radioactive waste generated in facilities and activities shall be managed in an integrated, systematic manner up to its disposal.”
R2	Recommendation: The Government should ensure that safe management routes are made available for all radioactive waste, including disused sealed radioactive sources.

2.2. MILESTONES AND TIMEFRAMES

Swedish position

Decommissioning of Barsebäck 1 and 2, Oskarshamn 1 and 2, Ringhals 1 and 2, and Ågesta should be completed between 2025 and 2035. Other operating reactors are expected to be shut down between 2040 and 2045 and start decommissioning from then on. Decommissioning of nuclear facilities is, according to SKB’s RD&D programme report, planned to continue until the 2070s.

The European Spallation Source (ESS) facility is now being commissioned. According to plan, it should become operational in 2025 and remain in operation until 2065. After that, ESS should be decommissioned, and after shutdown will continue to produce waste from decommissioning well after 2065.

The construction of the final spent fuel disposal facility is expected to start during the second half of the 2020s and to start operation in the second half of the 2030s, together with the encapsulation plant.

The Interim spent fuel storage, Clab should be able to accommodate the storage of spent fuel after implementation of its extended licensed capacity until the final disposal facility is available.

Work for expanding the disposal facility for short-lived low level waste (LLW) and intermediate level waste (ILW), SFR is expected to start in 2024, and operation of the extension should be able to start around 2035. Operation is planned to continue until 2070.

The final disposal facility for LILW-LL, SFL is expected to start operation in the mid 2050s and will stay in operation for about 10 years.

SKB presents milestones and timeframes every three years in the RD&D programme report, which addresses spent fuel and radioactive waste from NPPs and is focussed on developing disposal solutions for those types of waste.

ARTEMIS observation

Milestones and timeframes are set up by SKB in the RD&D-programme report on the basis of the progresses made on knowledge and research and are accounted for in the *National Plan*. Hence, the timeline of disposal for all sorts of waste in Sweden is primarily defined by the needs of the owners NPPs on a commercial base. Thus, the lifetime of disposal facilities is not fully aligned with the duration of operational phase and the decommissioning period of other nuclear or non-nuclear facilities.

The ARTEMIS Review Team observed that the *National Plan* is used only to present a snapshot of the status of the management of spent fuel and radioactive waste in Sweden. While spent fuel and waste management from NPPs is thoroughly reviewed and planned in the RD&D programme, there is no such instrument to planify the stepwise management of all types of waste in Sweden, from cradle to grave.

2.3. PROGRESS INDICATORS

Swedish position

Sweden does not have a system of key performance indicators (KPIs) to support the formal monitoring of progress made as part of the national programme review performed by government.

As described above, SKB publishes an RD&D report every three years and presents it to SSM for review and to the government for approval. The RD&D report presents milestones and schedules for the different nuclear waste categories and the different storage and treatment facilities and disposal facilities. Every three years, SKB also presents cost estimates to the National Debt Office for RD&D, construction and operation of waste management facilities,

including interim storage of spent nuclear fuel at the Clab facility, as well as decommissioning of all facilities from reactors to repositories.

Monitoring takes place through the process of establishing a new report every three years. Milestones are reported by SKB and progress in realising these are assessed through this process. This is an open process involving, for example, concerned municipalities, authorities, NGOs, SSM and the government. The government may set conditions for the continuation of the programme.

ARTEMIS observation

The ARTEMIS Review Team noted that although the government sets conditions for the continuation of the programme, it does not set the monitoring conditions to assure that plans are effectively implemented to fulfil the objectives of the policies and strategies adopted for the management of all radioactive waste in the country.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
<p>Observation: <i>The National Plan presents the policies for managing radioactive waste and spent fuel in Sweden. It is compiled by SSM and regularly updated but it is not used as an instrument to support and monitor implementation of Sweden’s national policies for all types of radioactive waste and for spent fuel. Sweden lacks such an instrument.</i></p>	
(1)	<p>BASIS: SF-1 Safety Objective, para 2.2 states that <i>“The fundamental safety objective applies for all facilities and activities, and for all stages over the lifetime of a facility or radiation source [...]. This includes [...] management of radioactive waste.”</i></p>
(2)	<p>BASIS: SF-1 Safety Objective, para 3.9 states that <i>“Government authorities have to ensure that arrangements are made for preparing programmes of actions to reduce radiation risks, including actions [...] for disposing of radioactive waste. Government authorities have to provide for control over sources of radiation for which no other organization has responsibility, such as some natural sources, ‘orphan sources’ and radioactive residues from some past facilities and activities.”</i></p>
(3)	<p>BASIS: GSR Part 1 (Rev. 1) Responsibilities and functions of the government, para 2.2 states that <i>“[...]Typically, the regulatory body, as designated by the government, is charged with the implementation of policies by means of a regulatory programme and a strategy set forth in its regulations or in national standards [...].“</i></p>
S1	<p>Suggestion: The Government should consider using the National Plan as a strategic planning component to support and monitor implementation of the national policies for all types of radioactive waste and for spent fuel.</p>

3. INVENTORY OF SPENT FUEL AND RADIOACTIVE WASTE

Swedish Position

There is a waste classification system established by the Swedish nuclear industry and described in a Waste Handbook developed in cooperation with SKB that serves as the de facto national waste classification system. However, there is no legally defined waste classification scheme in Sweden for radioactive waste. There is also a characterization process being developed, informed and influenced by the safety aspects of the disposal of the waste in appropriate facilities.

The national programme segments material into two general categories: radioactive waste or spent nuclear fuel. The radioactive waste is further separated into short-lived and long-lived material.

The characterization system is largely destination-driven and customized concerning existing and planned repositories. There are five general classes of radioactive material that requires safe storage and disposal routes. Material is characterized as either radioactive waste or spent nuclear fuel. Sweden's *National Plan* and strategy for the management of spent nuclear fuel is well defined and well documented. It provides a description of the origin, treatment, transport, interim storage and disposal of spent nuclear fuel in Sweden. It also gives estimation of the quantities of spent nuclear fuel as well as estimates of future quantities forecast until year 2050.

Apart from spent fuel, the classification system describing radioactive waste includes four classes of material. These classes are:

- (a) "Cleared material" which is material with so small amounts of radioactive nuclides that it can be released from regulatory control including disposal as conventional non-radioactive waste;
- (b) Very low-level waste, small concentrations of short-lived nuclides with a half-life of less than 31 years (VLLW-SL) and much lower amounts of longer-lived radionuclides, suitable for disposal in shallow land burials licensed by SSM. There are four shallow land burial sites in Sweden, three operating burial sites at the same location as nuclear power facilities and one at the Studsvik Tech Park which is closed;
- (c) Low and intermediate level waste, short-lived (LILW-SL) material containing restricted amounts of nuclides with half-life of more than 31 years. The boundary between low and intermediate level is determined by the dose rate on the waste package. LLW requires less shielding during handling and should have a surface dose rate of less than 2 mSv/h, whereas intermediate level waste may have package dose rates up to 500 mSv/hr. This waste is stored in the disposal facility for operational waste (SFR) in rock caverns within crystalline bedrock beneath the Baltic Sea, covered by about 60 meters of rock;
- (d) Low and intermediate long-lived waste (LILW-LL) containing significant amounts of long-lived nuclides with a half-life greater than 31 years exceeding the restricted quantities for short-lived waste. This waste is planned to be disposed of in a deep geological disposal facility (SFL) situated in rock caverns in crystalline bedrock.

The *National Plan* is based on data reported by licence holders who are required to submit information to SSM annually. To facilitate uniform reporting, SSM has developed and distributed a template to all licence holders of nuclear installations and is reported in accordance with the characterization scheme described above. Additionally, licence holders also report if the waste originates from operation or demolition of nuclear facilities. In addition to the annual

reporting requirements, all licence holders are required to keep complete and up-to-date records of all spent fuel and nuclear waste generated or present at their facility where the activities are carried out or have been carried out, including information such as: identity, origin, amount of waste, radionuclide specific content, etc. Disused sealed sources or other non nuclear waste that is accepted for treatment and disposal by Cyclife Sweden AB, are included in their annual report together with the nuclear waste.

Sweden's constitution supports the right of public access to official records. Information on spent fuel and radioactive waste, including waste inventories, is available to the public in various reports.

The *National Plan* has documented estimates of future waste arisings with the assumption that the current six nuclear reactors in operation will continue to operate for up to a lifetime of 60 years, with associated waste generation from these facilities plus the waste from the seven other reactors (including the Ågesta reactor) that are now closed.

The forecasted estimates of radioactive waste that will be generated from dismantling and demolition of nuclear facilities have significant uncertainties due to the lack of information of the characterization of such waste and associated disposal routes. This includes secondary waste that is expected to arise in conjunction with dismantling and demolition operations. Factors affecting estimates of future waste volumes include various volume reduction and decontamination efforts that could be carried out.

For material from dismantling and demolition activities, it is assumed that part of the waste will not be capable of clearance, and thereby classified as short-lived waste. As such, this material has been included in estimates of the volumes destined for the extended SFR. For very low-level waste, it is assumed that further disposal could take place by shallow land burial.

Radioactive waste from non-nuclear activities (such as the European Spallation Source) includes forecasts that are somewhat uncertain. Limited information is available on the amount and composition of this waste; however, it is estimated that the majority of this waste by volume will be short-lived low and intermediate level waste.

ARTEMIS Observation

The ARTEMIS Review Team noted that the *National Plan* and strategy on managing spent nuclear fuel is very well defined and documented providing the life cycle of the fuel from origin to disposal. It also provides a forecast of future quantities to 2050.

The ARTEMIS Review Team noted that the estimates of volumes of the radioactive waste that will be generated by the decommissioning activities of all power reactors are uncertain.

The ARTEMIS Review Team also noted that the waste volume estimates reported in the national inventory do not include various other material, such as a portion of non-nuclear waste, NORM, such as mining material, certain disused sealed radioactive sources and molten material containing long-lived nuclides, to name a few. This material does not appear to have been quantified in the estimates and consequently do not currently have a defined disposal route.

With regard to the national inventory, the ARTEMIS Review Team noted that the official records information collected by SSM on spent fuel and radioactive waste is not currently available in the form of a searchable central database as originally envisioned. The ARTEMIS Review Team considers that development of such a database would set a common landscape where multiple parties (SSM, SKB, etc) could collaborate on a plan for disposal decisions as well as providing simpler access and compilation of the information by SSM and members of the public (see also chapter 5).

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES

Observation: *The national inventory and records of spent nuclear fuel are very well defined and well maintained by the regulatory organization and the waste generators. Information on waste streams associated with non-nuclear radioactive waste and certain other categories of radioactive waste could be further improved to provide a sound basis which will inform the national plan and decision-making for ultimate disposal routes. Such improvements would foster improvement in transparency and communication with public stakeholders resulting in increased public confidence.*

(1)	<p>BASIS: GSR Part 1 (Rev. 1), Requirement 35, para. 4.6.4 states that “<i>The regulatory body may or may not be the sole entity responsible for the maintenance of these registers and inventories, but it shall be involved in their proper retention and use. [...] “ This includes maintaining an inventory of radioactive sources and inventories of radioactive waste and of spent fuel, as well as records of doses from occupational exposure.”</i>”</p>
(2)	<p>BASIS: GSR Part 3, Requirement 3, para. 3.54 states that “<i>Registrants and licensees shall provide the regulatory body as required with appropriate information from their inventory records of radiation generators and radioactive sources.”</i></p> <p>para 3.55 states that [...] “<i>(d) An inventory, as required in para. 3.53, of radiation generators or radioactive sources is checked periodically to confirm that they are in their assigned locations and are under control.”</i>”</p>
(3)	<p>BASIS: GSR Part 5, Requirement, para. 3.5 states that “<i>The national policy on radioactive waste management has to set out the preferred options for radioactive waste management. It has to reflect national priorities and available resources and has to be based on knowledge of the waste to be managed (e.g. knowledge of the inventory and of waste streams) now and in the future. It has to assign responsibilities for various aspects of radioactive waste management, including regulatory overview.”</i></p>
S2	<p>Suggestion: The Government should consider establishing and maintaining a national database such that records of all radioactive waste and spent fuel are centralized and accurately reflected to inform decision making on storage and disposal routes.</p>

4. CONCEPTS, PLANS AND TECHNICAL SOLUTIONS FOR SPENT FUEL AND RADIOACTIVE WASTE MANAGEMENT

Swedish position

Nuclear and radioactive waste management in Sweden is mainly based on the nuclear industry and their obligations to manage their own wastes. Radioactive waste management in non-nuclear activities and industry is bound to the waste management system of nuclear facilities especially for the disposal part.

SKB is the central actor in the nuclear industry waste management. It operates the existing centralized interim storage facility for spent nuclear fuel (Clab) in Oskarshamn and the disposal facility for short lived low and intermediate level wastes (SFR) in Forsmark. In addition to the operating facilities, SKB is also in the licensing process for an encapsulation facility and a deep geological disposal facility for its owners' spent nuclear fuel together with much smaller amounts of fuel from Studsvik Nuclear AB. SKB is owned by Vattenfall AB, Forsmarks Kraftgrupp AB, OKG Aktiebolag and Sydkraft Nuclear Power AB. In addition to the mentioned disposal facilities, SKB is planning to implement a disposal facility for long lived low and intermediate level wastes (SFL) but the process for developing this facility is in early stage.

Another key actor in the radioactive waste management field is Cyclife Sweden AB which offers treatment of nuclear and non-nuclear wastes on a commercial basis. For those non-nuclear waste that can be treated and disposed of to the SFR facility, Cyclife Sweden AB provides a complete management service including providing for disposal by SKB. The waste management responsibility is usually transferred to Cyclife Sweden AB when non-nuclear radioactive wastes are managed by Cyclife Sweden AB. For the disposal, Cyclife Sweden AB has contractual agreement with SKB. However, SKB does not coordinate Cyclife's commercial or operational interactions regarding the processing of wastes from nuclear facilities.

The third key actor in Swedish waste management is AB Svafo, which is responsible for the treatment, storage and disposal of legacy radioactive wastes as well as some non-nuclear radioactive wastes from healthcare, industry, and government agencies. AB Svafo is also responsible for the decommissioning of historic nuclear research and development facilities. Related to the disposal, AB Svafo has an agreement with SKB.

Shallow land burial disposal facilities for the very low level short lived radioactive wastes are operated by the NPP operators in Oskarshamn, Forsmark and Ringhals.

Other disposal facilities are, or will be, operated by SKB. The main task of SKB is to provide nuclear waste and spent nuclear fuel management services for its owners. In addition to this, SKB has contracts with Cyclife Sweden AB, AB Svafo, Westinghouse fuel fabrication plant and Studsvik Nuclear AB for the waste disposal from their facilities. The new European Spallation Source (ESS) has signed a ten-year contract with SKB, ending in 2025, with the objective of exploring possibilities for disposal of the wastes from ESS. Up to the date of the ARTEMIS peer review, this contract had not led to any final agreement for the disposal of future ESS wastes by SKB.

Very low, low and intermediate level waste

The predisposal management of the operational waste produced at nuclear power plants is usually done by the NPP operators according to the SKB's specifications for interim storage and disposal. For the waste destined to be disposed of in shallow land burial facilities, the specifications are delivered by the shallow land burial facility operator. Some fractions of the

operational wastes are delivered to Cyclife Sweden AB for treatment and the radioactive residues are delivered back to the waste producer. Other nuclear facilities follow approximately similar procedures for their nuclear waste management.

Most of operational waste is disposed of in the three shallow land burial facilities and SFR. There are some nuclear wastes that are not suitable to be disposed of in these facilities. This inventory is either stored at the waste generator or in the interim storage facility, Clab. The planned destination of this waste is the future disposal facility for the long lived low and intermediate level wastes (SFL). According to SKB's plans it will be operational in mid 2050s.

The disposal of short lived low and intermediate level wastes is done in SFR, which is a disposal facility constructed at a depth of 60 meters in Forsmark. The facility is designed for solid radioactive waste and the disposal rooms underground are allocated for waste with different kinds of characteristics and packing. The current capacity of SFR is 63 000 m³ but a licence for extending the facility by 117 000 m³ was granted by the government in 2021. The extension is mainly allocated for disposing of the decommissioning waste from NPP, and it will be constructed at a depth of 120m.

The concept for radioactive waste from the decommissioning of NPPs and other nuclear facilities is similar to that for the operational waste. The pretreatment of the waste is done by the operators and the waste is destined to shallow land burial facilities, SFR or SFL based on their characteristics.

The waste management concept for the radioactive waste produced in facilities licensed under the radiation act (non-nuclear radioactive waste) is different than for the nuclear waste. The waste which can be treated and packed in such way that they fulfil the waste acceptance criteria of SFR can be delivered to Cyclife Sweden AB. For the waste which cannot be disposed of in SFR, the owner must take care of its management. In practice this means the interim storage by the owner.

Spent fuel management

The concept for spent fuel management in Sweden is direct disposal in crystalline bedrock. Before the disposal, the spent fuel is stored at least nine months at the NPP site after being taken out of the reactor. After this time, the spent fuel from all NPPs is delivered to Clab in Oskarshamn for an interim storage period of 30-40 years before the encapsulation and disposal.

SKB has started the development of the spent fuel disposal concept in 1970s. The spent fuel will be packed in a copper canister with a nodular cast iron insert. The copper canister will be placed in a disposal facility at a depth of 450 to 500 meters. The copper canisters are placed in vertical disposal holes embedded with bentonite clay. In addition to the technical barriers, the natural barrier, i.e. a suitable host rock, is an essential component of the concept.

During the development of the technical concept for disposal for spent fuel disposal, SKB has conducted a site selection process, which has included decades of site studies in several candidate municipalities. For a successful site selection process, local acceptance is vital and to achieve this, SKB has interacted with all stakeholders during the process to take into account other views. SKB submitted the licence application for the spent fuel disposal in 2011 and the government granted the licence in 2022.

ARTEMIS observation

The ARTEMIS Review Team considers that concepts and processes for managing radioactive wastes from nuclear facilities in Sweden are well defined. The interaction between NPP operators, SKB, Cyclife Sweden AB, AB Svafo and Studsvik Nuclear AB is coordinated by SKB and is effective for the final disposal of all waste streams from the nuclear facilities.

Disposal of the very low-level wastes in shallow land burial facilities and disposal of short lived low and intermediate waste in SFR have been routinely and safely operated for decades.

The SFL disposal facility for long lived low and intermediate waste is included in the future plans of SKB but the work for designing the facility concept and site selection process is in the initial stages. This poses problems for waste management planning, as the waste acceptance criteria are not yet defined, and the waste destined to be disposed in SFL cannot yet be treated and conditioned. The planned operational time of 10 years for SFL is very short and allows little flexibility if delays occur in the predisposal management steps. Large amounts of waste need to be characterized, treated, and conditioned properly for the disposal and the treatment cannot be started before the waste acceptance criteria is defined for the disposal facility. This issue is discussed in more detail in chapter 5.

The ARTEMIS Review Team also noted that the planned inventory of SFL does not incorporate all the radioactive waste which does not yet have a management route defined, particularly the non-nuclear radioactive waste that cannot be disposed of in the SFR and the wastes from ESS.

In the area of spent fuel disposal, the ARTEMIS Review Team concludes that SKB has done impressive work in developing the KBS-3 disposal concept and site selection process to a point in which Östhammar municipality has accepted the disposal facility and governmental licence for the project was granted. To achieve this, SSM and the Land and Environment Court have had crucial roles in reviewing the licence application and supporting the government in its decision-making process.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES

Observation: *Sweden started the development of the KBS-3 concept in the 1970s and at the same time started the site studies to find suitable location for the planned disposal concept. During the 50 years of R&D-work, the concept has been developed from a plan to an industrial concept and the site studies have resulted in the selection of a suitable disposal site. The concept and site have been approved both on national and local level and the construction works are scheduled to start in the near future.*

All this realised as a governmental licence for the disposal project in 2022 with aim to avoid imposing an undue burden of the spent fuel problem for the future generations.

(1)	<p>BASIS: SF-1 Principle 7, para 3.29 states that “Radioactive waste must be managed in such a way as to avoid imposing an undue burden on future generations; that is, the generations that produce the waste have to seek and apply safe, practicable and environmentally acceptable solutions for its long term management. The generation of radioactive waste must be kept to the minimum practicable level by means of appropriate design measures and procedures, such as the recycling and reuse of material.</p>
GP1	<p>Good Practice: Sweden has designed the KBS-3 for spent nuclear fuel disposal concept and developed it to a mature concept, carried out a successful siting process and interacted with all stakeholders for achieving wide acceptance and a governmental licence for the proposed disposal project.</p>

5. SAFETY CASE AND SAFETY ASSESSMENT OF RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT ACTIVITIES AND FACILITIES

Swedish position

In Section 10 of the Act on Nuclear Activities, the obligations of the licence holders with regard to safety are stipulated. Since radioactive waste management activities and facilities might cause release of radiotoxic or chemotoxic substances and thus an impact on the environment and on human health, safety is also a concern in the licensing under the Environmental Code.

Based on the Act on Nuclear Activities and the Radiation Protection Act, SSM specified requirements for safety assessment, safety review and reporting in its regulation. According to SSM guidance, a first preliminary safety report (F-PSAR) is expected to be part of the licence application. In the regulation, the later steps are described as follows: “A preliminary safety analysis report shall be compiled before an installation may be constructed and before major alterations or major changes to an existing installation are carried out. Before trial operation of the installation may begin, the safety analysis report shall be renewed in order to reflect the installation as built. The safety analysis report shall be supplemented before the installation may subsequently be put into routine operation, taking into account the experience gained from the trial operation.” While terminology used in IAEA’s Safety Standards, e. g. concerning the concept of a Safety Case, is not necessarily the same as the one being used in Swedish Acts, regulations and applications, the elements required in the Safety Standards are considered to be well accounted for.

Specific regulations are in place concerning the post-closure safety of disposal facilities. These address, inter alia, requirements for repository design and its barrier functions, and for the analysis and reporting of safety. Protection goals are stipulated and principles such as passive safety, optimization and the implementation of Best Available Techniques are set.

Licence applications for the spent fuel disposal facility at Forsmark in the Östhammar municipality and the related encapsulation facility, adjacent to the Clab interim storage facility at Oskarshamn, were submitted by SKB in 2011. The application is based on the KBS-3 concept, the development of which was based on multiple safety reports. Following requests by SSM, additional analyses were subsequently performed. Based on findings by the Land and Environment Court, the government expressed requests for additional analyses concerning copper corrosion mechanisms, which were addressed by SKB in 2019. After further exchanges concerning potential needs for updates, the Government decided that the final disposal facility for spent fuel and encapsulation facility were permissible under the Environmental Code. The licences under the Act on Nuclear Activities include a licence condition concerning a step-wise review process by SSM prior to construction, trial and routine operation. An application to the Land and Environment Court for a licence is planned by SKB in 2023. An ensuing application for SSM’s licence will be supported by an updated safety assessment.

All operational facilities are also subject to periodic safety reviews (at least once every ten years). Recent reviews include the facilities operated by Cyclife Sweden AB, by Studsvik Nuclear AB and by AB Svafo (all submitted in 2015 and with completed SSM reviews by 2017). In 2018, SKB submitted safety reviews for the spent fuel storage facility, Clab and for the LILW-SL disposal facility, SFR. Both were reviewed by SSM by 2020. Arrangements for waste treatment and packaging at nuclear power plants are integrated with, and subject to regulatory supervision as part of general reactor operations.

Modifications of facilities require safety reviews and the notification of SSM. Recent important modification projects requiring licences under the Environmental Code and the Act on Nuclear

Activities include the capacity increases of both Clab (spent fuel storage) and SFR (LILW-SL disposal).

Following the government's 2021 approval of plans to increase Clab's storage capacity, the Land and Environment Court decided on licensing conditions (2022). SKB's application to SSM, which included plans for modifications to the design and operation and was, inter alia, based on a preliminary safety analysis report (PSAR), was rejected by SSM in 2022 and then revised by SKB. The revision (submitted by SKB in 2022) included a revised PSAR.

SKB's application for increasing SFR's disposal capacity included a F-PSAR addressing the design, operation and post-closure radiation safety of the facility. Following the recommendations made by the Land and Environment Court and by SSM, the plans were approved by the Government in 2021. The licence under the Act on Nuclear Activities contains conditions for a stepwise process for the construction and test operation of the extension, and for routine operation of SFR. Before each step, SKB must submit a safety report, which must be reviewed and approved by SSM before the step may commence. A licence under the Environmental Code which includes conditions with regard to noise, transport and releases of non-radioactive substances to water was issued by the Land and Environment Court.

Since the planned LILW-LL disposal facility, SFL is envisaged to be operational only in the mid-2050s, as of this writing, only preliminary conceptual and safety considerations have been undertaken.

ARTEMIS observation

The ARTEMIS Review Team observes that the legal and regulatory requirements concerning safety demonstration as well their implementation by the applicants and the regulatory review practices are in line with IAEA Safety Standards. The ARTEMIS Review Team particularly acknowledges the stepwise development and the status of the post-closure safety assessments of disposal facilities, especially of the planned spent fuel disposal facility, which represent or even define state-of-the-art methodologies. Particularly, during the review meeting the ARTEMIS Review Team learned that the issues of design optimisation and Best Available Techniques are being addressed appropriately and that the necessary RD&D activities are undertaken.

Given that the spent fuel disposal facility is now approaching implementation, issues of radiation protection and occupational safety during construction, operation and closure become increasingly important. The way of addressing these issues in safety assessments and reviews was not yet obvious and clear to the ARTEMIS Review Team. The ARTEMIS Review Team considers it beneficial for Sweden as well as for programmes in other countries if the actors, particularly SKB and SSM, would share the relevant assessments and reviews to make them more visible and known (nationally and internationally). The same could apply to the relevant assessments and reviews associated with the SFR facility.

The ARTEMIS Review Team notes that the start of operation for the planned LILW-LL disposal facility SFL is foreseen only for the mid-2050s. However, the ARTEMIS Review Team also points out that a considerable volume of waste, especially non-nuclear radioactive waste, which is potentially to be disposed of at SFL, is already being stored by various waste owners. While these materials are conditioned in a way allowing for storage, it is not yet clear which conditions and waste acceptance criteria (WAC) will be established for SFL, whether they will allow for all of the existing and arising LILW-LL to be accepted by SFL, and what kind of (re-)conditioning will be required in order to comply with the WAC. On one hand, the conditions have to be based on the design of, and the safety assessments for, SFL, which are

still yet to be developed in detail and needs to account for the nature and volume of the planned inventory. On the other hand, the national strategy needs to endeavour to provide conditions which will facilitate acceptance of wastes at SFL. Also, the question arises whether the conditioning state of the waste will allow for acceptance at SFL, or for re-conditioning if necessary. Thus, iteration involving the waste owners and SKB and accounting for the waste inventory as well as for the development of the SFL and the safety assessment is necessary in order to develop conditions, including WAC, serving their purposes. During the review meeting, the ARTEMIS Review Team learned that the actors are well aware of this issue and that informal exchange and iteration have been initiated. However, the ARTEMIS Review Team also observes that a process including a time schedule and milestones involving SKB and waste owners in order to develop preliminary conditions, in particular WAC, for the disposal of waste in the SFL would serve several purposes. It would serve SFL planning and development as well as the waste owners' plans for waste characterisation and (re-)conditioning. It would also help avoiding a situation in which waste would be left in storage since it could not be accepted at SFL. It could also increase clarity and transparency. The question of timing is particularly important given that a rather short time period is planned for SFL operation. SSM could play a role in initiating such a process. The ARTEMIS Review Team is aware of the finding of the IRRS mission that "*SSM does not have a mandate to issue regulations prescribing requirements for pre-licensing activities, but when becoming a licensee, the applicant must show an ability to fulfil all relevant requirements.*" A change concerning this situation would help SSM to become more active in the issue of preparing waste for SFL disposal.

The ARTEMIS Review Team recognises that shallow land burial facilities for VLLW-SL do not fall under the regulations for radioactive waste repositories. During the review mission, the ARTEMIS Review Team learned that, as for other shallow land burial facilities (for non-radioactive waste), a surveillance period of 30 years has been set, but that the fate of the facilities after this period and responsibilities remain unclear and should be addressed.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES

Observation: *It is not yet clear which Waste Acceptance Criteria (WAC) will be set up for SFL, whether they will allow for all the existing and arising LILW-LL to be accepted by SFL, and what kind of (re-)conditioning will be required in order to comply with the WAC.*

Establishing the preliminary conditions for acceptance of LILLW-LL by SFL would significantly contribute to ensuring that SFL planning and development as well as (re-)conditioning and ensuing acceptance at SFL will go on without obstacles and that no waste will be left in storage since it cannot be accepted at SFL. This could also increase clarity and transparency.

(1)	BASIS: SSR-5 Requirement 2 states that <i>“The regulatory body shall establish regulatory requirements for the development of different types of disposal facility for radioactive waste and shall set out the procedures for meeting the requirements for the various stages of the licensing process. It shall also set conditions for the development, operation and closure of each individual disposal facility and shall carry out such activities as are necessary to ensure that the conditions are met.”</i>
(2)	BASIS: SSR-5 para 3.9 states that <i>“The regulatory body has to engage in dialogue with waste producers, the operators of the disposal facility and interested parties to ensure that the regulatory requirements are appropriate and practicable.”</i>
(3)	BASIS: SSR-5 Requirement 20 states that <i>“Waste packages and unpackaged waste accepted for emplacement in a disposal facility shall conform to criteria that are fully consistent with, and are derived from, the safety case for the disposal facility in operation and after closure.”</i>
(4)	BASIS: SSG-14 para 6.38 states that <i>“[...] Waste acceptance criteria may be developed by means of an iterative dialogue between regulatory body, the operator of the facility and the generator of the waste. [...]”</i>
(5)	BASIS: SSG-14 para 6.41 states that <i>“The proposed waste acceptance criteria should be published at the earliest opportunity, to facilitate compatibility of the waste generated and its safe management at the waste generation sites prior to its emplacement in the disposal facility.”</i>
S3	Suggestion: SSM should consider initiating, without further delay, a forum involving SKB and waste owners that fosters development, in a timely manner, of the preliminary conditions, in particular WAC, for the disposal of waste in the SFL. The forum should aim to establish time schedules and milestones for developing such conditions.

6. COST ESTIMATES AND FINANCING OF RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT

Swedish position

A company or other entity with a licence to conduct nuclear activities, as issued to nuclear power plants and other facilities under the Act on Nuclear Activities, is obliged to implement and finance the measures required to ensure the safe management and final disposal of the facility's operational waste and its residual products, e.g., spent fuel and decommissioning waste. These financial obligations in relation to the management of residual products of nuclear activities are specifically regulated by the Financing Act.

Licensees under the Act on Nuclear Activities are obliged to carry out and finance the safe decommissioning and demolition of facilities after operations have ceased. All nuclear power companies and other licensees have the full financial responsibility for all their respective costs. According to the Financing Act, a licensee under the Act on Nuclear Activities is required to establish a cost calculation for the aforementioned activities and supply this to the Swedish National Debt Office, every third year. The cost estimates are reviewed by the Swedish National Debt Office who then propose fees for the management of nuclear waste based on the estimates.

Current licensees under the Act on Nuclear Activities that are responsible for financing under the Financing Act include:

Licensees with nuclear power reactors:

- Barsebäck Kraft AB (two reactors, none in operation)
- Forsmarks Kraftgrupp AB (three reactors, all in operation)
- OKG Aktiebolag (three reactors, one in operation)
- Ringhals AB (four reactors, two in operation)

Licensees without nuclear power reactors

- AB Svafo
- Chalmers tekniska högskola AB
- Cyclife Sweden AB
- Vattenfall AB (with respect to the closed Ågesta reactor)³
- Ranstad Industricentrum AB
- Ranstad Mineral AB
- Studsvik Nuclear AB
- Westinghouse Electric Sweden AB

Each licensee is responsible for financing their respective obligations according to the Financing Act and has an unlimited liability. In addition to the unlimited liability for the licensees, their parent companies also have a limited liability in the event that a licence holder cannot fulfil its obligations.

SKB jointly owned by the nuclear power plant licensees, has been established to carry out certain responsibilities of the licensees. SKB calculates the costs using a four-step process.

³ Vattenfall AB is treated as a licensee without any reactor according to the Financing Act and Act on Nuclear Activities, even though the Ågesta facility that it now owns (permanently closed in 1974) was technically a power reactor.

In the first step, SKB calculates the costs associated with a reference scenario. The reference costs are based on the licensees' current plans and assumptions in terms of operational lifetimes for the reactors and the corresponding expected volumes of waste and spent fuel that are generated. In the second step, the reference costs are scaled down by SKB to fit the assumptions that are stipulated by legislation. Hence, for example, according to the Financing Act, operational waste should not be included. Furthermore, each reactor is assumed to have a nominal operational lifetime of 50 years as opposed to the reference scenario above in which those reactors still in operation are assumed to operate for a total of 60 years. In the third step, calculated costs are adjusted with respect to prospective real price and cost changes in payroll costs, labour productivity and prices for machinery investments and other inputs. As a fourth step, SKB then adds an "uncertainty premium" (contingency) to the cost estimate.

The latest audited cost estimate, Plan 2019, amounts to expected total costs of SEK 116 billion in 2019 prices. A revised cost estimate, Plan 2022, was published in September 2022 and is under review by the Debt Office. To secure the financing of their future obligations, licensees are required to pay a nuclear waste fee annually into the nuclear waste fund. The fee is proposed by the Debt Office and decided by the Government every three years for the coming three-year period and is calculated and decided separately for each licensee.

Licence holders for activities involving radiation but which do not constitute nuclear activities (i.e. industry, research and medical applications) are not subject to the provisions of the Act on Nuclear Activities or the Financing Act, but are nevertheless obliged to finance the cost of waste management through the provisions of the Radiation Protection Act. Financial securities may be required from private organisations licensed under the Radiation Protection Act to ensure that all potential future costs of radioactive waste management from their activities can be met. The actual costs of waste disposal are typically paid in the form of fees to Cyclife Sweden AB, which then takes responsibility for the wastes it accepts for treatment and conditioning for disposal in SKB's facilities.

There is also a state-sponsored financing scheme administered by SSM for the recovery of orphan sources and clean-up of non-nuclear radioactive waste where no responsible person can be identified. Where possible, recovered disused sealed radioactive sources and other non-nuclear waste are submitted by SSM to Cyclife Sweden AB for treatment, conditioning and storage, pending final disposal.

The future disposal of radioactive waste from the research facility European Spallation Source (ESS) is not covered by the Financing Act. SKB has agreed with ESS to explore whether capacity for disposal of low and intermediate level waste, including that arising from decommissioning, can be made available in its facilities; however, the parties have not reached any agreement yet. The statutes of the ESS consortium (which currently has 13 members) state that all member countries contribute with a specified amount for financing the decommissioning of the facility. Costs above the specified cost are expected to be covered by Sweden. There is ongoing discussion between key stakeholders in ESS regarding whether the consortium's provision for decommissioning covers all related costs for the final disposal of related waste arisings or if additional financing arrangements will need to be established. SSM monitors the developments as part of the continuing licensing process during commissioning of the ESS.

Only limited amounts of long-lived radionuclides can be disposed of in SFR, even after its extension is complete. Waste with a higher content of long-lived radionuclides therefore has to be safely stored until the planned SFL geological disposal facility is in operation, which, according to current plans, will be in the mid-2050s. Also, even though SKB has entered into agreements on final disposal of nuclear and non-nuclear radioactive waste with both Cyclife

Sweden AB and ESS, these agreements do not necessarily mean that SKB will accept waste for disposal without reservation.

Several orphan sources are recovered every year and SSM is usually able to commission Cyclife Sweden AB to manage these. When Cyclife Sweden AB accepts to manage an orphan source, the company also assumes the ownership of the source. Orphan sources are transported to the Studsvik Tech Park, where they are treated, conditioned and stored pending disposal. However, if an orphan source is of a type where a treatment method or a disposal solution is lacking or unclear, Cyclife Sweden AB will not accept it, despite the availability of financing. The orphan source must then be stored by the finder while awaiting the availability of a suitable management method. In practice, this means that a private person or a recycling facility could become an involuntary holder of radioactive material for which they may lack competence and necessary facilities to manage.

Legacy waste is stored on the Studsvik Tech Park in AB Svafo's facilities and responsibility for its management in accordance with the provisions of the Act on Nuclear Activities has been transferred to AB Svafo. Non-nuclear radioactive waste in this context include waste from healthcare, as well as industry and government agencies such as the Armed Forces.

The management and disposal of the legacy waste have been financed to a certain extent by funds that were generated and distributed to different organisations through a special law, the so-called Studsvik Act, which was repealed in 2017. These funds are, however, widely considered not to be sufficient to cover all the future costs associated with handling and final disposal of the legacy waste. At the time of preparing this report, the Government has appointed the National Debt Office to review the current financing arrangements and propose actions in connection with the management and disposal of historical wastes.

The decommissioning and site remediation of the Ranstad uranium mining and milling facility that started in 2010 has been completed after the dismantling of the processing plant in 2017 and the subsequent radiological controls and preparations for site release. The regulator, the Swedish Radiation Safety Authority (SSM), decided in 2019 on the free release of the industrial site from regulatory requirements.

The Swedish Environmental Protection Agency manages a national funding programme on remediation of contaminated land from past practices. Potentially contaminated areas are identified, investigated and classified. No area has yet been identified for remediation in respect of radioactive substances only. However, identification of potentially contaminated areas is an ongoing process.

ARTEMIS observation

Sweden places a high level of importance on ensuring there is sufficient financial provision for the safe management of its nuclear radioactive waste and spent fuel, through to the closure of all disposal facilities. Sweden has developed detailed cost estimates for all the activities necessary for the safe management of its nuclear radioactive wastes, to the point of disposal. These estimates have been developed using methods recommended in international studies. The ARTEMIS Review Team noted the high level of effort that is devoted to ensuring that the costs are as accurate as possible, through benchmarking with similar projects, sensitivity studies and regular updates.

The principle of "the polluter pays" is applied and there are clear and well-defined processes for funding the activities needed for the safe management of nuclear radioactive waste and spent fuel.

Funds collected according to the Financing Act are closely managed with the aim of protecting their value and there are rules in place to ensure that they can only be used for the purposes for which they were collected. Thus, there is confidence that finance will be available when required. There are processes in place for updating the fees to ensure that they are sufficient.

Regarding non-nuclear radioactive waste, as stated in chapter 1.1, Sweden’s national policy does not contain effective provision for cases where the waste generator does not or cannot discharge their responsibility. The ARTEMIS Review Team considers that the policy does not provide a contingency for cases in which the main approach fails to ensure that all radioactive waste is managed safely.

The ARTEMIS Review Team points out that a licensed facility for the disposal of waste from the operation and decommissioning of the ESS facility may not be available when needed, since SKB plans to close SFL in 2060, whereas current plans show that ESS will be operational until 2065.

Moreover, the ARTEMIS Review Team was also informed that funding is insufficient for the treatment and disposal of a part of radioactive waste that is the responsibility of AB Svafo.

The ARTEMIS Review Team found that the final costs for disposal of long-lived waste in SFL are very difficult to determine. Cyclife Sweden AB has stated that it is too much of a financial risk for the company to assume responsibility for the interim storage and disposal for some long-lived radioactive waste.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: <i>Financial and contractual agreements for the disposal of radioactive wastes arising from the operation of the European Spallation Source are not yet finalized. Funds allocated to AB Svafo are not sufficient to cover all the future costs associated with handling and final disposal of the legacy waste. For non-nuclear radioactive waste an individual or a recycling facility could become an involuntary holder of radioactive material for which they may lack competence, financial resources and necessary facilities to manage.</i>	
(1)	BASIS: GSR Part 5 Requirement 1 states that <i>“The government shall provide for an appropriate national legal and regulatory framework within which radioactive waste management activities can be planned and safely carried out. This shall include the clear and unequivocal allocation of responsibilities, the securing of financial and other resources, and the provision of independent regulatory functions.”</i>
(2)	BASIS: GSR Part 2 Requirement 2, para. 2.5 states that <i>“The government shall promulgate laws and statutes to make provision for an effective governmental, legal and regulatory framework for safety. This framework for safety shall set out the following: (16): Responsibilities and obligations in respect of financial provision for the management of radioactive waste and of spent fuel, and for decommissioning of facilities and termination of activities.”</i>
R3	Recommendation: The Government should ensure that the responsibilities and obligations in respect of securing financial provisions allow for the sustainable management of all legacy waste and non-nuclear radioactive waste.

7. CAPACITY BUILDING FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT – EXPERTISE, TRAINING AND SKILLS

Swedish position

Legal provisions

The legislation includes provisions for capacity building for the various parties responsible for the safe management of radioactive waste and spent fuel in Sweden.

The Environmental Code requires that the person responsible for an activity that may cause environmental damage must acquire the necessary knowledge to reduce the risk of injury or other inconveniences to people and the environment.

The Radiation Protection Act requires that any worker who in an activity may be exposed to ionizing radiation needs to have a good knowledge of the conditions, terms and regulations under which the activity is carried out. This person must also be aware of the hazards that may be associated with the activity and have the skills necessary for effective radiation protection.

The Radiation Protection Act and the Nuclear Activities Act require that all parties involved ensure that sufficient financial, administrative and human resources are available for maintaining safety.

The Nuclear Activities Act adds that when contractors and subcontractors are engaged, they must provide human resources with the required qualifications and skills.

The SSM regulations require the licensee to ensure that workers performing activities involving ionizing radiation have the necessary skills and qualifications for tasks that have an impact on radiation protection. In addition, the required competencies must be systematically identified and documented. Training or other measures should be taken as appropriate.

National surveys

Maintaining a national level interest in sciences and technology, and competencies is a common issue for all actors in the area.

As part of its government mandate, SSM must specify and describe the research that the authority believes is necessary for Sweden to maintain a national supply of skills, including in the long term. SSM receives an annual financial allocation from the Government for research, which may be used for both basic and applied research, as well as for the development of methods and processes to enhance national competence within the Authority's area. Within this framework, SSM supports basic and applied research that contribute to the development of national expertise in addition to the RD&D programme conducted by SKB.

Competence, organization, and staffing

The regulators and operators for the management of radioactive waste and spent fuel that require expertise are SSM, SKB, Cyclife Sweden AB and AB Svafo. All of them have integrated processes to develop, attract and retain skills into their management systems. The fields to be covered by these competences are very broad and concern in particular natural and material sciences and technology development. In order to secure competence in the country, collaborations with universities and university colleges is part of the long-term competence management of the actors working in the area.

Capacity building for radioactive waste and spent fuel management at SSM was addressed in the 2022 IRRS report. The IRRS team observed that *“In 2021, SSM underwent a very significant organizational change. The organisational structure was shifted from a ‘competence oriented’*

approach to a 'task-oriented approach' ... to ensure internal independence between the divisions". The IRRS Team further observed that "cooperation, communication and exchange of expertise between experts located in the different divisions has been adversely affected by the new organisational structure". Findings related to maintaining a sufficient critical mass of qualified personnel, strengthening individual training programs, availability of expertise related to radioactive waste disposal, and capabilities to maintain independent assessment and undertake international cooperation were made by the IRRS team.

SSM is responsible for many of Sweden's obligations in relation to international conventions and other agreements, and contributes to the development of international standards and recommendations.

A challenge for SKB is the construction of the new facilities that will then be operated for a long time. SKB has developed an extensive RD&D programme supporting the development of knowledge and skills in the following areas:

- design, structure, manufacture, and installation of the barriers and components to be used in the facilities ;
- inspection and testing to verify that the system barriers and components are produced and installed in accordance with approved specifications, and thereby satisfy the requirements.

Where appropriate and possible, SKB supports PhD projects that can contribute to the creation and preservation of good research environments. In addition to developing knowledge in issues of importance for final disposal of waste, the PhD students funded by SKB constitute a significant injection of skills, particularly expert skills, for SKB as well as for other actors in the area.

ARTEMIS observation

Legal provisions

The ARTEMIS Review Team noted that appropriate legal provisions are taken to ensure that for all parties involved in decommissioning and radioactive waste and spent fuel management, sufficient financial, administrative and human resources are available for maintaining safety are available.

National survey

In the autumn of 2021, SSM provided a report regarding the National strategy for skills supply in radiation safety. The report identifies waste management as an integral part of the competence needs for nuclear activities. Decommissioning, transport, storage and disposal of disused sealed radioactive sources, substances and wastes are considered core competencies. Proposals were made to the government to secure competence base for all businesses to be conducted in a radiation-safe manner. These highlight a need to:

- strengthen the coordination at the national level. This requires as a priority the designation of responsible authorities to participate in efforts to ensure and develop the national supply of expertise in the field of radiation protection and continuous monitoring of the expertise at the national level. It is also important that the government be committed to maintaining the conditions necessary to provide long-term expertise and to coordinating education and research at national level;

- maintain international research collaboration and education and training ;
- enhance the attractiveness of the field of radiation protection.

There is a national trend of a declining interest in degrees in technology and natural sciences. Sustainable strengthening of education, training, international research collaboration and attractiveness in the field of radiation protection is a challenge for all actors in the area. The Nuclear Training and Safety Center AB (KSU) has been highlighted as an important actor to provide training contributing to safe nuclear power including waste management.

Final disposal entails a broad need for competence in the fields of nuclear technology and radiation protection, but also in geoscience, geotechnology, materials science, construction technology, instrument and measurement techniques and competence concerning climate evolution. The pool of specialized scientists and experts is small, creating competition among organizations working in the field of radiation protection to attract the best experts and researchers.

The ARTEMIS Review Team considers that the strategy proposed by SSM to secure competence within Sweden is appropriate to face the future challenge of waste management. It is important that the government support these proposals and accompany them with an action plan (see suggestion below).

SSM

SSM is supported by permanent advisory committees, covering safe management of spent fuel and radioactive waste and research and development. Members are appointed by SSM's Director General and represent other national or international authorities and independent institutions with relevant competences.

Over the past three decades, SSM and its predecessors have implemented research programmes aimed at developing autonomous competence and tools in the field of geological disposal. One million euros is made annually available from the Waste Fund for open research calls on nuclear waste management including PhD and postdoctoral projects. Additional funding can be used on request for procurement of external experts to support SSM's review and assessment work and authorization activities.

As described in the previous section, the IRRS 2022 mission set recommendations to SSM related to competence building as a consequence of the recent reorganisation. In particular, the IRRS Team highlighted that SSM should ensure:

- there are sufficient qualified staff to fulfil all its statutory and regulatory functions;
- the availability of competences related to radioactive waste disposal;
- capabilities to maintain independent assessment and to undertake international cooperation.

The ARTEMIS Review Team notes that these recommendations are essential to support the SSM regulatory missions. The situation is expected to improve as SSM is working strategically on recruiting staff and developing skills to achieve its goals and conducting its duties effectively. SSM is systematically analysing the potential skills the Authority needs in the short and long term to accomplish its current and future tasks.

SKB

SKB has performed research for 40 years and much of the knowledge at SKB has been developed in cooperation with external partners. SKB cooperates with universities in Sweden

and abroad and participates in projects and conferences in the framework of international institutions such as IAEA, OECD-NEA and EU. SKB is also cooperating with other waste organisations like Posiva (Finland), NWMO (Canada) and Enresa (Spain). These collaborations have been and will continue to be important for ensuring access to competence and expertise.

SKB also organizes reviews of its plans and results by international experts.

The ARTEMIS Review Team noted the efforts made by SKB to preserve information and knowledge at long term. SKB has for many years been working on issues concerning archiving and preservation of knowledge and information about the final repositories, both during their operating time, covering a few generations, and in the significantly longer term after their closure.

Cyclife Sweden AB and AB Svafo

Based on the documentation and the discussions, the ARTEMIS Review Team observes that Cyclife Sweden AB and AB Svafo implement actions to develop in-house competence and training, to transfer knowledge and skills, to attract & retain competence and to monitor employee suitability.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: <i>SSM has identified the need to increase coordination at the national level to strengthen and sustain the Swedish competence base in nuclear and radiation safety. This is particularly true in the areas of radioactive waste and spent fuel management, which require a wide range of expertise and research.</i>	
(1)	BASIS: GSR Part 1 (Rev. 1) Requirement 11 states that <i>“The government shall make provision for building and maintaining the competence of all parties having responsibilities in relation to the safety of facilities and activities.”</i>
S4	Suggestion: The Government should consider actions to improve national coordination of strategies to strengthen and maintain the competence needed for all parties with responsibilities related to radioactive waste and spent fuel management.

APPENDIX A: TERMS OF REFERENCE

1. Introduction

On 17th January 2018, Sweden requested the IAEA to organize an Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation Programmes (ARTEMIS). On 23rd March 2020, the Swedish Radiation Safety Authority (SSM) proposed the IAEA to organize back-to-back Integrated Regulatory Review Service (IRRS) and ARTEMIS missions, with the IRRS mission in late 2022 and the ARTEMIS mission in spring 2023.

Sweden's request for the ARTEMIS review is to satisfy its obligations under Article 14(3) of the Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community Framework for the Responsible and Safe Management of Spent Fuel and Radioactive Waste (hereinafter the *EU Waste Directive*).

In line with the requests, the ARTEMIS review will be carried out in late April 2023 in a coordinated manner with the IRRS mission, scheduled in November 2022. The ARTEMIS review will be led by the IAEA by the Department of Nuclear Safety and Security who will be supported by the Department of Nuclear Energy.

2. Objective

The ARTEMIS review will provide an independent international evaluation of Sweden's radioactive waste and spent fuel management programme.

The review will be conducted by an international team of experts selected by the IAEA and will be based on the relevant IAEA Safety Standards and proven international practices.

3. Scope

The ARTEMIS review will evaluate the Swedish national programme and the national framework for executing country's obligations for safe and sustainable radioactive waste and spent fuel management.

Sweden has expressed interest in discussion of the following topics: No areas identified

It was agreed to exclude: No exclusions

The outcomes from the 2022 IRRS mission to Sweden will be taken into account as appropriate to avoid unnecessary duplication in line with the Supplementary Guidelines on the Preparation and Conduct of IRRS-ARTEMIS back-to-back Missions, applicable for situations when an IRRS mission is conducted before an ARTEMIS mission. These Supplementary Guidelines are not a substitute for the ARTEMIS Guidelines but supplement them with the specific provisions that need to be taken into account while conducting IRRS-ARTEMIS back-to-back missions.

4. Reference material

The ARTEMIS review will cover all documentation submitted by National Counterpart for the scope of the review, including the results of a national self-assessment, which should be based on the ARTEMIS self assessment questionnaire provided by the IAEA.

For IRRS-ARTEMIS back-to-back missions, the National Counterpart will include in the reference material the sections of the IRRS Reference material relevant to the ARTEMIS review (e.g. parts of the IRRS self-assessment report dealing with radioactive waste and spent fuel management) as soon as they are available as well as the IRRS final draft mission report.

For IRRS-ARTEMIS back-to-back missions, identified areas of possible overlap will be addressed only by one mission, either IRRS or ARTEMIS, depending on the scope and nature of the reviews. The National Counterpart will be able to bypass in each self-assessment certain questions to avoid addressing twice the same issues. Namely, questions dealing with the General Safety Requirements (GSR) Part 1 Requirement 10 in Module 1 of eSARIS Self-assessment of IRRS will be covered in the ARTEMIS mission and certain questions of topics 1, 3, 5 and 7 of ARTEMIS self-assessment questionnaire dealing with legal and regulatory framework will be covered by IRRS mission.

The provisional list of reference material is provided in **Annex 1** (this list is subject to updates and should be finalized by submission of the advance reference material).

All documents for the purpose of the ARTEMIS review will have to be submitted in English.

Reference material for the purpose of the ARTEMIS review shall be submitted to the ARTEMIS mission webpage on the Global Nuclear Safety and Security Network (GNSSN) of the IAEA.

5. Modus operandi

The working language of the review, including the review mission, will be English.

The National Counterpart is the Swedish Radiation Safety Authority (SSM). The National Counterpart Liaison Officer for the review is Ms Åsa Zazzi (Department of Regulation and Knowledge Development, Section of Plant Safety Assessment International Policies and Co-operation, SSM).

The timeline for the key steps of the review process is provided below:

- Self-assessment: questionnaire was made available to Sweden as of **5 May 2021**.
- Preparatory Meeting: **14 October 2022 (Teams meeting)**.
- The reference material and the results of the self-assessment questionnaire will be provided to the IAEA as soon as they are available and not later than **16 February 2023**.
- Questions based on a preliminary analysis of the reference material and the self-assessment results will be provided to the National Counterpart from the review team by **31 March 2023**.
- The review mission will be held during **16 – 27 April 2023 (12 days) in Stockholm, Sweden**. The mission schedule is included in annex 2 and summarized in the bullets below:
 - Sunday 16 April: arrival of team members and initial team meeting.

- Monday 17, Tuesday 18, Wednesday 19 and Thursday 20 April: interviews/exchange/discussion with Counterparts on the basis of preliminary analysis and drafting of recommendations and suggestions.
- Thursday 20 April: Session after lunch reserved for further discussions if required.
- Friday 21 April: finalization of identified recommendations, suggestions and good practices.
Friday 21 April: Presentation of recommendations, suggestions and good practices to the Counterparts
- Monday 24 and Tuesday 25 April: Review and fact checking of draft Report by Swedish Counterparts
- Monday 24 April: Site visit for team members to SKB's facilities in Oskarshamn
- Tuesday 25 April: Team meeting with discussion on comments from counterpart
- Wednesday 26 April: Discussions with the Counterparts on the draft Report and finalization of the Report by the Review Team.
- Thursday 27 April: Delivery of final draft Report to host and Exit Meeting.

6. International peer review team

The IAEA will convene an international team of experts to perform the ARTEMIS review according to the agreed Terms of Reference. The team will comprise:

- Eight qualified and recognized international experts from government authorities, regulatory bodies, waste management organizations and technical support organizations, with experience in the safe management of radioactive waste and spent fuel. Among the experts, the IAEA will identify one expert with enough knowledge and experience in the regulatory field as well as in the radioactive waste and spent fuel management, decommissioning and remediation field to participate in both the IRRS and ARTEMIS missions. This expert will cover IRRS Modules 5 to 9 on aspects for waste and spent fuel management facilities and will ensure that the ARTEMIS mission is informed on the IRRS review findings and mission.
- Two IAEA staff to coordinate the mission. The coordinator of the ARTEMIS review is Mr Gérard Bruno from the Waste and Environmental Safety Section of the Department of Nuclear Safety and Security. The deputy coordinator is Ms Rebecca Robbins from the Waste Technology Section of the Department of Nuclear Energy.
- One IAEA staff for administrative support who will assist the Review Team to assemble the Review Report.
- A senior member of IAEA staff from the Department of Nuclear Safety and Security will oversee the closure of the review mission.

The peer review team will be led by a Team Leader. The Team Leader will be Mr François Besnus, IRSN, France.

The review mission may include the presence of up to two observers, including the possibility of an observer from the EC. The National Counterparts will be notified of any proposed observers; the presence of any observers will be agreed between the IAEA and the National Counterpart in advance of the mission.

7. Reporting

The findings of the ARTEMIS review will be documented in a final ARTEMIS Review Report that will summarise the work of the review and contain any recommendations, suggestions and good practices. The report will reflect the collective views of the review team members and not necessarily those of their respective organizations or Member States, or of the IAEA.

Prior to its finalization, the ARTEMIS Review Report will be delivered to the National Counterpart for fact-checking.

8. Funding of the peer review

The ARTEMIS review will be funded by Sweden. The costs for the services will be limited to the travel costs and per diem of the peer review team (external experts and IAEA staff) in line with IAEA Financial Regulations and Rules.

The cost of the ARTEMIS review were paid to the IAEA as voluntary contribution before the start of the mission. Sweden is aware that the review cost includes 7% programme support costs.

If the actual cost of the ARTEMIS review exceeds the estimated voluntary contribution, Sweden agrees to cover such additional cost to the IAEA. Similarly, if the actual cost is less than the estimated voluntary contribution, any excess will be refunded to Sweden through the Counterpart.

These Terms of Reference have been agreed between the IAEA and SSM during the preparatory meeting held on-line on 14 October 2022.

Annex 1

Provisional list of reference material

- Responses to the ARTEMIS Self-assessment Questionnaire
- Sweden's third National Report on Implementation of Council Directive 2011/70/Euratom, SSM2021-3334-1
- 7th Joint Convention National Report – Report Ds 2020:21
- Sweden IRRS ARM Summary Report – Report SSM 2022:11
- The IRRS self-assessment report including parts dealing with radioactive waste and spent fuel management, SSM2021-1032-16
- The IRRS Review Report
- Report SSM 2021:15 National Plan - Responsible and safe handling of spent nuclear fuel and radioactive waste in Sweden
- RD&D Programme 2022. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste, SKB TR-22-11
- STATUS AND TREND PROJECT on Spent Fuel and Radioactive Waste, Third cycle 2020-2023, National profile of Sweden, Reference date 2019-12-31, SSM2020-6683
- Plan 2022. Costs from and including 2024 for the radioactive residual products from nuclear power. Basis for fees and guarantees for the period 2024-2026. SKB TR-22-12.
- Selected regulations and legislations

APPENDIX B: MISSION PROGRAMME

Time	Sun 16 April	Mon 17 April	Tue 18 April	Wed 19 April	Thur 20 April	Fri 21 April	Sat 22 April	Sun 23 April	Mon 24 April	Tue 25 April	Wed 26 April	Thur 27 April
9h00 - 10h00	Arrival of Team Members	Entrance meeting General presentation Feedback on IRRS findings (legal and regulatory aspects of RW and SF mgt)	Waste and Spent Fuel Inventory	Safety case and safety assessment	Capacity building	Finalization of Recommendations and Suggestions	Report drafting	Report drafting	Travel to site visit	Swedish counterparts send comments	Discussion with Counterparts on the draft report	Delivery of final draft report
10h00 - 12h00		National Policy and Framework										Exit Meeting
12h00 - 14h00		Lunch										
14h00 - 18h00	Initial team meeting (at the hotel)	National Strategy	Concepts, Plans and technical solutions	Cost estimates and financing	Session reserved for further discussions if required/ drafting of the report	Presentation of draft Suggestions & Recommendations to Counterparts	Delivery of draft report to Counterparts	SITE VISIT (Review of draft report by Swedish counterparts)	late return to Stockholm	Team meeting (discussion on comments)	Finalising Report	
18h00 - 19h00		Team meeting	Team meeting	Team meeting	Team meeting	Team meeting						
19h00		Report drafting	Report drafting	Report drafting	Report drafting	Report drafting						

APPENDIX C: RECOMMENDATIONS AND SUGGESTIONS

Area		R:Recommendations S: Suggestions G: Good Practices	Recommendations, Suggestions or Good Practices
1.	NATIONAL POLICY AND FRAMEWORK FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT	R1	The Government should supplement its policy and strategy so that responsibilities and resources are allocated to ensure safe and sustainable management of all non-nuclear radioactive waste.
2.	NATIONAL STRATEGY FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT	R2	The Government should ensure that safe management routes are made available for all radioactive waste, including disused sealed radioactive sources.
		S1	The Government should consider using the National Plan as a strategic planning component to support and monitor implementation of the national policies for all types of radioactive waste and for spent fuel.
3.	INVENTORY OF SPENT FUEL AND RADIOACTIVE WASTE	S2	The Government should consider establishing and maintaining a national database such that records of all radioactive waste and spent fuel are centralized and accurately reflected to inform decision making on storage and disposal routes.
4.	CONCEPTS, PLANS AND TECHNICAL SOLUTIONS FOR SPENT FUEL AND RADIOACTIVE	GP1	Sweden has designed the KBS-3 for spent nuclear fuel disposal concept and developed it to a mature concept, carried out a successful siting process and interacted with all stakeholders for achieving wide acceptance and a governmental licence for the proposed disposal project.

Area		R:Recommendations S: Suggestions G: Good Practices	Recommendations, Suggestions or Good Practices
	WASTE MANAGEMENT		
5.	SAFETY CASE AND SAFETY ASSESSMENT OF RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT ACTIVITIES AND FACILITIES	S3	SSM should consider initiating, without further delay, a forum involving SKB and waste owners that fosters development, in a timely manner, of the preliminary conditions, in particular WAC, for the disposal of waste in the SFL. The forum should aim to establish time schedules and milestones for developing such conditions.
6.	COST ESTIMATES AND FINANCING OF RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT	R3	The Government should ensure that the responsibilities and obligations in respect of securing financial provisions allow for the sustainable management of all legacy waste and non-nuclear radioactive waste.
7.	CAPACITY BUILDING FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT – EXPERTISE, TRAINING AND SKILLS	S4	The Government should consider actions to improve national coordination of strategies to strengthen and maintain the competence needed for all parties with responsibilities related to radioactive waste and spent fuel management.

APPENDIX D: LIST OF ACRONYMS AND ABBREVIATIONS USED IN THE TEXT

Term	Meaning
ARM	Advanced Reference Material
ARTEMIS	Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation
BAT	Best available technology
Clab	Central Interim Storage Facility for Spent Nuclear Fuel
Clink	Integrated central interim storage facility and encapsulation
ESS	European Spallation Source ERIC
F-PSAR	First Preliminary Safety Analysis Report
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ILW	Intermediate level waste
ILW-LL	Long-lived intermediate waste
ILW-SL	Short-lived intermediate waste
IRRS	Integrated Regulatory Review Service
KBS-3	SKB's planned method for disposal of spent nuclear fuel
LILW-LL	Low and intermediate long waste, long-lived waste
LILW-SL	Low and intermediate waste, short-lived waste
LLW-LL	Long-lived low level waste
LLW-SL	Short-lived low level waste
NORM	Naturally occurring radioactive material
NPP	Nuclear Power Plant
PSAR	Preliminary Safety Analysis Report
RD&D	Research development and demonstration
SEK	Swedish Crown (Krona)
SFL	Disposal facility for long lived low and intermediate level waste
SFR	Disposal facility for short lived low and intermediate level waste
SKB	Swedish Nuclear Fuel and Waste Management Company (Svensk Kärnbränslehantering AB)
SSM	Swedish Radiation Safety Authority (Strålsäkerhetsmyndigheten)
VLLW-SL	Very low level waste, short-lived
WAC	Waste acceptance criteria

APPENDIX E: IAEA REFERENCE MATERIAL USED FOR THE REVIEW

- [1] INTERNATIONAL ATOMIC ENERGY AGENCY, Fundamental Safety Principles, Safety Fundamentals No. SF-1, Vienna (2006).
- [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Governmental, Legal and Regulatory Framework for Safety, General Safety Requirements No. GSR Part 1 (Rev. 1), Vienna (2016).
- [3] INTERNATIONAL ATOMIC ENERGY AGENCY, Leadership and Management for Safety, General Safety Requirements No. GSR Part 2, IAEA, Vienna (2016).
- [4] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).
- [5] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for Facilities and Activities, IAEA Safety Standards Series No. GSR Part 4, IAEA, Vienna (2009).
- [6] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Radioactive Waste, IAEA Safety Standards Series No. GSR Part 5, IAEA, Vienna (2009).
- [7] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Facilities, IAEA Safety Standards Series No. GSR Part 6, IAEA, Vienna (2014).
- [8] INTERNATIONAL ATOMIC ENERGY AGENCY, Disposal of Radioactive Waste, IAEA Safety Standards Series No. SSR 5, IAEA, Vienna (2011).
- [9] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Fuel Cycle Facilities, IAEA Safety Standards Series No. NS-R-5 Rev. 1, IAEA, Vienna (2014).
- [10] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Energy Basic Principles, Nuclear Energy Series, NE-BP, Vienna (2008).
- [11] INTERNATIONAL ATOMIC ENERGY AGENCY, Radioactive Waste Management and Decommissioning Objectives, Nuclear Energy Series, NW-O, Vienna (2011).
- [12] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Fuel Cycle Objectives, Nuclear Energy Series, NF-O, Vienna (2013).
- [13] INTERNATIONAL ATOMIC ENERGY AGENCY, Policies and Strategies for Radioactive Waste Management, IAEA Nuclear Energy Series No. NW-G-1.1, IAEA, Vienna (2009).
- [14] INTERNATIONAL ATOMIC ENERGY AGENCY, Policies and Strategies for the Decommissioning of Nuclear and Radiological Facilities, IAEA Nuclear Energy Series No. NW-G-2.1, IAEA, Vienna (2012).
- [15] INTERNATIONAL ATOMIC ENERGY AGENCY, Policy and Strategies for Environmental Remediation, IAEA Nuclear Energy Series No. NW-G-3.1, IAEA, Vienna (2015).
- [16] INTERNATIONAL ATOMIC ENERGY AGENCY, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, IAEA International Law Series No. 1, IAEA, Vienna (2006).
- [17] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Glossary – Terminology used in Nuclear Safety and Radiological Protection, IAEA, Vienna (2018).
- [18] Official Journal of the European Union No. L 199/48 from 2nd Aug 2011, COUNCIL DIRECTIVE 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste, Brussels (2011).

APPENDIX F: SITE VISIT

On Monday 24 April the ARTEMIS review team, accompanied by staff from SSM, visited the central interim storage facility for spent nuclear fuel, Clab, and the Äspö Hard Rock Laboratory. Both facilities are located in the Municipality of Oskarshamn, and are operated by SKB.

All spent nuclear fuel generated in Sweden is stored in Clab, which has been in operation since 1985. The ARTEMIS team visited both the above-ground reception building where spent fuel is unloaded from transport casks to water-filled pools, and the underground storage area where the fuel is stored in pools. The water in the pools covers the fuel to a depth of eight metres and provides for radiation shielding and cooling. The rock cover above the storage pools is approximately 30 metres.

The Äspö Hard Rock Laboratory was constructed in the late 1980s and has since then been used for e.g. experiments, field tests, and development and demonstration of disposal technologies. The shaft and main tunnel reach a depth of 460 metres, and experiments and tests have been conducted in niches and short tunnels that branch out from the main tunnel.

The ARTEMIS team was impressed by facilities visited, and noted that the Äspö Hard Rock Laboratory has been instrumental for developing the KBS-3 disposal concept to a mature technology.

The team would like to thank SKB for hosting the site visit and for informative discussions.