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

MISSION

TO

BELGIUM

Brussels, Belgium

3-13 December 2023

DEPARTMENT OF NUCLEAR SAFETY AND SECURITY
DEPARTMENT OF NUCLEAR ENERGY

IAEA

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

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REPORT OF THE

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REPORT OF THE

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

TO

BELGIUM

Mission dates: *3-13 December 2023*
Location: *Brussels, Belgium*
Organized by: *IAEA*

ARTEMIS REVIEW TEAM	
Mr Jussi Heinonen	ARTEMIS Team Leader (Finland)
Mr John Rowat	Reviewer (Austria)
Ms Barbara Pastina	Reviewer (Finland)
Mr Frederic Ledroit	Reviewer (France)
Mr Tomaž Žagar	Reviewer (Slovenia)
Ms Lucy Bailey	Reviewer (United Kingdom)
Ms Jessie Quintero	Reviewer (United States of America)
Ms Mathilde Prevost	IAEA Team Coordinator
Mr Vladimir Michal	IAEA Deputy Team Coordinator
Ms Kristina Nussbaum	IAEA Admin. assistant

IAEA-2023

EXECUTIVE SUMMARY

On 17 March 2021, the Kingdom of Belgium, requested the International Atomic Energy Agency (IAEA) to organize and carry out, in the second half of 2023, a review within an Integrated Review Service for Radioactive Waste and Spent Fuel, Decommissioning and Remediation (ARTEMIS).

The objective of the ARTEMIS Peer Review Service was to provide independent expert opinion and advice on the radioactive waste and spent nuclear fuel management programme in Belgium, based on the relevant IAEA Safety Standards and proven international practice and experiences, following the guidelines of the ARTEMIS review service, requested in line with the 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 ARTEMIS mission was organized by the Department of Nuclear Safety and Security and by the Department of Nuclear Energy as back-to-back to an Integrated Regulatory Review Service (IRRS) mission. The conduct of the ARTEMIS mission and the preparation of the associated mission report have been carried out in due consideration of the IRRS mission, including the IRRS mission report, conducted from 19 to 30 June 2023.

The Preparatory meeting for the ARTEMIS review was held in June 2023. The review of the Advance Reference Material (ARM) was carried out in October and November 2023. The ARTEMIS review mission to Belgium was performed from 3 to 13 December 2023 by a team of seven experts from Austria, Finland, France, Slovenia, the United Kingdom and the United States of America, as well as three IAEA staff members. One expert from the European Commission was invited to observe the mission.

Belgium has a long history of a variety of nuclear developments and activities that generated, and are still generating, radioactive waste and spent fuel, with highly diverse characteristics. Five reactors are in operation and two are shutdown at two sites in Doel and Tihange. Low- and intermediate-level radioactive waste is also generated from the use of radiation sources in medical and industrial applications, as well as in science and research, and from the numerous decommissioning activities that are now well advanced at several early nuclear facilities. Those include the research reactor BR3 at SCK CEN commissioned in the 1960s and facilities of Belgium's nuclear industry that covered almost all activities in the nuclear fuel cycle. Radioactive waste and spent fuel, when declared as waste, are managed by ONDRAF/NIRAS, the Belgian Agency for Radioactive Waste and Enriched Fissile Materials management after acceptance.

During the mission, the ARTEMIS Review Team held discussions with the representatives from the ONDRAF/NIRAS, the Federal Agency for Nuclear Control (FANC), the Belgian Nuclear Research Centre (SCK CEN), the Directorate-General for Energy, Synatom – the organization in charge of the management of the fuel cycle of Belgian nuclear plants, and the Commission for Nuclear Provisions (CNP).

The ARTEMIS Review Team very much appreciated additional information presented by the Belgian counterparts to address the experts' questions during the mission, continuous and open discussions and the commitment to understand and engage with the ARTEMIS Review Team findings to best inform the process of continuous improvement of radioactive waste management in Belgium.

Based on these exchanges, covering subjects such as the Belgian national policy for spent fuel and waste, the waste inventory, and safety assessments, as well as cost estimation for the predisposal and eventual disposal of radioactive waste, the ARTEMIS Review Team noted that Belgium has developed and implemented a comprehensive policy for the current activities in pre-disposal and disposal management of radioactive waste. For the long-term management of radioactive radium-bearing waste and NORM substances that are to be managed as radioactive waste, a policy proposal is being prepared and is expected by 2024. The first part of the national policy for deep geological disposal of intermediate and high-level waste was adopted in 2022 and public debate related to the development of a comprehensive policy began in 2023.

Over the last decades Belgium has established a robust national infrastructure to deal with the management of radioactive waste and spent fuel, including implementing decommissioning and remediation activities. This infrastructure is centred on the national agency, ONDRAF/NIRAS, that closely interacts with producers of radioactive waste and spent fuel, and it is supervised and/or supported by other governmental organizations and supply chain. This is adequate to address recent operational needs and to advance preparation for future obligations on radioactive waste and spent fuel management that will come towards the end of nuclear facilities lifecycle.

ONDRAF/NIRAS is demonstrating a strong commitment to prepare and implement plans for the long-term management of high-level and/or long-lived waste and spent fuel. This includes preparation for a deep geological repository that requires comprehensive research, development and demonstration (RD&D) activities and wide public consultations with public. The ARTEMIS Review Team concludes that ONDRAF/NIRAS and other relevant Belgium organizations are very dedicated and ready to address the ultimate solution for the safe disposal of high-level and/or long-lived waste and spent fuel.

The ARTEMIS Review Team prepared recommendations (R) and suggestions (S) into a draft report which was handed over at the official exit meeting held on 13 December 2023. These are aimed at enhancing the Belgian regulatory framework and implementation of the National Programme for radioactive waste and spent fuel management. The ARTEMIS Review Team provided the following recommendations and suggestions:

- The Government should formulate a well-defined policy decision regarding spent fuel management options, specifically addressing the choice between reprocessing and direct disposal. Policy or policies should encompass all nuclear power plants and research reactors.
- The Government should establish, without undue delay, a comprehensive geological disposal policy for the management of category B&C waste including all the necessary milestones and initiate as soon as possible the site selection process.
- The Government should establish a policy for management of radium-bearing waste in a timely manner to enable the effective remediation of the existing exposure situation.
- The Government should complete the process of establishing safety requirements and a licensing scheme specific to disposal facilities.
- The Government should ensure that waste streams that are non-conforming, have no clear end point or are waiting for a policy decision are included in the National Programme with their proposed associated management options.
- ONDRAF/NIRAS should focus its main resources on solutions that are technically feasible and internationally acknowledged for the long-term management of category B&C waste of the Belgian inventory.

- The Government should act upon an ONDRAF/NIRAS' proposal to revise the legal framework to incorporate additional provisions to allow the definition and the review of the required information for the reference programmes of the waste producers.
- ONDRAF/NIRAS should include in the national inventory a category for radium-bearing waste from past industrial activities to make the radioactive waste inventory complete.
- SCK CEN should consider extending its international cooperation through the EDF/DP2D Graphite Reactor Decommissioning Demonstrator, as this is a particularly timely opportunity.
- ONDRAF/NIRAS should develop the next safety case for geological disposal based on a reference host rock and also assess the range of alternative host rocks (in a stylised approach) to support a future site selection process.
- The Government should consider enhancing the harmonization and justification of financial parameters to be used by all relevant nuclear actors in the determination of nuclear provisions (time frames, discount rates, inflation rates).
- The Government should consider developing and maintaining a national skills strategy for radioactive waste management.
- The Government should ensure adequate financial and human resources will be available for ONDRAF/NIRAS to fulfil its mission.
- ONDRAF/NIRAS should consider exploring means to increase in-house staff resource in the safety case area, including actively recruiting and developing younger team members.

Good practices are so noted to encourage their continued use and improvements, to encourage a careful consideration of any changes to them, and to publicise practices that could be of value to other national programmes. In this regard, the Review Team noted the following good practices in Belgium:

- The centralized management of the radioactive waste by Belgoprocess prior to disposal contributes to the minimization of waste and helps to optimize the interdependencies of the different waste management steps.
- The proposed approach for remediation of the radium-contaminated Umicore site in Olen is a very effective means for waste minimization.

The ARTEMIS Review Team suggests that a follow-up mission in around 3-4 years from now could bring value to Belgium's efforts to improve its waste management. The ARTEMIS Review Team considers that combined follow-up together with IRRS mission would be an effective way to address overlapping areas, recommendations and suggestions.

I. INTRODUCTION

The Kingdom of Belgium requested on 17 March 2021 the IAEA to organize an Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS) mission, taking notion of the results of the Integrated Regulatory Review Service (IRRS) mission to be conducted in the Kingdom of Belgium prior to the ARTEMIS mission.

Belgium noted the ARTEMIS review will contribute 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 from 3 to 13 December 2023 in a coordinated manner as a back-to-back mission with the IRRS mission which occurred from 19 to 30 June 2023.

The review was performed by a team of seven 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. Subsequent to a preparatory meeting in June 2023, and the receipt and review of Advanced Reference Material in October 2023, in December 2023 the ARTEMIS Review Team evaluated Belgium's radioactive waste and spent fuel management programme.

II. OBJECTIVE AND SCOPE

The ARTEMIS review provided an independent, international evaluation of Belgium's national programme and the national framework for executing the country's obligations for responsible and safe radioactive waste and spent fuel management.

The ARTEMIS review was performed against the relevant IAEA Safety Standards and proven international practice and experiences with the combined expertise of the international peer review team selected by the IAEA.

Belgium indicated its interest in discussing the specific topic of the policy of spent fuel management (research reactors and commercial plants) during the review mission.

The outcomes from the 2023 IRRS mission to Belgium were taken into account, where relevant and 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 hosted before an ARTEMIS mission. These guidelines did not substitute IRRS and ARTEMIS guidelines, respectively, but supplemented them with the specific provisions that need to be taken into account while conducting back-to-back missions.

III. BASIS FOR THE REVIEW

A) PREPARATORY WORK AND IAEA REVIEW TEAM

A preparatory meeting for the ARTEMIS Review, was conducted on the 7th of June 2023 online. The preparatory meeting was carried out by the appointed Team Leader Mr Jussi Heinonen, the IAEA coordinator and deputy coordinator Ms Mathilde Prevost and Mr Vladimir Michal respectively, and the team of National Counterparts led by Mr Peter De Preter from Belgian National Agency for Radioactive Waste and enriched Fissile Material (ONDRAF/NIRAS).

The meeting participants had discussions regarding:

- the Terms of Reference for the ARTEMIS review; and
- the relevant detailed aspects for organization and conduct of the review.

IAEA staff presented the ARTEMIS principles, process and methodology. This was followed by a discussion on the work plan for the implementation of the ARTEMIS review in Belgium in December 2023.

Mr Peter De Preter was appointed as the National Counterpart for the ARTEMIS mission and designated IAEA point of contact.

Belgium provided IAEA with the Advance Reference Material (ARM) for the review on 3 October 2023.

B) REFERENCES FOR THE REVIEW

The review was made in accordance with Version 2.0 of the guidelines for the ARTEMIS review service. The Belgian responses to the ARTEMIS self-assessment questionnaire were used as a key basis for the review, together with the rest of the ARM and materials presented during the review mission and the associated discussions. In accordance with the Statute of the IAEA, the ARTEMIS review was made against the IAEA Safety Standards. Other IAEA publications were considered where relevant. The complete list of IAEA publications for this review is provided in Appendix E.

C) CONDUCT OF THE REVIEW

The initial Review Team meeting took place on Sunday, 3 December 2023 in Brussels, directed by the ARTEMIS Team Leader Mr Jussi Heinonen, the ARTEMIS Team Coordinator Ms Mathilde Prevost and the Deputy Team Coordinator, Mr Vladimir Michal.

The ARTEMIS entrance meeting was held on Monday, 4 December 2023, with the participation of the Belgian National Agency for Radioactive Waste and enriched Fissile Material (ONDRAF/NIRAS), the Federal Agency for Nuclear Control (FANC), the FPS Economy, S.M.E.s, Self-employed and Energy, the Belgian Nuclear Research Centre (SCK CEN) senior management and staff. Opening remarks were made by Mr Marc Demarche (Director-General, ONDRAF/NIRAS), Mr Peter De Preter (Advisor long-term management, ONDRAF/NIRAS), Ms Mathilde Prevost (IAEA Team Coordinator) and Mr Jussi Heinonen (ARTEMIS Team Leader).

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

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

The ARTEMIS Exit Meeting was held on Wednesday, 13 December 2023. Opening remarks were made by Mr Marc Demarche (Director-General, ONDRAF/NIRAS). A presentation of the results of the Review Mission was given by the ARTEMIS Team Leader Mr Jussi Heinonen. Closing remarks were made by Ms Hildegarde Vandenhove, Director of the Division of Radiation, Transport and Waste Safety, Department of Nuclear Safety and Security and Mr Alex Reuter (Counsellor, Office of the Deputy Prime Minister and Minister of the Economy and Employment).

An IAEA press release was issued.

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

1.1. NATIONAL POLICY

Belgian position

Belgium has a rich history of nuclear activities dating back to the 1950s and 1960s when the Belgian Nuclear Research Centre (SCK CEN) commissioned six research reactors: BR1, BR2, VENUS, VENUS-F, BR02 (now dismantled), and BR3 (currently undergoing dismantling). Commercial use of nuclear energy was started in 1974, with connection of Doel 1 to the grid. By 1985, Belgium operated seven commercial nuclear power reactors, four in Doel and three in Tihange.

In 2003, the Federal Parliament enacted a law formalizing Belgium's national policy to phase out nuclear energy for commercial electricity production by 2025. This law prohibited the construction of new nuclear power plants and set a 40-year operational limit for existing plants, excluding nuclear research reactors. In 2013 and 2015 the Government decided to allow an additional 10 years of operation for the three oldest units. In 2022 the Government approved a law to allow operation of Doel 4 and Tihange 3 until year 2035 and in June 2023 the Government reached an intermediate agreement with nuclear power plant operator Electrabel and its mother company Engie. Terms of continued operation and possible transfer of radioactive waste and spent fuel liabilities are under negotiation between the nuclear power plant owners and the Belgium Government. The results of this negotiation may have a significant impact on the current spent fuel and radioactive waste management framework.

Belgium's nuclear industry historically covered diverse activities in the nuclear fuel cycle, including reprocessing plants, MOX fuel fabrication facilities, UO2 fuel fabrication facilities, radioactive waste treatment and storage facilities, and radioisotope production facilities for medical and industrial use. Furthermore, between 1922 and 1977, Union Minière (now Umicore) manufactured radium and uranium products in Olen. Certain industries also utilize naturally occurring radioactive materials (NORM), requiring regulatory oversight and the management of radioactive waste.

The main guiding principles for the responsible and safe radioactive waste and spent fuel management are outlined in the Law of 3 June 2014. These include among others minimization of waste generation, management of interdependencies, safety objectives, graded approach and waste generator liability for costs. ONDRAF/NIRAS use waste categorization where:

- Category A waste contains short-lived radionuclides with limited amounts of long-lived radionuclides. It corresponds to low-level waste in the IAEA classification.
- Category B waste contains long-lived radionuclides in quantities that pose a risk for a very long time. It corresponds to intermediate-level waste in the IAEA classification.
- Category C waste contains large quantities of long-lived radionuclides and emits a significant amount of heat. It includes high-level waste and spent fuel declared as waste. It corresponds to high-level waste in the IAEA classification.

Regarding radioactive waste and spent fuel management, the Government has established national policies for the:

- decay and clearance of very short-lived radioactive waste (VSLW);
- centralised short-term and medium-term radioactive waste management;
- near surface disposal of category A radioactive waste;

- first step towards deep geological disposal of category B&C radioactive waste;
- safe storage followed by reprocessing or disposal of the spent fuel from commercial nuclear reactors; and
- management of the spent fuel from research reactors.

With the law of 3 June 2014, National policies on spent fuel and radioactive waste management are established by the Government in Royal Decrees.

In 2010, ONDRAF/NIRAS proposed a "Waste Plan" to initiate a policy decision regarding the long-term management of category B&C waste and to develop a strategy for NORM and Radium-bearing waste. This initiative was not processed in government to a policy decision. ONDRAF/NIRAS submitted the next policy proposal in 2018 for deep geological disposal of category B&C waste. After taking into account outcomes of the strategic environmental assessment (SEA) in 2020, the policy proposal was approved as the Royal Decree of 28 October 2022, establishing the first part of the National Policy for the long-term management of category B&C radioactive waste.

The Royal Decree proposes the solution of deep geological disposal within Belgian territory, without limiting the disposal design (repository or deep boreholes), host formation, or specific site(s) in advance. It mandates ONDRAF/NIRAS to organize a national social debate, aiming to confirm the option of deep geological disposal for category B&C waste and proposing a participative, and transparent decision-making process for the development and implementation of such a disposal facility. The outcome of the process is to be used to establish the second part of the national policy. The national social debate (participatory process), organised by the King Baudoin Foundation, has been started in 2023 and is expected to be finalised at the end of March 2024. The schedule for subsequent steps in policy development have not been clearly established.

In line with the national policy for spent fuel management from commercial nuclear reactors, the nuclear operator sent spent fuel abroad (to France) for reprocessing, and the resulting waste was repatriated, transferred to ONFRAF/NIRAS and is currently stored at Belgoprocess. In 1998, the Federal Government decided to halt the reprocessing. Subsequently, Electrabel, the nuclear power plants' (NPPs') operator, has stored the spent fuel at the NPP sites. The national policy for spent fuel from commercial nuclear reactors, outlined in the National Programme, advocates safe storage with the option of reprocessing or direct disposal. Synatom, the owner of spent fuel, has not declared the spent fuel as waste and has not requested ONDRAF/NIRAS to assume responsibility. ONDRAF/NIRAS since 1993 has considered two scenarios in its Research, Development, and Demonstration (RD&D) programme: direct disposal of spent fuel and reprocessing followed by the disposal of reprocessing waste. Synatom has also in its most recent reference programme (2023) indicated that it is not planning to reprocess anymore any spent fuel including mixed oxide-fuel (MOX).

The policy for research reactor spent fuel management varies between installations:

- The policy for BR2 reactor spent fuel is reprocessing;
- For research reactors BR1, BR3 and VENUS / VENUS-F, there is not yet a policy decision whether spent fuel will be reprocessed or not.

The former radium product production site in Olen is today operated by Umicore and operations revolve around the production of high-tech materials based on cobalt, nickel and germanium. Historic landfill sites containing radium-bearing waste remain on the site, as well as some areas that have Ra-226 contamination. There are also three licensed storage facilities with radium-bearing waste. FANC informed the ARTEMIS Review Team that remediation of the affected

areas will be treated as an existing exposure situation using appropriate provisions in GRR-2001 Remediation of the site will involve multiple government and regional stakeholders.

This will be a project with some complexities, and appreciable amounts of radium-bearing waste will be generated by remediation activities. This project will have interfaces with the national programme for radioactive waste management. ONDRAF/NIRAS is preparing a policy proposal for the disposal of the radioactive waste resulting from remediation of the site.

Belgium policy and strategy for spent fuel and radioactive waste management is described in the National programme from 2015. Programme is planned to be updated in due time after ARTEMIS mission and government pending agreement with nuclear power plant owner is finalized.

ARTEMIS observation

The ARTEMIS Review Team considers that Belgium has a comprehensive framework in place concerning current spent fuel and radioactive waste management activities. The ARTEMIS Review Team has made the following observations for enhancement of Belgium policy framework. These enhancements are needed for Belgium to make progress in the safe management of spent fuel and the radioactive waste management. Observations are in line with those Belgium has identified as part of the self-assessment gap-analysis.

The main element for progress in category B&C waste management is the establishment of clear policy for geological disposal and for the spent fuel management affecting geological disposal development. Belgium has a long history in geological disposal RD&D and has established the needed prerequisites for geological disposal development. Therefore, the ARTEMIS Review Team considers that the Belgium government has all necessary elements to set geological disposal as a clear category B&C management solution and launch site-selection process for geological disposal facility.

Some elements of geological disposal policy development, as described in the Royal Decree of 28 October 2022, and planned to be addressed before the next category B&C policy decision, could be debated and decided alongside the site selection process. The ARTEMIS Review Team was informed during the mission that partitioning and transmutation and other disposal solutions, like deep boreholes, are to be assessed. The ARTEMIS Review Team considers that, even if it might be important for Belgium to follow international development in these topics and evaluate their usefulness in radioactive waste management, they are not technically feasible alternatives to overcome the need of a geological disposal facility.

There is broad international consensus that geological disposal is a necessity. This is also highlighted in EC directive 2011/70/Euratom, which states "*It is broadly accepted at the technical level that, at this time, deep geological disposal represents the safest and most sustainable option as the end point of the management of high-level waste and spent fuel considered as waste. Member States, while retaining responsibility for their respective policies in respect of the management of their spent fuel and low, intermediate or high-level radioactive waste, should include planning and implementation of disposal options in their national policies.*"

Based on the advance reference material, and the presentations and discussions with the counterparts, the ARTEMIS Review Team considers, that historic facilities and contaminated areas at the Umicore site in Olen are under sound management and proper regulatory control. Nevertheless, remediation of historical sites such as the Umicore site in Olen usually present greater uncertainties than waste management activities at a Class I facility, and potential

exposures at the Umicore site in Olen are substantial. For these reasons, the ARTEMIS Review Team considers that remediation activities for the site should be prioritized for earlier rather than later attention.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *The Belgian government has not established clear policies for all spent fuel management options or geological disposal development. Consequently, ONDRAF/NIRAS lacks clear premises for the development of a repository for category B&C radioactive waste, and the site selection process has not been initiated.* *The waste landfills and contamination at the former radium product manufacturing site in Olen are identified as an existing exposure situation. ONDRAF/NIRAS is preparing a policy proposal for the disposal of the radioactive waste resulting from remediation of the site. An effective remediation can only proceed once government policy is established.*	
(1)	**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."*
(2)	**BASIS: GSR Part 1 (Rev. 1) Requirement 10 states that** *"The government shall make provision for the safe decommissioning of facilities, the safe management and disposal of radioactive waste arising from facilities and activities, and the safe management of spent fuel."*
(3)	**BASIS: SSR 5 Requirement 1 states that** *"The government is required to establish and maintain an appropriate governmental, legal and regulatory framework for safety within which responsibilities shall be clearly allocated for disposal facilities for radioactive waste to be sited, designed, constructed, operated and closed. This shall include: confirmation at a national level of the need for disposal facilities of different types; specification of the steps in development and licensing of facilities of different types; and clear allocation of responsibilities, securing of financial and other resources, and provision of independent regulatory functions relating to a planned disposal facility."*
(4)	**BASIS: GSR Part 3 Requirement 47 states that** *"The government shall ensure that existing exposure situations that have been identified are evaluated to determine which occupational exposures and public exposures are of concern from the point of view of radiation protection."*
R1	**Recommendation: The Government should formulate a well-defined policy decision regarding spent fuel management options, specifically addressing the choice between reprocessing and direct disposal. Policy or policies should encompass all nuclear power plants and research reactors.**
R2	**Recommendation: The Government should establish, without undue delay, a comprehensive geological disposal policy for the management of category B&C waste including all the necessary milestones and initiate as soon as possible the site selection process.**

R3	**Recommendation: The Government should establish a policy for management of radium-bearing waste in a timely manner to enable the effective remediation of the existing exposure situation.**

1.2. LEGAL, REGULATORY AND ORGANISATIONAL FRAMEWORK (PARTLY REFERRING TO IRRS)

The IRRS mission in 2023 concluded that Belgium has an established legal framework for radiation protection and nuclear safety and security. The ARTEMIS mission, organized as a back-to-back mission, has specifically focused its review on legal and organizational framework aspects related to spent fuel and radioactive waste management.

Belgian position

The fundamental law governing safety policy is the Law of 15 April 1994. Based on this law, specific regulations in form of Royal Decrees for protecting the public, workers, and the environment from ionizing radiation dangers and safety requirements for nuclear installations have been established. The main safety regulations relevant to spent fuel and radioactive waste management are:

- the Royal Decree of 20 July 2001 concerning the general regulation on protection of the population, of the workers and of the environment against ionising radiation (GRR-2001), and
- the Royal Decree of 30 November 2011 concerning safety requirements for nuclear facilities (SNRI-2011).

Under the Royal Decree of 20 July 2001, facilities primarily engaged in predisposal radioactive waste management follow the licensing procedure of Class I nuclear facilities. For other nuclear facilities, their waste management installations are licensed through their operational license granted based on the class of the nuclear facility. The operator is mandated to undertake all necessary activities in compliance with the Royal Decrees of 20 July 2001 and 30 November 2011, applicable to all Class I facilities.

Radioactive waste disposal facilities, classified as Class I nuclear installations, follow the licensing procedure for nuclear installations with certain modifications. FANC has prepared a licensing procedure for disposal facilities, pending adoption by Royal Decree. This procedure, distinct from the general Class I licensing process, includes regulatory provisions for facility closure and release from regulatory control. Additionally, another Royal Decree specifying safety requirements for disposal facilities, based on the Western European Nuclear Regulators' Association (WENRA) Safety Reference Levels, has been prepared by FANC. Both draft Royal Decrees are currently pending government approval.

ONDRAF/NIRAS is a public organization responsible for managing radioactive waste in Belgium. The missions and operating rules of ONDRAF/NIRAS are established in Article 179, § 2, of the Law of 8 August 1980 and the Royal Decree of 30 March 1981. The other main actors, established as part of legal framework, in spent fuel and radioactive waste management are:

- the producers of radioactive waste (e.g Electrabel, SCK CEN and users of radiation sources);
- the owners of the spent fuel (SCK CEN and Synatom);

- ONDRAF/NIRAS subsidiary Belgoprocess;
- the Federal Agency for Nuclear Control (FANC) and its subsidiary Bel V;
- the Federal Government and its administrations;
- the Commission for Nuclear Provisions (CNP).

The legal framework for spent fuel and waste management financial liabilities consists of several acts and Royal Decrees. The legal framework establishes provisions for the human and financial resources necessary for the management of the radioactive waste and spent fuel. It also provides provisions and a framework for the RD&D required for development of waste management facilities and activities.

Public consultation is established through the Law of 13 February 2006, which mandates that federal plans and programmes with potential environmental impacts undergo assessment, including public participation. The Law of 3 June 2014 stipulates that national policies for radioactive waste or spent fuel management are to be regarded as plans and programmes within the meaning of the Law of 13 February 2006. As an example of implementation, policy proposals must go through an SEA process before establishment as a Royal Decree.

ONDRAF/NIRAS is obligated by Royal Decree to establish and implement an information and communication programme that covers all its activities. It informs the general public through various channels. ONDRAF/NIRAS has an extensive local partnership programme in the municipalities of Mol and Dessel, described further in Sections 2 and 7 of this report. The Law of 29 December 2010 provides the mechanism to finance these activities and to provide added value for the integration of a disposal facility in a local community.

ARTEMIS observation

The ARTEMIS Review Team considers that Belgium has in general a comprehensive legal, regulatory and organizational framework for the safe management of spent fuel and radioactive waste. The legal framework establishes, in relation to spent fuel and radioactive waste management, provision for safety, responsibilities, resources, financing and public participation. Regulatory and safety frameworks were evaluated more comprehensively as part of the 2023 IRRS mission and according to the procedures for back-to-back mission, are not re-evaluated as part of the ARTEMIS mission.

The ARTEMIS Review Team received information about the content and status of two Royal Decrees prepared by FANC. Disposal facility safety requirements should enter into force as a matter of urgency, as they are needed to establish the dedicated regulatory basis for all disposal installations including the later phases of the category A disposal facility in Dessel, the future radium-bearing waste disposal and the category B&C geological disposal facility. The ARTEMIS Review Team considers that setting clear requirements is a key prerequisite for ONDRAF/NIRAS when moving forward in implementing all necessary radioactive waste disposal facilities.

The ARTEMIS Review Team has also identified other specific needs for enhancement of the legal framework which are addressed in the following sections of this report.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *FANC has prepared safety requirements and a licensing scheme specifically tailored to disposal facilities, and a proposal for Royal Decrees has been submitted for Government approval. These provisions are important for the later steps in the operation of the Dessel near surface disposal facility and critical for the development of the radium-bearing waste disposal facility and the deep geological disposal facility for category B&C radioactive waste.*	
(1)	**BASIS: GSR Part 1 (Rev. 1) Requirement 2, para 2.5 states that** *"The government shall promulgate laws and statutes to make provision for an effective governmental, legal and regulatory framework for safety."*
R4	**Recommendation: The Government should complete the process of establishing safety requirements and a licensing scheme specific to disposal facilities.**

2. NATIONAL STRATEGY FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT

2.1. SCOPE

Belgian position

Belgium's national strategy for radioactive waste management is reflected in their "*National Programme for the Management of Spent Fuel and Radioactive Waste*" which was published in October of 2015. Belgium drafted an unofficial update (dated 2.10.2023) as part of advance reference material of Artemis mission. It is expected that Belgium will publish an update of the National Programme in due time after Artemis mission and finalization of the Government agreement with Engie. Drafting of the *National Programme* is coordinated by the National Programme Committee with input from many players. FANC is asked to comment on the National Programme, but does not participate in its development of the strategy. The National Programme is endorsed by the Federal Council of Ministers. Figure 2-1 gives a synoptic view of the National Programme for the management of radioactive waste, the responsibility for management (producers/owners vs. ONDRAF/NIRAS), the management strategy as well as the status of the policy in 2023.

Belgium has a rich history of nuclear activities, resulting in a diverse inventory of spent fuel and radioactive waste. The main streams stem from the operation and decommissioning of nuclear power plants, research reactors, the use of radiation sources, radioisotope production, and past practices in the nuclear fuel cycle, including the production of radium and uranium products. This has given rise to a large number of radioactive waste streams that have a broad range of characteristics (see Section 3). Radioactive waste is managed according to waste categories A, B, and C described earlier in this report.

Table 2 – Overview of the existence of national policies on the management of spent fuel and radioactive waste (green box: policy approved; yellow box: no formal policy; grey box: not applicable)

Waste category	Management by producers or owners	Transfer of waste	Management by ONDRAF/NIRAS	
			Short- and medium-term management (waste processing, conditioning and storage)	Long-term management (disposal)
Very short-lived waste	decay and clearance		not applicable	
Category A	the on-site management of radioactive waste by producers must comply with a set of principles, but it is not subject to a national policy	→	centralised management at the sites of Belgoprocess	surface disposal the first part of the national policy on deep geological disposal was established by royal decree on 28 October 2022
Category B				
Category C (reprocessing waste)	not applicable			
Category C (spent fuel)				
Spent fuel from Synatom	storage, possibly followed by reprocessing		not applicable (see Annex A)[11]	
Spent fuel from SCK CEN	For BR2 : storage, followed by reprocessing For BR1/BR3 : storage, followed by either direct disposal or reprocessing			
Spent fuel from Thetis	the spent fuel was declared as waste and handed over to ONDRAF/NIRAS			
Radium-bearing substances to be managed as radioactive waste by ONDRAF/NIRAS	on-site management of waste producers, such as storage of the radium-bearing substances by UMICORE (see further)	→	these wastes will immediately move from on-site management by the owners to a long-term management solution	policy proposal expected by 2024 covered by the long-term management policy for category B waste or the policy proposal for the long-term management of radioactive radium-bearing waste[12]
NORM substances to be managed as radioactive waste by ONDRAF/NIRAS				

Fig. 2-1. Synoptic view of the national programme for the management of spent fuel and radioactive waste (Table 2 from self-assessment report)

The overall national strategy addresses:

- Short- and medium-term management of radioactive waste and spent fuel by its owners;
- The radioactive waste management by ONDRAF/NIRAS, which includes:
  - centralised short-term and medium-term management;
  - surface disposal of category A waste;
  - deep geological disposal of category B&C waste;
  - long-term management of radioactive radium-bearing and NORM waste;
- Waste acceptance system and related waste acceptance criteria; and
- Public participation mechanisms regarding category A, B&C waste disposal.

The national strategy includes a reference scenario and alternative scenarios, mostly drafted for cost calculation purposes and to define the RD&D plan. Waste producers are obligated to submit a reference programme, which defines their waste inventory and schedule of transfer at least every five years to ONDRAF/NIRAS. The Reference Scenario is developed by ONDRAF/NIRAS based on information from waste producers. Together with other involved organizations, ONDRAF/NIRAS maintains current status of waste management developments (industrial scenario). Every 5 years (at most), ONDRAF/NIRAS produces an "adequacy report" to check the consistency between the reference scenario and the industrial scenario. Such a

report was produced for the first time in 2023 and shows “broad” consistency with a few exceptions.

The integrated management of all current and future waste streams is carried out by ‘NOA’, which is a consultation, coordination and advice committee. Both ONDRAF/NIRAS and Belgoprocess management are involved in the NOA. NOA defines management processes for all current and future waste streams and ensures the availability of strategic support and operational and financial resources. NOA develops dedicated approaches for non-conform conditioned waste packages (short-term, medium-term and long-term approach, ‘KML-system’) and follows-up waste streams currently with no endpoint. NOA also defines RD&D needs for challenging waste streams and follows up on them. NOA ensures the proper functioning of the waste management processes with all interfaces and underlying processes, periodically evaluating and redirecting (if deemed necessary) existing management processes for each waste stream.

The situation of national strategy implementation is addressed in Section 2.2 of this report.

The waste acceptance system and related waste acceptance criteria

The interdependencies between the different waste management steps are managed by the waste acceptance system. The waste acceptance system is an integral part of ONDRAF/NIRAS’ waste management strategy. This system ensures that at each step in the management chain, the radiological, physical and chemical properties of the radioactive waste meet the requirements of the subsequent management steps. This system includes the criteria that must be satisfied for non-conditioned and conditioned waste in order for ONDRAF/NIRAS to accept and take charge of the waste.

The waste acceptance criteria (WAC) for radioactive waste are established by ONDRAF/NIRAS and undergo formal verification by FANC. These criteria consider nuclear licence requirements for waste transport, treatment, conditioning, storage, and disposal. ONDRAF/NIRAS conducts checks not only upon initial acceptance but also post-acceptance during storage at Belgoprocess.

The waste acceptance system and criteria for individual steps and facilities are utilized as a strategic tool to assess the adequacy of existing and planned solutions in achieving the objectives of the National Programme. The system was recently amended by adopting legal provisions with incentives for owners to adhere to WAC requirements. The laws of 2021 make the owners of non-comforming waste packages indefinatelyindefinitely responsible for them. ONDRAF/NIRAS has indicated that the waste acceptance system is planned to be further enhanced, amongst other things to extend it to disposal and by involving FANC and waste producers more closely in the development of WAC.

As no disposal facility exists as an end-point for category B&C waste, prospective waste acceptance criteria for the category B&C waste destined for geological disposal have been defined. The WAC (including the prospective ones) will be gradually refined via RD&D activities. The waste acceptance system and associated RD&D activities are essential management tools to limit the risk of producing waste that ultimately does not meet the disposal requirements.

National strategy for challenging waste streams

ONDRAF/NIRAS mentioned the existence of non-conforming conditioned waste streams, waste streams without a clear endpoint or waste streams that have no national policy in place. Examples of non-conforming conditioned waste are:

- Bituminised waste (issues: bitumen overflow, corrosion);
- Cemented waste (issues: gel formation, corrosion of containers); and
- Cellulose-bearing waste (issues: formation of ISA resulting in radionuclide transport facilitated by organic complexation).

For these waste streams, ONDRAF/NIRAS presented a clear management strategy and several RD&D activities are ongoing. For category B&C waste in particular, the ARTEMIS Review Team was informed by ONDRAF/NIRAS that its approach for uncertainty management is that all open issues identified while using the so called "methodological tool: the Safety and Feasibility Statements" are subject to a research plan.

The ARTEMIS Review Team also asked questions concerning the disposal strategy of used sealed sources, the disposal of graphite from research reactor BR1 and the disposal of fresh (or lightly used fuel). Disused sealed sources (low- and high-activity) are considered for deep geological disposal but no final national policy is in place.

Public participation mechanisms

ONDRAF/NIRAS, under the Royal Decree of 1981, implements an extensive information programme using various channels, including its website, reports, publications, and visits to facilities like the HADES underground research laboratory.

Local partnerships between ONDRAF/NIRAS and municipalities like Dessel and Mol, integral to the near surface disposal project, serve as effective communication and engagement platforms. Local partnerships at Dessel (STORA) and Mol (MONA) engage with ONDRAF/NIRAS on technical and societal aspects and have provided important input to the waste management strategy. Tabloo, a communication centre near the future disposal site, serves as an information hub and community space (see Section 7).

Overall, nuclear actors, including the Federal Public Service Economy, effectively communicate with the public on nuclear activities, covering topics such as federal competences, the Commission on Nuclear Provisions, the Committee for the National Programme, as well as research activities in the nuclear domain.

ARTEMIS observation

The national strategy is built around finding optimized solutions for achieving long term safety for all waste streams. Hence, disposal solutions (i.e., long term solutions) are an essential element of the national strategy.

Strategy development in Belgium is very much driven by a set of policies, still not complete, that have developed and evolved over decades. The policy and legal framework has a large influence on the development of the national waste management strategy.

As shown in Table 2 of the ARTEMIS Self-Assessment Report (see Figure 2-1), the policy framework in Belgium is not complete. Regardless, ONDRAF/NIRAS has been able to adapt

through their waste acceptance mandate for centralised processing and storage of radioactive waste and their mandate for developing long term management solutions. The centralised processing and storage approach is an important part of Belgium's national strategy as centralisation contributes, among other things, to the minimisation of waste and harmonized processes for waste acceptance. Belgium has a targeted RD&D programme, using safety cases for disposal as well as the challenges from currently non-compliant waste as major drivers for the RD&D programme.

Belgian nuclear operators will make extensive use of clearance in their decommissioning strategy. Belgium is not planning to have a separate very low-level waste (VLLW) category and the infrastructure to support such a category. The preferred strategy for decommissioning is immediate dismantling. The integrated management system (IMS) combines both decommissioning and waste management strategies.

The National Programme is also shaped by financial constraints. The financial risk linked to the complex system of waste producers and policy uncertainties has been managed by adding ample risk factors in the cost provisions (see Section 6). The social dialogue with local communities has provided an important bottom-up driver for some aspects of the National Programme. The Review Team noted the success of the communication centre Tabloo (see Section 7) and the development of the management strategy for radium-bearing waste (see Section 3).

The ARTEMIS Review Team notes that the waste streams that are non-conforming, have no clear end points or are waiting for a policy decision are not fully addressed in the National Programme. The Government should ensure that such waste streams are included in the National Programme along with their proposed associated management options. It is important that the National Programme address all waste streams, in order to support decision-making and foster transparency.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *The National Programme does not clearly address the waste streams that are non-conforming, have no clear end points or are waiting for a policy decision.*	
(1)	**BASIS: GSR Part 5, para. 5.5 states that** *"In the predisposal management of radioactive waste, decisions often have to be made at a time when no disposal facility is available and the waste acceptance criteria for disposal are unknown. A similar situation would arise if radioactive waste were to be stored over long periods of time for reasons of safety or for other reasons. In both cases, consideration has to be given to whether, for the purposes of safety, the radioactive waste will be stored in a raw, a treated or a conditioned form. The anticipated needs for any future steps in radioactive waste management have to be taken into account as far as possible in making decisions on the processing of the waste."*
R5	**Recommendation: The Government should ensure that waste streams that are non-conforming, have no clear end point or are waiting for a policy decision are included in the National Programme with their proposed associated management options.**

2.2. MILESTONES AND TIMEFRAMES

Belgian position

Short- and medium-term management of spent fuel by its owners

The management strategy for commercial spent nuclear fuel is shown in Figure 2-2. Spent fuel producers can, under specific conditions, treat and store spent fuel without immediate involvement from ONDRAF/NIRAS. Synatom does not foresee any further reprocessing of spent fuel. Current practice involves storing spent fuel in cooling ponds before transfer to wet and dry storage facilities in respectively Tihange and Doel . New dry interim storage facilities in Tihange and Doel are under construction and in the future spent fuel conditioning in a separate facility (ICC) is foreseen before transfer to Belgoprocess.

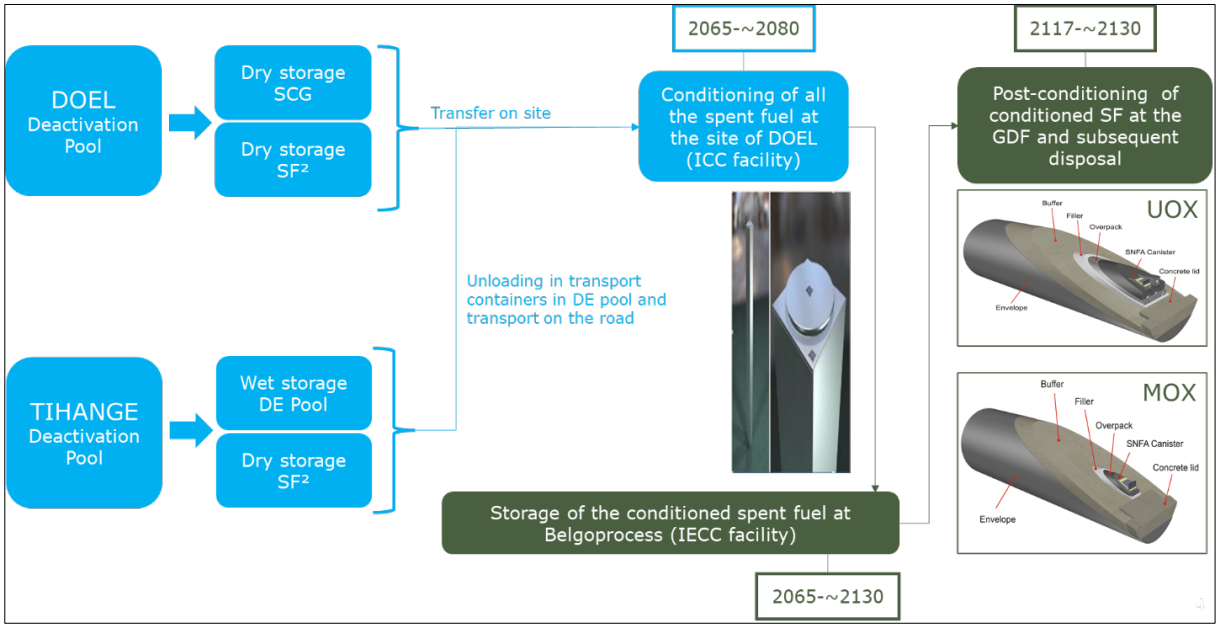

Fig. 2-2. Management strategy for commercial spent nuclear fuel. Source: ONDRAF/NIRAS

Concerning the management of spent nuclear fuel from research reactors, SCK CEN's BR2 reactor's spent fuel undergoes reprocessing, and the resulting waste is stored at Belgoprocess. BR3 reactor's spent fuel is safely stored at Belgoprocess for a maximum of 50 years. The status of BR1 and VENUS / VENUS-F spent fuel will be determined later as part of the policy on deep geological disposal or as a separate policy. SCK CEN is researching the feasibility of treating and conditioning spent fuel from these reactors, including the option of reprocessing.

Centralised short-term and medium-term management of radioactive waste

Belgoprocess centrally manages radioactive waste at sites in Dessel and Mol, using various treatment and conditioning facilities, including CILVA, PAMELA, and Building 280X. Storage facilities for conditioned waste are in operation, with plans for four new storage facilities.

Management strategy for category A waste

The development of near surface disposal for category A waste in Dessel was decided in 2006, with ONDRAF/NIRAS obtaining a construction and operation licence in April 2023. The main milestones and timeframes are presented in the National Programme (2023, updated 2.10.2023, Table 4). The current strategy is to cement and store the category A packages until disposal in the surface facility at Dessel. The construction of the surface facility is planned to start in 2025 and the operational phase will last approximately 30 years (until 2060).

Deep geological disposal of category B&C waste

The first part of the national policy on deep geological disposal of category B&C waste was established by the Royal Decree in October 2022. The next parts of the policy will address decision-making processes, elements like reversibility, retrievability, monitoring, and site selection. It will also set a timeline for implementing the deep geological disposal solution for category B&C waste.

For cost assessments and RD&D planning, the milestones and timeframes are presented in the ONDRAF/NIRAS Reference Scenario and the technical reports supporting it (NIROND TR 2021-16 E V2). The main phases are the following:

- **2019-2023:** Part I of the National Policy defining the bases for the final disposal of B&C waste addressing the decision to go for deep geological disposal, the selection of one or several sites, whether the repository should be on the Belgian territory (or in an international repository), as well as the reversibility of the decision;
- **2023 - 2035:** participative process for site selection and for the establishment of the various parts of the National Policy;
- **By 2035:** choice of one or more site(s) for deep geological disposal (National Policy will then be complete);
- **2036 – 2045:** Preparation of the licence application for the deep geological disposal facility;
- **2046 - 2050:** licensing process.

Long-term management of Radium-bearing waste and NORM waste

For radium-bearing waste with an activity level between 15 and 1,000 Bq/g, ONDRAF/NIRAS is developing a dedicated disposal solution (see Sections 3 and 4). This proposal will be subject to the SEA process in 2023-2024 and is expected to be submitted to the Federal Government in the same year. Consequently, remediation projects for sites contaminated with radium-bearing substances and the disposal of such substances as radioactive waste will be defined after 2024.

ARTEMIS observation

Management strategy for spent nuclear fuel

The strategy and roadmap for spent nuclear fuel management is reasonable although it hinges on the important assumption on the licensing date of the geological disposal facility (2050).

Concerning the milestones and timeframes for spent nuclear fuel management, there is a need for enhanced communication and cooperation between waste producers and ONDRAF/NIRAS to understand constraints on the front and back/end of the fuel cycle and formulate strategies with up-to-date waste inventories and schedule information (see discussion in Section 3).

The answers presented to the ARTEMIS review team concerning the disposal strategy of used sealed sources, the disposal of graphite from research reactor BR1 and the disposal of fresh (or lightly used) fuel were clear and the management strategy is reasonable. The management strategy of graphite is discussed further in Section 4.

Management strategy for Category A waste

The short-, medium- and long-term management strategy for category A waste is sound; a near surface disposal facility in Dessel for category A waste has been licenced and is scheduled to be constructed in the next 5-10 years (after the public tendering process). The timeline for the short-, mid- and long-term management of this waste category seems reasonable.

In summary, for category A waste management there is a clear national strategy and progress with disposal has been demonstrated.

Disposal of Category B&C waste

As there is currently no comprehensive government decision on the disposal policy and strategy for category B&C waste, it is difficult for ONDRAF/NIRAS to draft a focused national strategy with clear milestones and timelines for the disposal of Cat B&C waste. Nonetheless, a roadmap with milestones and timeframes was formulated, mostly for cost estimates and RD&D plans, including reference and alternative scenarios and underlying assumptions. The timeline presented for the management of category B&C waste seems feasible if no further delays occur.

The development of strategy for the management of category B&C waste is also hindered by the ongoing consideration of alternative management options or optimisation technologies to a deep geological repository (in galleries), such as partitioning/transmutation (P/T) and deep borehole disposal which are unsuitable for the management of large amounts of HLW and ILW.

For several decades now, international consensus supports deep geological disposal as the main long-term management solution for HLW and spent nuclear fuel (IAEA, SSR-5). Although the ARTEMIS Review Team acknowledges the requirement by the Government to keep a technological awareness of alternative management options (e.g. P/T and deep borehole disposal), too many options may stretch the ONDRAF/NIRAS resources too far (see Section 7). Furthermore, P/T is currently not a sustainable option for large amounts of waste and would require nonetheless a geological disposal facility for a fraction of the volume containing highly radiotoxic and long-lived radionuclides. Similarly, deep borehole disposal may be viable for small amounts of HLW but, if selected, the reversibility and retrievability principles may become a significant issue. ONDRAF/NIRAS should focus its main resources on solutions that

are technically feasible and internationally acknowledged for the long-term management of category B&C waste.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *The further development of the strategy for the management of Cat B&C waste is hindered by the ongoing consideration of alternative management options to geologic disposal, such as partitioning/transmutation and deep borehole disposal which are unsuitable for the management of large amounts of HLW and ILW. The international consensus states that, for large amounts of high-level waste, deep geological disposal is the only long-term management solution.*	
(1)	**BASIS: SSR-5 Requirement 4 states that** *"Throughout the process of development and operation of a disposal facility for radioactive waste, an understanding of the relevance and the implications for safety of the available options for the facility shall be developed by the operator. This is for the purpose of providing an optimized level of safety in the operational stage and after closure."*
(2)	**BASIS: NW-G-1.1, para. 11.3 states that** *"All the appropriate alternative technical management options for a radioactive waste category to reach the identified end points should be identified. The potential technical options can be narrowed down through the elimination of those that, for various reasons, are unsuitable. "*
R6	**Recommendation: ONDRAF/NIRAS should focus its main resources on solutions that are technically feasible and internationally acknowledged for the long-term management of category B&C waste of the Belgian inventory.**

2.3. PROGRESS INDICATORS

Belgian position

The national strategy is presented in the National Programme: 2015 and unofficial update of 2023. Progress since 2015 is described in the *National Reports* (last report 2021). The progress in implementing the *National Programme* is formally monitored every three years in the *National Report*. This evaluation is supported by some general key performance indicators (KPI) defined in the National Programme (see Figure 2-1). They relate to the existence of:

- a national policy;
- general and dedicated regulations related to radiation protection and safety;
- operational management;
- a financing mechanism;
- RD&D plan.

In addition to the tri-annual monitoring in the National Report, ONDRAF/NIRAS updates the national inventory annually, Belgoprocess monitors storage capacities, and ONDRAF/NIRAS recalculates waste management costs every five years. Additionally, the Commission for Nuclear Provisions conducts a triennial audit of companies with nuclear liabilities (Synatom and Electrabel) and their cost assessment methods.

ARTEMIS observation

For category A waste, ONDRAF/NIRAS has made significant progress since 2015. Most notably, a construction and operating licence has been issued for a near surface disposal facility for category A waste in Dessel. However, for the management of category B and C waste, due to the status of the national policy-making process, there is no firm timetable and neither clear progress indicators, as discussed in Section 2.2.

The ARTEMIS Review Team notes that progress on the waste management strategies and particularly concerning challenging waste streams (non-conforming waste streams or streams having no clear end-points) is internally followed by the NOA through monthly meetings.

Periodic revision of the National Programme, and periodic review of the implementation of the National Programme through the National Report (every three years) provides a programme-wide indicator for performance.

3. INVENTORY OF SPENT FUEL AND RADIOACTIVE WASTE

Waste Classification and Inventory of Waste Streams

Belgian Position

The counterparts provided an overview of Belgium's three-level system for classification of radioactive waste. This system is based upon the IAEA's 1994 system of radioactive waste classification (IAEA Safety Series No. 111-G-1.1). The three categories of radioactive waste in Belgium system are:

- Category A waste contains short-lived radionuclides with limited amounts of long-lived radionuclides and is equivalent to LLW in the IAEA classification.
- Category B waste contains long-lived radionuclides in quantities that pose a risk for a very long time and as such must be isolated from man and the environment for thousands of years. Category B waste emits no or little heat. It is equivalent to ILW in the IAEA classification.
- Category C waste contains large quantities of long-lived radionuclides and emits a significant amount of heat. It includes spent fuel declared as waste and vitrified waste from the reprocessing of spent fuel from commercial nuclear reactors. Category C waste poses a risk for a very long time and must be isolated from people and the environment for thousands of years or even for a period of the order of one million years. It is equivalent to HLW in the IAEA classification.

Category A waste is intended for near surface disposal; category B and C waste are intended for geological disposal.

Overall, the information presented to the ARTEMIS Review Team was more focused on inventory pertaining to category A wastes as a near surface disposal facility for category A wastes is soon to be constructed. A series of presentations provided an overview of the major waste streams that need to be managed under the Belgian Programme. Excluding radium-bearing wastes, operational wastes from NPPs, future decommissioning waste arisings from NPPs and high-level radioactive waste are the major waste streams.

Of the major waste streams the largest uncertainties in regard to inventories reside with decommissioning wastes as these have yet to be generated. Presentations from the counterparts indicated they are following established methods for estimating radiological inventories using established methods such as those described in IAEA Safety Reports Series No. 95. As indicated by the volumes of wastes from NPP arisings, extensive use will be made of clearance to reduce the volumes of decommissioning wastes that are generated. The need for a very low-level waste (VLLW) waste category is not foreseen.

Belgium's inventory of radioactive wastes includes some waste streams that were processed in the past but do not conform with current WAC. ONDRAF/NIRAS has a system in place for managing non-conforming conditioned waste, namely the KML-system. These streams include, among others, bituminized waste, evaporator concentrates solidified in cement. There are studies underway to determine how bituminized waste and cemented evaporator concentrates should be reconditioned.

Category A wastes containing cellulose have been identified by ONDRAF/NIRAS as problematic waste stream. Records for the amount of cellulose in category A packages from the past are not always available as criteria on the admissible amount of cellulose have become

much more stringent over time and the systematic declaration of small amounts was not required. Studies are underway to develop techniques for non-destructive assay of the amount of cellulose in such waste packages. In parallel with these efforts, studies are underway to assess in more detail the amount of cellulose that can be accepted in the near surface disposal facility.

Until ONDRAF/NIRAS takes charge of spent fuel from commercial nuclear power plants and research reactors (in the form of reprocessing waste or as radioactive waste) the spent fuel is managed by its owners. The spent fuel from the commercial nuclear power plants of Doel and Tihange, that has not been reprocessed in the frame of the four reprocessing contracts concluded in the period 1976–1978, is currently stored at the plant sites: in cooling ponds, and in the dedicated dry storage facility in Doel or the dedicated wet storage facility in Tihange. There will be no fresh fuel to be disposed. The inventory of leaking fuel rods is small, equivalent to only one fuel assembly. There are procedures in place to manage the processing and disposal of leaking rods.

The original fuel from the BR1 research reactor (RR) is still present in the reactor. The expected inventory of BR1 fuel amounts to 29 tHM. The fuel of the VENUS RR (low-enriched uranium oxide and plutonium oxide with a very low burnup) awaits further use. The BR2 RR fuel (highly enriched uranium, low enriched as from 2026) is to be reprocessed and disposed as vitrified waste. The BR3 fuel, which amounts to 2.4 tHM, is being managed by ONDRAF/NIRAS.

All disused sealed sources are to be considered for deep geological disposal. As a consequence, disused sealed sources (low-, medium- and high-activity) are excluded from the inventory to be disposed in the near surface disposal facility.

What follows is a compilation of inventory information from the advance reference materials provided by the counterparts. The numbers are indicative of the quantities of radioactive waste that will be managed in Belgium.

Waste Category	**Number of packages, monoliths or assemblies**	**Waste volumes m^3, or tHM**
A	66,100 packages 8,800 monoliths	53,500
B	31,700	8,700
C (vitrified waste)	770	140
C (spent fuel)	9,800	4,100 tHM

Table 3-1. Estimated total inventory of existing and planned conditioned waste, 31 December 2020, based on the reference programme of Synatom. [source: National Report, August 2021]

Category	Type of waste	Volume (m^3)	Notes
A+B	Building 150 Belgoprocess Site	15,022	
A+B	Bituminised and cemented ILW from Eurochimic reprocessing plant	3,907	Mainly Cat B
A+B	Operational wastes from NPPs (filters, concentrates, resins, etc)	1,900	Mainly Cat A
B	Alpha and radium contaminated waste, conditioned Thetis spent fuel.	4,130	
B	ILW from reprocessing of commercial spent fuel	154	
B	Conditioned ILW from PAMELA, and BR2 RR and BR3 RR	215	
C	HLW from reprocessing of spent fuel	70	Vitrified HLW

Table 3-2. Existing inventory of radioactive waste at Belgoprocess, 31 December 2020 (adapted from the National Report, August 2021)

During the review meeting, the counterparts provided a gross materials balance for the decommissioning of Belgium's nuclear power plants (NPPs). The overall materials balance for decommissioning of the seven commercial NPPs is:

Gross amount of materials to be managed: 1,875,000 Tons

Amount of material to be cleared from regulatory control: 1,853,000 Tons

Category A waste: 22,000 Tons

Category B waste: 420 Tons

The materials balance shows that the clearance process will be instrumental for minimizing the generation of radioactive waste.

Transfer of Information for Waste Inventory

Belgian Position

ONDRAF/NIRAS maintains a centralized database for its inventory of radioactive waste. This system is called IRA-3. The inventory of radioactive waste in Belgium is updated each year from the data in IRA-3. A new initiative to consolidate various waste-related databases was presented. The new system is called BASE. It will provide a single repository for all waste-related information and ensure the provenance of the data. It should eliminate issues that arise from having multiple databases and should ensure that all users are provided with the same data.

The Royal Decree of March 30, 1981 and its modifications of April 25, 2014 require ONDRAF/NIRAS to prepare an adequacy report at least every five years. The adequacy report is an analysis that compares the reference scenario of ONDRAF/NIRAS against the industrial scenario for present and future waste arisings. Information in the industrial scenario includes

waste quantities, waste forms, radionuclide inventories and waste processing and disposal routes for waste streams.

ONDRAF/NIRAS described several challenges they have in conducting the analysis required for the adequacy report. These challenges relate primarily to the timeliness, completeness and reliability of the data provided in the reference programmes of waste producers. An example cited was a fundamental change of that actual data compared to the initial assumption of the reactor pressure vessel internals and lack of timely notification thereof.

ONDRAF/NIRAS suggested that the information transfer process would be much improved if the regulatory framework were amended so that:

1. ONDRAF/NIRAS could prescribe the information that waste producers need to provide in their reference programmes;
2. ONDRAF/NIRAS had the option to review and request revision of the reference programmes; and
3. Waste producers were obliged to notify ONDRAF/NIRAS in a timely manner when significant changes are made to their reference programmes.

ARTEMIS Observation

All planning begins with the dimensioning of a problem and inventory information is essential for dimensioning waste management programmes. The ARTEMIS Review Team considers the issue of information transfer from the waste producers to ONDRAF/NIRAS to be critical for efficient and effective planning, and an area where significant improvement could be made.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *The ARTEMIS review has revealed that a more effective means for transfer of waste inventory data from the waste producers to ONDRAF/NIRAS should be established. More timely and better quality information from the reference programmes of waste producers would improve planning, implementation and efficiency of the National Programme.*	
(1)	**BASIS: GSR Part 5, Requirement 6 states that:** *"Interdependences among all steps in the predisposal management of radioactive waste, as well as the impact of the anticipated disposal option, shall be appropriately taken into account."*
R7	**Recommendation: The Government should act upon an ONDRAF/NIRAS' proposal to revise the legal framework to incorporate additional provisions to allow the definition and the review of the required information for the reference programmes of the waste producers.**

Categorization of Radium Bearing Waste

Belgian Position

As was mentioned in Section 1, there is a pressing need to remediate parts of the Umicore site at Olen. Historical operations on the site, dating from the time when Union Miniere was the site operator, left behind some storage facilities containing radium- bearing wastes and some areas that have radium contamination. It was pointed out that the site in Olen is an operating site and that only specific parts of the site need to be remediated. The operations at the site in Olen by the site's current operator, Umicore, do not generate any streams of radioactive waste.

There is a proposal for remediating the storage facilities containing radium-bearing wastes and the areas that have radium contamination. This proposal was developed by multiple agencies of the national and regional governments , namely FANC, ONDRAF/NIRAS and OVAM, together with Umicore. This proposal, dated 2022, has been made available to the public and an English translation of it was made available to the ARTEMIS Review Team.

The proposal for radium-bearing materials foresees a specific National Policy for their management. After the policy has been published, there will be an assessment of technical alternatives, the first design and safety assessment of the disposal facility, the assessment of waste conditioning requirements and the development of WAC for this facility.

ONDRAF/NIRAS, FANC and SCK CEN presented key aspects of the proposal for remediation activities at the Olen site. It is clear that large volumes of radium-bearing wastes will be generated from remediation activities. Potential disposal routes for these wastes were presented and discussed. A shallow depth repository was presented as a promising alternative for disposal of some of the radium-bearing wastes generated by remediation activities at Olen.

During the review meeting, there was only brief discussion of the UMTRAP storage facility. The UMTRAP facility was not considered in the remediation proposal for the Olen site. However, the ARTEMIS Review Team was informed that the facility contains appreciable volumes of radium bearing wastes that will need to be managed as radioactive waste.

ARTEMIS Observation

The present system for radioactive waste classification in Belgium dates from the early 1990s. Since that time, the international system for classification of radioactive waste has been broadened to include additional categories of radioactive waste, and the system has evolved, strengthening the link between waste class and the disposal endpoint. The current version of the international system for radioactive waste classification is found in IAEA Safety Standards Series GSG-1 (2009). In light of the significant changes in the waste streams that are soon to be generated, the ARTEMIS Review Team considers that it would be timely for Belgium to update its national system for radioactive waste classification, in particular to address radium-bearing wastes.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *The ARTEMIS Review Team was informed that significant quantities of radium-bearing waste from past industrial activities in Belgium are not yet included in the National inventory.*	
(1)	**BASIS: GSR Part 5, para. 1.3. states that:** *"[…] The remaining radioactive waste from all sources that is not cleared, discharged or reused 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."*
R8	**Recommendation: ONDRAF/NIRAS should include in the national inventory a category for radium-bearing waste from past industrial activities to make the radioactive waste inventory complete.**

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

The ARTEMIS Review Team considered the concepts, plans and technical solutions, operational and/or planned, for spent fuel and radioactive waste management facilities and activities, including research and development activities needed to manage the spent fuel and radioactive waste from generation to disposal.

The main source of information for the ARTEMIS Review Team to assess this topic was presented in the extensive Advance Reference Material. Presentations containing more detailed information on various aspects of this topic were delivered by knowledgeable Belgium experts. They responded to questions from the ARTEMIS Review Team for clarification or aiming at testing the degree of thoroughness in the approach that has been implemented.

Spent Fuel Storage Facilities at the NPP Sites

Belgian position

Spent fuel removed from the NPP reactors is first stored in cooling ponds for 3-5 years and then transferred to the wet storage facility in Tihange or the dry storage facility in Doel. In addition, two new facilities for the dry interim storage of spent fuel (Spent Fuel Storage Facility or SF2) are planned to be operational at the Tihange and Doel nuclear sites respectively in 2023 and in 2025. Both facilities are designed for an operating lifetime of 80 years. As indicated in its reference programme of 2023, Synatom plans to transfer the spent fuel to ONDRAF/NIRAS between 2065 and 2079. The spent fuel will then be stored in a new facility pending the availability of the deep geological disposal.

Synatom is responsible for all RD&D related to the short- and medium-term management of spent fuel such as RD&D related to the dry storage of spent fuel performed with Tractebel.

ARTEMIS observation

The ARTEMIS Review Team was informed that prior to its transfer to ONDRAF/NIRAS, the spent fuel will be conditioned in a dedicated facility, named ICC, which will be located at the Doel NPP site. The existence of a dry storage facility since 1995 in Doel was one of the drivers for selecting this site for the ICC facility. Indeed, the already stored spent fuel in dual purpose casks could be transferred on site from the dry storage facilities to the ICC facility without transport on public roads. The Tihange spent fuel stored in dry storage could be transferred to a transport package through the wet storage facility before being transported by public roads to the ICC facility. The ARTEMIS Review Team concluded that there are existing solutions and plans in place to manage properly the commercial spent fuel in storage facilities until disposal.

Radioactive Waste Management Facilities

Belgian position

Predisposal

The main existing or planned predisposal radioactive waste management facilities are:

- the on-site waste treatment and conditioning facilities operated by Electrabel at the NPP sites of Doel and Tihange; and
- the treatment, conditioning and storage facilities at the Belgoprocess site of ONDRAF/NIRAS.

ONDRAF/NIRAS pursues a policy of centralising the short-term and medium-term management of the radioactive waste. This centralised management is performed by Belgoprocess, a subsidiary of ONDRAF/NIRAS. This policy contributes to the minimisation of waste, as it reduces the number of storage facilities and therefore the waste generated by the decommissioning of these facilities. It also helps to manage the logistical interdependencies of the different waste management steps and allows to centralise the controls and competences, which, in turn, enhances the overall safety of the waste management. The ARTEMIS Review Team was also informed that this policy, a so-called "*de facto"* policy, is specified in the legal framework under Article 27b of the Royal Decree of 20 July 2001.This article states that:

- the presence in a facility of radioactive material unused for 5 years and for which no further use is planned is to be justified. If needed, FANC may require the operator to remove the radioactive sources or substances from the facility; and
- when a source or substances are declared as "radioactive waste", notification of their evacuation must be submitted to ONDRAF within 6 months.

The radioactive waste, unconditioned or conditioned, is centralised at the Belgoprocess sites in Dessel and in Mol. Thus, Belgoprocess operates several treatment and conditioning facilities as well as various storage facilities for conditioned waste.

Belgoprocess and ONDRAF/NIRAS have developed a tool to monitor storage capacities and anticipate any needs for new storage capacity. Such a tool was needed to mitigate against:

- the delays in implementing the near surface disposal project;
- the uncertainties regarding the planning of deep geological disposal;
- the existence of non-conforming conditioned waste streams, some of which need to be physically separated from the conforming waste streams;
- the approaching end of life of some storage facilities.

The tool is based on a reference scenario of the evolution of the storage capacities and on alternative scenarios considering, for example, delays in the implementation of a planned facility or variations in the waste production forecasts. Evaluations of the different scenarios enable timely decisions about expanding the storage capacities. As a result, the construction of four new storage facilities is planned.

There are several RD&D activities related to the management of radioactive waste. Belgoprocess conducts applied RD&D to develop further treatment and conditioning techniques, among which RD&D on plasma technology and pyrolysis. Electrabel conducts RD&D on treatment and conditioning processes of resins and concentrates.

Disposal

The main planned disposal facility is the category A waste near surface disposal project in Dessel, which received the construction and operation licence in 2023. The facility design provides for the disposal of 1,000 monoliths (waste packages) per year. The total amount of category A waste that is planned to be placed in the disposal facility has been estimated at 53,500 m^3 of post-conditioned waste or 25,300 monoliths. A licence for the construction of 34 modules has been requested, which provides for a reserve of 5 modules.

There are also plans for the deep geological disposal of category B&C waste and the long-term management of radioactive radium-bearing waste for which the national policy to be proposed by ONDRAF/NIRAS to the Federal Government considers a shallow-depth disposal at or close to the Umicore site.

RD&D activities focusing on long-term management are defined and coordinated by ONDRAF/NIRAS. A central element in its RD&D into the deep geological disposal of category B&C waste in poorly indurated clays is the HADES URL. ONDRAF/NIRAS' RD&D aims at a better understanding of the Boom Clay/Ypresian Clay as reference host rocks and the main processes affecting post-closure safety. Another research priority is to improve the understanding of the generation and transport of free gas through the repository and possible effects on the transport of radionuclides.

ARTEMIS observation

On the basis of all information provided, the ARTEMIS Review Team concluded that Belgium has established solutions for short-term and medium-term predisposal management of the radioactive waste arising from existing nuclear facilities. Solutions for disposal are being developed for category A waste as well as for radium-bearing and category B&C waste.

Regarding the storage facilities at Belgoprocess, the ARTEMIS Review Team noted the existence of a tool developed by Belgoprocess and ONDRAF/NIRAS to monitor the storage capacities and anticipate any needs for new storage capacity. In addition, the team was informed that a storage occupancy rate (90%) is defined as an upper limit beyond which Belgoprocess must inform the FANC. The ARTEMIS Review Team considers that the tool aiming at monitoring the radioactive waste storage capacities together with the requirement to report on to the safety authority enables identification of the need for additional storage capacity in a timely manner.

The ARTEMIS Review Team also noted the various ongoing RD&D activities aiming at supporting the development of the deep geological disposal, defining solutions for some waste streams, and investigating areas of optimization regarding the final quantity of waste to be disposed of.

Finally, the ARTEMIS Review Team acknowledges the policy established in Belgium centralizing the radioactive waste storage facilities at Belgoprocess premises and thus contributing to prevent the accumulation of waste stored by producers. Indirectly this also helps to minimize the waste that would have been produced to dismantle the multiple storage facilities at producers' sites. During the 2023 IRRS Mission, it was emphasized that there is a requirement about minimizing waste in Article 17/5 of GRR-2001 that is only applicable to facilities undergoing decommissioning but not for all facilities and activities. This led to Recommendation 7 of the IRRS mission report ("Upon proposal from FANC, the Government should revise the royal decree GRR-2001, to incorporate a requirement that all authorized parties keep the generation of radioactive waste to a minimum"). Notwithstanding this recommendation, the ARTEMIS Review Team considers that, at the implementation level, the storage centralization policy is a good practice.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *Belgium established a policy centralizing the radioactive waste storage facilities at Belgoprocess premises. The provisions of the article 27b of the Royal Decree of 20 July 2001 prevent the accumulation of waste stored by producers. This policy reduces the number of storage facilities, optimizes interdependencies, and thus enhances the overall safety of the waste management.*	
(1)	**BASIS: GSR Part 5, Requirement 6 states that** *"Interdependences among all steps in the predisposal management of radioactive waste, as well as the impact of the anticipated disposal option, shall be appropriately taken into account."*
(2)	**BASIS: WS-G-6.1, para. 5.3 states that** *"The storage of waste in centralized facilities rather than in a multitude of on-site facilities should be considered, since there will be opportunities to adopt more stringent safety standards and at the same time to realize economies of scale."*
GP1	**Good Practice: The centralized management of the radioactive waste by Belgoprocess prior to disposal contributes to the minimization of waste and helps to optimize the interdependencies of the different waste management steps.**

Management of Radioactive Waste from Decommissioning

Belgian position

The upcoming NPP decommissioning will produce large quantities of category A&B waste. The timing of the category A near surface disposal facility is in line with the timing of the decommissioning projects, so that the category A waste generated during the decommissioning can be directly disposed of in the near surface disposal facility. Estimates of the expected quantities of category B waste indicate that these can be stored at Belgoprocess until the deep geological repository is operational, assuming additional storage capacity is built as anticipated.

ARTEMIS observation

The ARTEMIS Review Team noted that solutions for waste arising from decommissioning are considered within the National Programme and that specific waste could require further actions to establish the feasibility of their foreseen conditioning.

The ARTEMIS Review Team questioned the specific waste that may arise from the decommissioning of research reactors, such as the graphite from the BR1 reactor. The BR1 reactor core is a cubic pile of graphite blocks serving as moderator and reflector, with 25 tonnes of metallic natural uranium in an aluminium cladding as fuel, inserted in horizontal channels in the graphite. The ARTEMIS Review Team noted that the BR-1 reactor is still in operation but, during its dismantling, 492 tonnes of graphite waste will be produced. The current reference programme is the direct conditioning in near surface disposal monoliths suitable for the category A final disposal. SCK CEN developed an ongoing specific action plan to ensure the suitability of this graphite waste for the category A disposal.

The ARTEMIS Review Team encourages SCK CEN to keep interaction with the EDF DP2D Graphite Reactor Decommissioning Demonstrator which is designated as one of the IAEA

collaborating centres for programme and strategy definition for graphite reactor decommissioning. The facility, that is operational since 2022 in Chinon (France), is used to test, improve and optimize innovative robotic and remote handling technologies, physical tests on representative full-scale mock-ups as well as simulators and associated digital models.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *The decommissioning of the BR-1 reactor will generate graphite waste that is intended to be disposed of in the category A near surface disposal. This requires specific actions for which the experience gained from international projects could be valuable for SCK CEN. In this context, the newly operational EDF/DP2D Graphite Reactor Decommissioning Demonstrator could be helpful for sharing experience on the graphite waste management arising from the decommissioning of such reactors.*	
(1)	**BASIS: GSR Part 6 Requirement 10, para. 7.5 states that** *"*[…] *The decommissioning plan shall be updated as necessary in the light of relevant operational experience gained, available lessons learned from the decommissioning of similar facilities, new or revised safety requirements, or technological developments relevant to the selected decommissioning strategy.* […]*".*
(2)	**BASIS: NW-G-1.1, para. 12.1 states that** *"The experience obtained in other countries (e.g. those with similar spent fuel and radioactive waste management issues) as a way of identifying better policies and strategies. This could include identifying new technologies for radioactive waste management."*
S1	**Suggestion: SCK CEN should consider extending its international cooperation through the EDF/DP2D Graphite Reactor Decommissioning Demonstrator, as this is a particularly timely opportunity.**

Waste Management at the Umicore Site in Olen

Belgian Position

As mentioned in Section 1, historical operations resulted in storage facilities containing radium-bearing waste and other areas with radium contamination at the Umicore Site in Olen. A proposal for remediating the storage facilities and contaminated areas has been developed (see Section 3) by FANC, ONDRAF/NIRAS, OVAM and Umicore. ONDRAF/NIRAS, FANC and SCK CEN provided information to the ARTEMIS Review Team on key aspects of the proposal.

Remediation will generate a large volume of radium-bearing waste. It was discussed how the radium-bearing waste would be segregated and the potential disposal routes for the various waste streams were described. Among other things, a shallow depth repository, to be sited on or near the Umicore site in Olen, was presented as a means for disposal of some of the radium-bearing waste. SCK CEN presented key results of a preliminary safety analysis that examined the feasibility of using shallow depth disposal.

The proposed potential segregation routes and estimated waste volumes for wastes generated by remediation can be summarized as follows. A large fraction of the radium-contaminated materials at the Umicore site in Olen are only lightly contaminated (circa 1,000,000 m^3). These

are identified as being suitable for disposal in hazardous waste facilities and will not be classified as radioactive waste arisings. Approximately 30,000 m^3 of the radium-contaminated materials are to be classified as radioactive waste suitable for disposal in the shallow depth facility mentioned above. Lastly, a very small fraction of the radium-bearing materials, estimated to be several thousand cubic metres, will be managed as category B radioactive waste.

Future arisings of radium-bearing wastes from the UMTRAP storage facility are included in the estimated volumes, although UMTRAP is not yet included in the remediation proposal.

ARTEMIS Observation

The radium-bearing radioactive waste generated at the Umicore site in Olen would be classified as NORM in the IAEA system of waste classification (GSG-1). The IAEA guidance applicable to remediation of the site in Olen is GSG-15; the IAEA guidance applicable to management of NORM residues is SSG-60. In planning for remediation, the counterparts have made extensive use of waste segregation and the process of specific clearance to greatly reduce the amount of materials that need to be managed as radioactive waste, and they have done systematic analysis to optimize the routes for radioactive waste disposal. Their approach is consistent with IAEA guidance that has only recently been published (GSG-15 and SSG-60). In IAEA Member States there have been few applications of this guidance for NORM residues that are as systematic and broad in scope as the Belgian proposal.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *Plans for remediation of the Olen site indicate that, by volume, less than 5% of the Ra-226 residues at the Olen site will need to be managed as radioactive waste.*	
(1)	**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."*
(2)	**BASIS: GSR Part 5 Requirement 8 states that** *"All radioactive waste shall be identified and controlled. Radioactive waste arisings shall be kept to the minimum practicable."*
(3)	**BASIS: GSG-15 (Rev. 1), para. 9.16 states that** *"Segregation of residual materials on the basis of characterization data is particularly important for maximizing the amount of material that can be reused or recycled, or disposed of in landfill sites. This then minimizes the volume of material to be managed as radioactive waste and helps to identify appropriate management options* […]*."*
GP2	**Good Practice: The proposed approach for remediation of the radium-contaminated Umicore site in Olen is a very effective means for waste minimization.**

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

The IRRS mission 2023 concluded that Belgium has an established legal framework for radiation protection and nuclear safety and security. All existing waste management facilities have current licences, and their safety has been reviewed and assessment by FANC. Therefore the ARTEMIS Review Team focused on the disposal safety demonstration.

Belgian position

Belgium has a wide range of radioactive waste for which it needs to find disposal solutions. The current safety case position for each waste group is summarised below.

Category A Waste (low-level waste)

ONDRAF/NIRAS first requested a licence for the near surface disposal facility in Dessel in 2013. The safety case for this facility was submitted in February 2019. ONDRAF/NIRAS was hoping to receive authorisation mid-2020 for first waste emplacement in 2024, but this decision was delayed and the Government has only recently authorised the near surface disposal facility at Dessel. For the time-being there is "centralised safe management" of category A waste at Dessel.

A clear safety concept for near surface disposal was presented in which safety functions are assigned either a main (M) role or contributing (C) role, depending on the importance of the safety function and the extent to which they are well known and demonstrated. C-role safety functions have no linked design requirement, may be subject to high uncertainty, and are not essential to safety. It was also explained that a safety function can change from an M-role to a C-role over time, for example the infiltration layerbarrier in the near surface disposal concept is M-role for the first 1000 years when it is required to divert water away from the wastelimit water infiltration in the modules but becomes a C-role safety function at later times as it is likely to degrade.

This leads to three safety classes:

1. Safety Class (SC) – M-role for one or more safety functions, e.g. impervious top slab;
2. Safety Significant (SS) – C-role for one or more safety functions (no M), e.g. GCL in infiltration barrier;
3. Safety Relevant (SR) – important but not necessary, e.g. standard power supply.

Quality control is higher for the higher safety classification safety functions (termed QC1 to QC3). Safety functions providing mechanical support will be at least QC2, e.g. the concrete pedestals supporting the steel roof.

Category B&C waste (long-lived and heat-emitting waste)

In 2018, ONDRAF/NIRAS proposed a national policy for the long-term management of category B&C waste. This proposal was submitted to an SEA procedure in 2020, including a consultation of the institutional actors and the public between April and June 2020. Based on the outcomes of this procedure, ONDRAF/NIRAS submitted a revised policy proposal for the deep geological disposal of category B&C waste through a participative and reversible decisional process. After considering the advice from FANC, this revised proposal was adopted

by the Royal Decree of 28 October 2022, thereby establishing the first element of the national policy on the long-term management of category B&C waste.

The safety concept for B&C waste is more conceptual than for category A waste, but the safety concept is still an integrated description of the major safety functions with the systems, structures and components (SSC): in this case assigned M for main and S for supporting safety roles. S-role safety functions have no quantified design requirement but provide a qualitative supporting safety argument.

The last published Belgian Safety Assessment and Feasibility Report for category B&C waste is SAFIR 2 (published 2001), produced at the "methodological" stage to demonstrate feasibility of disposal of category B&C waste in poorly-indurated clay formations (Boom clay) with an overlying aquifer, with a limited consideration of Ypresian clay as an alternative host rock. This assessment assumed waste packaged in a 0.5cm thick primary stainless steel waste container, with a 3cm thick stainless steel overpack placed in a 1cm thick stainless steel disposal tube in a concrete-lined disposal gallery, backfilled with hydrated bentonite / sand and graphite. The SAFIR 2 assessment focuses on the normal evolution scenario in the reference Boom clay host rock, with a partial assessment of 8 alternative evolution scenarios (in which one or more of the safety barriers (EBS, host rock, aquifer) are assumed to be by-passed). Calculations were primarily deterministic using best estimate values, supplemented with stochastic calculations for parameter uncertainty sensitivity analysis.

A "Waste Plan" was produced in 2009 and submitted to the Government in 2010, seeking a decision in principle for geological disposal in poorly indurated clays (preferably Boom Clay). However, there was no decision, instead FANC told ONDRAF/NIRAS to investigate other host rocks. There was no further progress in policy decision until 2022, when a policy decision for geological disposal was made, but still no clear decision regarding the preferred host rock.

Nevertheless, ONDRAF/NIRAS continued work on disposal concept design, guided by the outcomes of the SAFIR 2 peer review, which acknowledged the role of the Boom Clay in providing safety, but recommended seeking more credit from the Engineered Barrier System. This led to the development of the carbon steel cement-lined super-container for category C waste. For category B waste the disposal concept is a concrete monolith.

Although there is no updated published geological disposal safety assessment, ONDRAF/NIRAS has continued to develop its safety assessment approach and is currently developing "a methodological and non-decisional Safety case (SFC 1)" with a reference option of a geological disposal facility for category B&C waste in Boom Clay or Ypresian clays at depths of 200m to 600m. This is planned for delivery in 2025.

Spent Nuclear Fuel

With the exception of the Thetis Research Reactor fuel, no spent fuel has been designated for disposal in Belgium (see Section 1 of this report). However, spent fuel is included in the current methodological RD&D programme for high-level and long-lived waste, investigating the feasibility of a Belgian geological disposal facility (without pre-judging that such a solution would be implemented).

Radium-bearing Waste

SCK CEN conducted a preliminary safety assessment for a disposal facility specific to radium-bearing waste in 2023 at the site of arising, based on a concrete box with clay liner. This engineered barrier is judged to last for 1600 years, noting the aquifer host rock. After this

period, radionuclides are assumed to be released into the aquifer and assumed to enter the biosphere via a well drilled at 1 metre from the facility.

ARTEMIS observation

The ARTEMIS Review Team noted a high degree of understanding of the safety case requirements by ONDRAF/NIRAS for both near surface disposal and deep geological disposal facilities, recognising the needs for the safe disposal of the wide range of waste in the Belgian inventory.

It was clear that there have been methodological developments to address the recommendations made in the SAFIR 2 peer review, including the development of a graded approach for B&C category waste and the development of a conceptual super-container for category C waste. It was also clear that ONDRAF/NIRAS has taken good advantage of international collaboration and information exchange with overseas disposal agencies to develop its thinking around the safety case concept, for example as developed by the OECD-NEA Integration Group for the Safety Case (IGSC).

The ARTEMIS Review Team was impressed with the commitment of the ONDRAF/NIRAS staff members and the evident skills of the safety case team. Given the small team size, the ARTEMIS Review Team considers that the ONDRAF/NIRAS safety case team makes an exceptional contribution to international collaboration, leading and co-leading important international safety case groups, such as the OECD-NEA IGSC. This is of great value to ONDRAF/NIRAS as well as other countries through the exchange of technical knowledge and collaborative development of safety case understanding.

Given the high level of evident safety case expertise in ONDRAF/NIRAS, more progress since SAFIR 2 might be expected. The ARTEMIS Review Team observed that it is only political will that is limiting progress. Understanding, RD&D, staff competence (albeit in a small team) and an appropriate regulatory framework are all in place, but national policy is vague and needs to be strengthened to give more impetus to the disposal programme.

The ARTEMIS Review Team understands the rationale behind the “reversibility” requirement for all decisions, but this is not an optimal situation for advancing the disposal programme. Optimisation is a forward-looking principle and needs to consider the optimal way forward at each stage. Flexibility can still be maintained, by following an adaptive process, but it is recommended that clear policy steps to progress the disposal programme are taken (as discussed further in the ‘National policy’ Section). The perceived current indecision in Belgium is costing time and money.

The safety case is a vehicle to integrate and develop understanding and hence can support and guide policy. ONDRAF/NIRAS could be more ambitious with its safety case for category B&C waste and move beyond the purely methodological stage to synthesise the understanding of host rock performance. For example, in both the UK and Japan generic safety cases were produced using a stylised approach to examine the performance of a range of host rock types. These safety cases were then used to inform the subsequent site selection process.

ONDRAF/NIRAS noted that their safety case team is constrained by lack of staff resource. The ARTEMIS Review Team felt this was too few and recommend increasing the staff resource to enable greater progress towards disposal implementation and to facilitate the training and development of the next generation of staff, noting safety case skills are a scarce skill set and tend to need to be developed in-house which requires significant time and forward planning. It

is also important that any licence holder, such as ONDRAF/NIRAS, maintains and develops safety case competences in-house. This is discussed further under Section 7.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *Lack of clear policy is hampering progress with geological disposal. There is a limit to how far another generic safety case (i.e. after SFC 1, foreseen in 2025) can go without confirmation of the host rock.*	
(1)	**BASIS: SSR-5 Requirement 3 states that** *"The operator of a disposal facility for radioactive waste shall be responsible for its safety. The operator shall carry out safety assessment and develop and maintain a safety case, and shall carry out all the necessary activities for site selection and evaluation, design, construction, operation, closure and, if necessary, surveillance after closure, in accordance with national strategy, in compliance with the regulatory requirements and within the legal and regulatory infrastructure."*
R9	**Recommendation: ONDRAF/NIRAS should develop the next safety case for geological disposal based on a reference host rock and also assess the range of alternative host rocks (in a stylised approach) to support a future site selection process.**

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

The ARTEMIS Review Team considered the cost estimates for spent fuel and radioactive waste management and its financing, the adequacy of national arrangements for establishment and maintenance of appropriate funding mechanisms.

The ARTEMIS Review Team considered how funding provisions for spent fuel management and decommissioning and waste management fees take into account cost estimates based on the national inventory and its estimates on changes, regarding volume and type of the waste, final end states and disposal methods.

The ARTEMIS Review Team was provided with extensive advance reference material about the topic and during the mission was provided with detailed presentations about distribution of roles and responsibilities, cost estimation methods in place and measures for long term stability and value preservation of accumulated financial provisions. The ARTEMIS Review Team was informed about challenges related to Belgian national policy changes on nuclear power plants life-time limitation, nuclear phase-out and LTOs due to recent problems with electricity supply from neighbouring countries, high dependency on fossil fuels, the accelerated energy transition and geopolitical tensions.

Belgian position

The approach to financing the costs for activities related to managing the radioactive waste, decommissioning and spent fuel in Belgium National Programme is based on the “polluter pays” principle. The radioactive waste producers and the owners of spent fuel cover the costs of the management of these materials as long as they are not transferred to ONDRAF/NIRAS. This includes costs for storing, transporting and reprocessing spent fuel and collecting, sorting, processing, storing and transporting the radioactive waste, until it is transferred to ONDRAF/NIRAS.

The responsibilities for cost assessments methods are distributed among several entities in Belgium. These responsibilities are grouped according to three main activities as listed here and schematical depicted below:

- management of operational waste, spent fuel and decommissioning waste from NPP operation;
- management of operational waste and decommissioning waste from other nuclear actors; and
- storage and final disposal in near surface and geological repositories by ONDRAF/NIRAS.

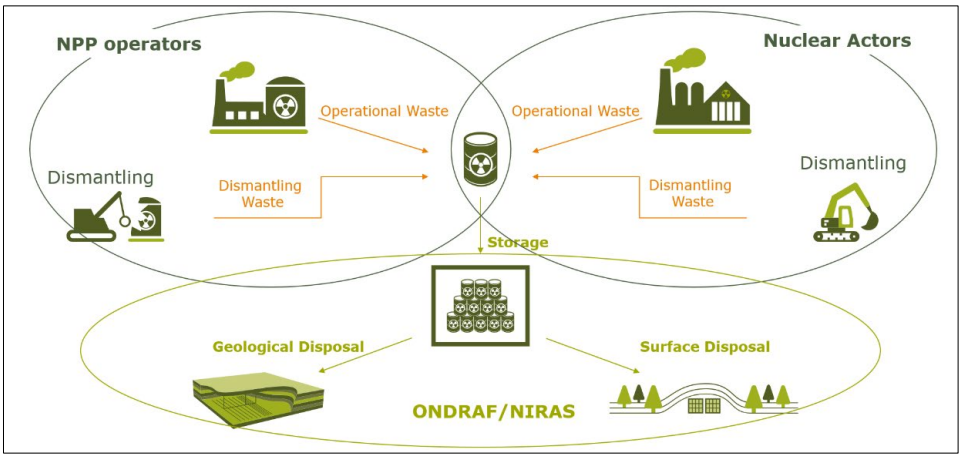

Fig. 6-1. Cost assessment responsibilities in Belgium (source: ONDRAF/NIRAS presentation)

Although there are many financially liable entities for radioactive waste and spent fuel management in Belgium, there are only two entities responsible for review and audit of financial nuclear liabilities, ONDRAF/NIRAS and the CNP. ONDRAF/NIRAS is responsible (by the Law of 8 August 1980) for establishing and maintaining inventory of the nuclear liabilities in Belgium. The CNP (established by the Law of 11 April 2003 and improved by the Law of 12 July 2022) is responsible for prudential control of adequacy and availability of the provisions for NPP decommissioning and spent fuel management.

The costs of radioactive waste management are financed through two sets of financing mechanisms. Firstly, there are the mechanisms set up by the NPP operators to finance their spent fuel and waste management activities, the decommissioning of their installations and the transfer of the waste to ONDRAF/NIRAS. Secondly, there are the financing mechanisms that ONDRAF/NIRAS has set up for the management, storage and disposal of the waste it accepts.

The CNP performs an audit of the nuclear provision of NPP operators every three years, based on ONDRAF/NIRAS recommendations.

Concerning the inventory of the nuclear liabilities in Belgium, ONDRAF/NIRAS evaluates the sufficiency of the provisions set up to cover the costs for radioactive waste management with the producers every five years. In addition, it evaluates the availability of the corresponding financial resources. The cost estimate of the radioactive waste and spent fuel activities in Belgium are published every five years by ONDRAF/NIRAS as an inventory report on nuclear liabilities (the fourth revision of report “Inventory of Nuclear Liabilities” was published in 2018 and is available online). This inventory is non-binding for the nuclear actors. The next revision of the report is in preparation and is expected to be available in 2024. The Inventory of Nuclear Liabilities report provides:

- a comparison between the cost estimated by the nuclear actors (when available) and cost estimated by ONDRAF/NIRAS;
- an analysis of the provisions and their funding mechanisms;
- and recommendations for the Ministers responsible for Economy and Energy.

The report on Inventory of Nuclear Liabilities includes cost estimates for all activities except management costs of future operational waste, including spent fuel that will be declared as waste in the future.

Synatom is responsible for management of spent fuel from NPPs, for development and implementation of spent fuel management programs, financial estimates, and instruments for

providing provisions for spent fuel management and for dismantling of nuclear power plants. Responsibility for decommissioning of NPPs resides with Electrabel.

The last inventory report that ONDRAF/NIRAS submitted to its supervisory ministers in 2018 concluded that the total estimated costs are sufficiently covered by provisions, with a total coverage rate of 99% (taking into account both the existing and planned provisions). This percentage, however, must be taken with caution, in particular because of the many uncertainties that affect the cost estimates and the sometimes rapid evolutions of the financial markets and long-term interest rates. The cost estimates contain contingencies based on a risk assessment for each cost item. Sensitivity analyses have been performed to evaluate the impact of changes to parameters such as the inflation rate, rate of financial return on the assets, period for instalment collection, etc.

ARTEMIS observation

The ARTEMIS Review Team notes that Belgium places a high level of importance on ensuring there are sufficient financial provisions in funds for management of its radioactive waste and spent fuel, disposal, and closure of the surface and geological repositories. 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 radioactive waste and spent fuel.

Cost estimate methods have been developed for the safe management of radioactive waste and spent fuel. These estimates have been developed using deterministic and probabilistic methods recommended in international studies. The ARTEMIS Review Team noted the high level of effort that is devoted to ensuring that costs are as accurate as possible, through benchmarking with similar projects, sensitivity studies and regular updates.

The system of nuclear provisions in Belgium is complex as it has evolved over many years. There are many waste producers not all owned and directly controlled by the Federal Government and many of the owners are also privately owned or owned by foreign investors. Audits and reviews of provisions established for radioactive waste and spent fuel management represent an important part of this system in Belgium as depicted in the figure below presenting a simplified map of stakeholders involved in cost estimates and financing of radioactive waste and spent fuel management.

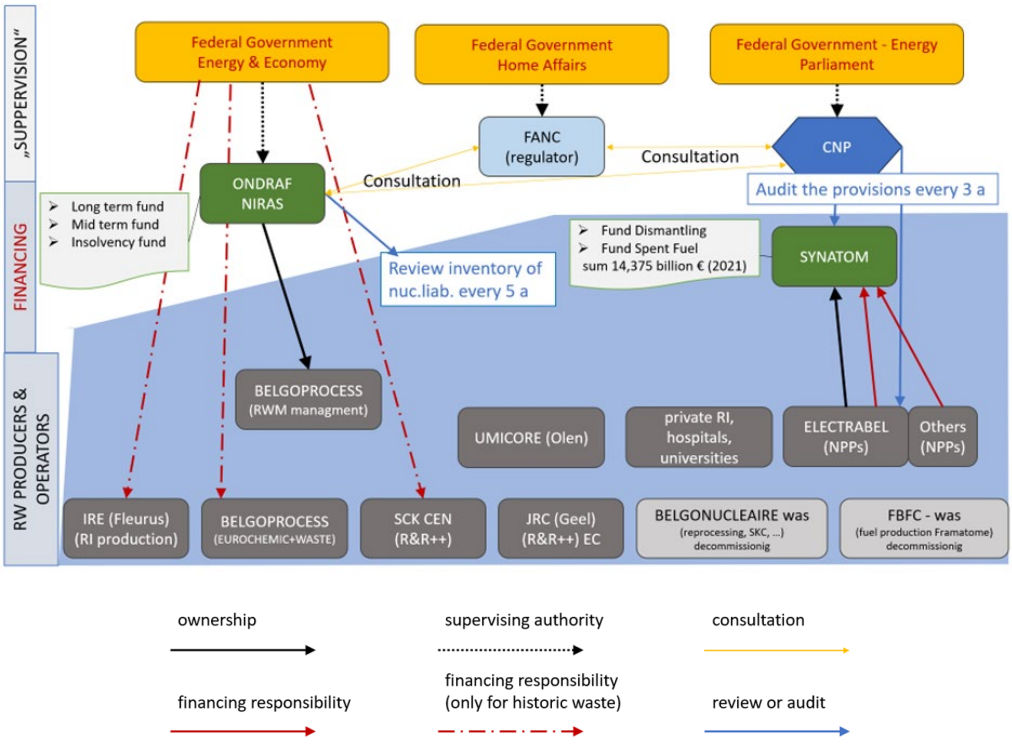

Fig. 6-2. Stakeholder map depicting cost estimates and financing of radioactive waste and spent fuel management system in Belgium

The ARTEMIS Review Team acknowledges that Belgium counterparts prepared transparent and comprehensive presentation materials describing established and complex mechanisms to fund radioactive waste management, spent fuel and decommissioning liabilities in Belgium. Presentations included enough data for complete answers to the ARTEMIS Review Team questions.

The ARTEMIS Review Team was informed about provisions in place to secure long-term stability and real value of funding through review and audit mechanism by individual actors in nuclear provisions management framework in Belgium. Financial parameters used within currently established system for the calculation of nuclear provisions applied by individual actors were found not to be always coherent. The system could be enhanced through harmonization and justification of financial parameters used by all relevant nuclear actors in the determination of nuclear provisions (e.g. time frames, discount rates, …).

Presented data include current estimates on the total overnight cost for geological disposal based on a reference host rock to support a future site selection process to €12 billion including contingencies, estimated uncertainties, risks, and opportunities. In this estimation base costs amount to €7.6 billion.

The ARTEMIS Review Team found that the final costs for disposal of category B&C waste includes significant uncertainties and risk. The contribution of estimated uncertainties, risks and opportunities to total value of category B&C disposal represents almost 60% of the base costs, which is very high for the current phase of the project. A significant reason for this uncertainty is the current undecided national policy on the end-point solution for category B&C disposal but also due to the specific methodology used to take into account the operational safety requirement that was integrated as a risk in the costing. More detailed studies of

operational safety are on-going and will be included in the base cost, which will reduce the level of the contingencies.

Moreover, this uncertainty represents an undue financial burden on future generations and could be reduced by political decisions on elimination of less developed scenarios.

According to IAEA safety fundamentals (SF-1, Principle 7, para. 3.29) radioactive waste must be managed in a such a way as to avoid imposing an undue burden on future generations, including undue financial burdens. An internationally recognised practice to reduce uncertainties and costs (IAEA NW-G-1.1, para. 11.3) is the elimination of less developed or otherwise less favourable technical solutions for waste disposal that, for various reasons, are unsuitable.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *Financial parameters used within nuclear management framework for the calculation of nuclear provisions applied by individual actors are not always coherent.*	
(1)	**BASIS: GSR Part 1 (Rev. 1) Requirement 10, para. 2.33 states that** *"Appropriate financial provision shall be made for:[…]* *(b) Management of radioactive waste, including its storage and disposal."*
S2	**Suggestion: The Government should consider enhancing the harmonization and justification of financial parameters to be used by all relevant nuclear actors in the determination of nuclear provisions (time frames, discount rates, inflation rates).**

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

Legal Provisions

Belgian position

There are provisions within the regulatory framework for capacity building among the various parties responsible for radioactive waste and spent fuel management.

ONDRAF/NIRAS was created by the Law of 8 August 1980 and is the responsible organization for managing radioactive waste as well as the only authorized entity to dispose of the waste. Its subsidiary, Belgoprocess, stores, treats, and conditions waste that has been transferred to ONDRAF/NIRAS. There is a provision, in the 1980 law, that requires licence holders to provide education and training for its personnel as well undertake research and development activities to comply with the National Programme for management of spent fuel and radioactive waste. Per the Royal Decree of 30 March 1981, ONDRAF/NIRAS must determine the appropriate research and development to fulfil its mission.

FANC is the independent safety authority in Belgium and was established by the law of 15 April 1994. The provisions for basic safety principles of radiation protection are laid out in the Royal Decree of 20 July 2001 (GRR-2001). GRR-2001 provides the safety requirements for nuclear facilities depending on the class of the facility. The Royal Decree of 30 November 2011 (SNRI-2011) provides the safety requirements for nuclear facilities and activities. It also requires licensees to have staff that meet certain skill and expertise requirements and that their subcontractors have the necessary skill and work according to the appropriate standards. Article 5 of the Law of June 2014 requires nuclear licensees provide for education, training, and research to develop and maintain the necessary competencies.

ARTEMIS observation

The ARTEMIS Review Team noted there are legal provisions for ensuring parties involved with waste management and spent fuel have appropriate research and development and sufficient training to maintain safety.

National Survey

Belgian position

In Belgium, there is no provision for conducting a national survey of nuclear competencies. FANC has recently started to analyse competencies within its organization. This effort was addressed in the IRRS report. ONDRAF/NIRAS counterparts indicated they have an established staffing scan, typically completed on a five-year timeframe but updated annually, for resource needs and skill gaps.

ARTEMIS observation

Without a national provision, agencies conduct the nuclear competence survey individually. The ARTEMIS Review Team notes it may be useful for Belgium to consider a competency review to identify resource needs and skill gaps and then identify solutions on a national scale. As Belgium moves through the phases of licensing, construction, operation, and decommissioning of its power plants and disposal facilities, different skill sets will be needed.

A national survey would identify those needed skills in advance so that timely measures can be taken to establish those needed competencies.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *FANC and ONDRAF/NIRAS individually perform competency surveys for their agencies. However, it may be useful for Belgium to have a strategy for maintaining radioactive waste management competencies on a national level to identify cross-cutting needs in resources or skills and potential means to address them.*	
(1)	**BASIS: GSR Part 3 Requirement 4, para 2.44, states that** *"The relevant principal parties and other parties having specified responsibilities in relation to protection and safety shall ensure that all personnel engaged in activities relevant to protection and safety have appropriate education, training and qualification so that they understand their responsibilities and can perform their duties competently, with appropriate judgement and in accordance with procedures."*
S4	**Suggestion: The Government should consider developing and maintaining a national skills strategy for radioactive waste management.**

Competence, organization, and staffing

Belgian position

The primary entities for the management of radioactive waste and spent fuel are: FANC as the nuclear safety regulator with Bel V providing technical support and ONDRAF/NIRAS and their subsidiary Belgoprocess as the waste management organization. Other organizations involved include SCK CEN as the manager of spent fuel from the research reactors and Synatom who has responsibility for the spent fuel at the NPPs.

FANC

The regulatory framework for competence for safety at FANC was evaluated as part of the Belgium IRRS mission earlier this year (2023).

ONDRAF/NIRAS

ONDRAF/NIRAS has about 200 employees, including external contractors, that manage a wide range of waste streams and a significant inventory. By 2030, they are projected to need a staff of approximately of 275. They have deep technical capacity, a well-regarded international collaboration network, and a well-established research and development program. ONDRAF/NIRAS counterparts acknowledged that future skill gaps are a risk due to among other things the uncertainty around the future of nuclear power in Belgium, small pool of resources in the nuclear field, and an increasing age of its current staff.

ARTEMIS observation

The ARTEMIS Review Team noted the impact of limited financial and human resources at ONDRAF/NIRAS considering the multiple waste streams and large inventory. One notable example is the small team (4 people) working part-time to support the safety case for category B&C disposal.

ONDRAF/NIRAS noted they must often prioritize work and rely on international collaborations to mitigate the resource constraints. The ARTEMIS Review Team noted that ONDRAF/NIRAS needs additional financial and human resources to maintain sufficient staff and competency to manage their current and expected workload. Further, as has been noted elsewhere in this report and the IRRS report, while ONDRAF/NIRAS is meeting its mission, the Government needs to make timely policy decisions to ensure ONDRAF/NIRAS can appropriately plan and prepare resources. Otherwise, as mentioned in Section 2 of this report, ONDRAF/NIRAS's limited staffing may be stretched too far by evaluating management options that are not feasible for the Belgian inventory.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *ONDRAF/NIRAS needs additional financial resources to ensure they can fulfil their mission. They currently do not have sufficient staff to address the numerous waste management and disposal issues.*	
(1)	**BASIS: GSR Part 1 (Rev. 1) Requirement 10, para. 2.33 states that** *"Appropriate financial provision shall be made for:[…]* *(b) Management of radioactive waste, including its storage and disposal."*
(2)	**BASIS: GSR Part 1 (Rev. 1) para. 2.34 states that** *"As an essential element of the national policy and strategy for safety, the necessary professional training for maintaining the competence of a sufficient number of suitably qualified and experienced staff shall be made available."*
(3)	**BASIS: GSR Part 1 (Rev. 1) Requirement 11 states that** *"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."*
R10	**Recommendation: The Government should ensure adequate financial and human resources will be available for ONDRAF/NIRAS to fulfil its mission.**

Further, finding staff with the specific technical competency to prepare safety cases is difficult and not easily acquired. Therefore, the ARTEMIS Review Team noted that ONDRAF/NIRAS needs the resources, and time, to train existing staff from within ONDRAF/NIRAS and hire and train additional staff if needed. This issue is discussed in more detail in the 'Safety Case' section.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *ONDRAF/NIRAS appears to be constrained by lack of staff resource. Whilst safety assessment calculations may be subcontracted (e.g. to SCK CEN), it is essential that ONDRAF/NIRAS develops/maintains sufficient in-house capability to "own" the safety case and develop / pass-on safety case expertise to the next generation. Safety case skills (particularly for geological post-closure safety cases) are a scarce skill set, not easily recruited and tend to have to be developed internally, which takes time and forward-planning.*	
(1)	**BASIS: GSR Part 2 Requirement 9, states that** *"Senior management shall determine the competences and resources necessary to carry out the activities of the organization safely and shall provide them."*
(2)	**BASIS: GSR Part 4 Requirement 5, states that** *"The first stage of carrying out the safety assessment shall be to ensure that the necessary resources, information, data, analytical tools as well as safety criteria are identified and are available."*
(3)	**BASIS: SSG-23 para. 4.95 states that** *"The regulatory body and the operator are required to put in place an appropriate management system to ensure the quality of all safety related work and activities. The following aspects should be taken into account in developing an appropriate management system which should be designed to provide an adequate basis for the development and review of the safety case: [...] The need to document and enhance the qualifications, competence and credibility of those conducting and reviewing the safety case and supporting assessment, for example, through the provision of training programmes and through their participation in international projects."*
S3	**Suggestion: ONDRAF/NIRAS should consider exploring means to increase in-house staff resource in the safety case area, including actively recruiting and developing younger team members.**

Research and International Collaboration to Support Capacity Building

Belgian position

ONDRAF/NIRAS has numerous ongoing research activities related to waste disposal and are discussed in more detail in the 'Technical Solutions' section. Other entities involved with nuclear waste management – FANC/Bel V, SCK CEN, Belgoprocess, Synatom – also conduct research and development activities. ONDRAF/NIRAS, FANC, Bel V, and Belgoprocess have been actively engaged for years in various international engagements with NEA, IAEA, EU, and other organizations.

In 2020, ONDRAF/NIRAS signed a public-public agreement with SCK CEN regarding collaboration on research and development activities. This agreement has allowed both organizations to create a shared plan for research priorities on a 5-year horizon.

ARTEMIS observation

The ARTEMIS Review Team notes that ONDRAF/NIRAS has both a well-established research and development program as well as significant international networks and collaborations. These activities and collaborations have served to bolster ONDRAF/NIRAS when staffing resources are constrained.

The ARTEMIS Review Team notes that the public-public agreement between ONDRAF/NIRAS and SCK CEN is a good performance in synchronizing research needs and tracking them from the research phase to implementation, aligning priorities, providing knowledge transfer, and maintaining competencies on challenging technical issues.

Education, Training, and Knowledge Management

Belgian position

ONDRAF/NIRAS and Belgoprocess have established programmes in place to provide training and staff are encouraged to attend. Belgoprocess' qualification is time-limited and must be renewed. FANC and Bel V have requirements for health physics experts and require inspections by Bel V to be carried out by certified health physics experts. FANC's regulations require licensees to meet certain qualifications, thus ONDRAF/NIRAS must demonstrate how their staff meet those qualifications in the licensing documents for Class I disposal facilities.

Within Belgium, there are several resources for providing education in the nuclear field. The Belgium Nuclear Higher Education Network (BNEN), a collection of multiple Belgian universities and SCK CEN, provides graduate level courses as well as continuing education training. The University of Hasselt offers a post-graduate degree for Radiation Protection, in a one-year programme. The degree meets the requirements of GRR-2001 for being certified as a health physics expert. The SCK Academy is another joint educational venture providing advanced degrees and continuing education in the nuclear field.

ONDRAF/NIRAS has numerous knowledge management efforts underway. One example includes their participation in an NEA project on records management. They are also currently developing a new system to ensure waste management documentation is maintained (BASE). The system includes new IT tools and a centralized database platform to provide a 'single point of truth' for the disposal conformity files.

The preservation of nuclear knowledge and memory is an important concept in Belgium, especially with respect to disposal. As part of the licensing of the near surface disposal facility in Dessel, the local community requested several conditions. As a result, a large community centre, Tabloo, was constructed at the disposal site that serves not only as community space but also to educate. ONDRAF/NIRAS also has a collaboration (LIBRA) with Thomas More University College and the University of Leuven, to provide resources within the local region to introduce and educate students about radioactive waste. Several means are used to reach the public, such as games, lectures, special projects. Tabloo will be used as a benchmark for long-term participation. ONDRAF/NIRAS staff also shared a copy of the book "The Story of Disposal: Civic Participation, the New Normal?".

ARTEMIS observation

ONDRAF/NIRAS and Belgoprocess have training requirements in place and provide the opportunity for continued learning for their staff. The ARTEMIS Review Team noted that ONDRAF/NIRAS employees must meet different levels of competencies depending on the project and their role (e.g., operator, regulator). The training protocols and requirements for FANC and Bel V were addressed in the IRRS Report.

The ARTEMIS Review Team considered the level of effort and passion shown by ONDRAF/NIRAS in support of the Tabloo communication centre as a good performance. Besides creating a beautiful building, ONDRAF/NIRAS has actively worked, in partnerships with other entities, to create thoughtful ways to engage with the public.

The ARTEMIS Review Team notes that ONDRAF/NIRAS has a comprehensive approach to knowledge management both internally (with its staff) and externally (with local, national, and international organizations). ONDRAF/NIRAS, however, would benefit from additional financial and human resources to support these efforts.

APPENDIX A: TERMS OF REFERENCE

Terms of Reference

1. Introduction

The Kingdom of Belgium demanded on 17 March 2021 the IAEA to organize an Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS) mission, taking notion of the results of the Integrated Regulatory Review Service (IRRS) mission to be conducted in the Kingdom of Belgium prior to the ARTEMIS mission.

Belgium noted the ARTEMIS review will contribute to satisfy its obligations under Article 14(3) of the European 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 that request, the ARTEMIS review will be carried out from 3 to 13 December 2023 in a coordinated manner as a back-to-back mission with the IRRS mission, scheduled from 19 to 30 June 2023. The given ARTEMIS review will be organized in the IAEA by the Department of Nuclear Safety and Security and the Department of Nuclear Energy.

2. Objective

The ARTEMIS review, performed by an international peer review team selected by the IAEA, will provide an independent international evaluation of Belgium's radioactive waste and spent fuel management programme, based on the relevant IAEA Safety Standards and proven international practices.

3. Scope

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

Belgium indicated its interest in discussing the specific topic of the policy of spent fuel management (research reactors and commercial plants) during the review mission.

The outcomes from the 2023 IRRS mission to Belgium will be taken into account, where relevant and 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 hosted before an ARTEMIS mission. These guidelines do not substitute IRRS and ARTEMIS guidelines, respectively, but supplement them with the specific provisions that need to be taken into account while conducting back-to-back missions.

4. Basis for the review

The ARTEMIS review will be based on the relevant IAEA Safety Standards and proven international practice and experiences, following the guidelines of the ARTEMIS review service.

5. Reference material

The review will cover all documentation submitted by the National Counterpart for the considered 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 mission, the National Counterpart will include in the reference material the sections of the IRRS Reference material relevant to the ARTEMIS mission (specific parts of the 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.

It must be noted that for IRRS-ARTEMIS back-to-back missions, identified overlaps will be addressed only by one mission, either IRRS or ARTEMIS, depending on the scope and nature of each one of them. As such, 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 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 the **Annex 1** (such a 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.

6. Modus operandi

The working language of the mission will be English.

The National Counterpart is ONDRAF-NIRAS. The National Counterpart Liaison Officer for the review is Peter De Preter, Advisor long-term management in ONDRAF/NIRAS.

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

- Self-assessment: questionnaire was made available to Belgium as of **March 2022**.
- Preparatory Meeting: **7 June 2023 (WebEx meeting)**.
- The reference material (in English) and the results of the self-assessment questionnaire will be provided to the IAEA as soon as they are available and not later than **3 October 2023**.
- Questions based on the preliminary analysis of the reference material and the self-assessment results will be provided by the review team by **17 November 2023**.
- Peer review mission: **3 to 13 December 2023 (10 days) in Brussels:**

- Sunday: arrival of experts and their meeting.
- Monday to Thursday: interviews/exchange/discussion with Counterparts on the basis of preliminary analysis and drafting of recommendations and suggestions.
- Thursday to Friday: drafting of the report - finalization of recommendations and suggestions - delivery of recommendations/suggestions/good practices – fact checking by Counterparts.
- Friday to Saturday: discussions of recommendations and suggestions with the Counterparts - drafting of the report (Review Team).
- Sunday: delivery of the report to the Counterparts
- Monday: fact checking of draft report by Counterparts - internal reflection of comments by Review Team - discussions with the Counterparts.
- Tuesday: discussions with the Counterparts on the draft report and finalization of draft report by Review Team.
- Wednesday: delivery of final draft report – exit meeting – closure.

7. International peer review team

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

- Seven qualified and recognized international experts from government authorities, regulatory bodies, waste management organizations, and technical support organizations with experience in the responsible and safe management of radioactive waste and spent fuel. Among the experts, the IAEA will identify a common expert with enough knowledge and experience in the regulatory field as well as in the Radioactive Waste and Spent Nuclear Fuel Management, Decommissioning and Remediation field to successfully participate in both the Belgium IRRS and ARTEMIS missions in respectively June and December 2023.
- Two IAEA staff, to coordinate the mission. The Coordinator of the ARTEMIS review is Ms Mathilde Prevost from the Waste and Environmental Safety Section of the Department of Nuclear Safety and Security. The deputy coordinator is Mr Vladimir Michal from the Waste Technology Section of the Department of Nuclear Energy.
- One IAEA staff for administrative support.
- A senior member of IAEA staff from the Department of Nuclear Safety and Security will oversee the closure of the review meeting.

The peer review team will be led by a Team Leader, assisted by a Deputy Team Leader, comprising from the review team as defined in the ARTEMIS guidelines. The Team Leader will be Jussi Heinonen, STUK, Finland. The IAEA will inform the National Counterpart regarding the composition of the proposed review team prior to submission of reference material.

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

8. Reporting

The findings of the peer review will be documented in a final report that will summarise the proceedings 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 organization or Member State or the IAEA.

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

9. Funding of the peer review

The peer review will be funded by the Kingdom of Belgium. 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. The Kingdom of Belgium is aware that the review cost includes 7% programme support costs.

If the actual cost of the ARTEMIS review exceeds the estimated voluntary contribution, the Kingdom of Belgium 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 Belgium through the Counterpart.

These Terms of Reference have been agreed between the IAEA and ONDRAF/NIRAS as National Counterpart during the preparatory meeting held on-line on 28 June 2023.

Annex 1: List of reference material

- Responses to the ARTEMIS Self-assessment Questionnaire
- Regulations and legislation (laws and royal decrees on radioactive waste management), including National Policies
- National Programme for SNF and RAW management
- 7th Joint Convention National Report
- 3rd National Report under EC Directive 2011/70/Euratom
- Specific parts of IRRS Self-assessment report dealing with radioactive waste and spent fuel management
- IRRS mission Report
- Plan of action for the management of radioactive radium-bearing waste
- Reference scenario ONDRAF/NIRAS

APPENDIX B: MISSION PROGRAMME

Time	Sun, 3 Dec	Mon, 4 Dec	Tue, 5 Dec	Wed, 6 Dec	Thurs, 7 Dec	Fri, 8 Dec	Sat, 9 Dec	Sun, 10 Dec	Mon, 11 Dec	Tue 12 Dec	Wed 13 Dec
9h00 – 10h00	Arrival of Team Members	**Opening** General presentation Feedback on IRRS findings (legal and regulatory aspects of RW and SF mgt)	Inventory	Safety case and safety assessment	Capacity building	**Presentation of Suggestions and Recommendations to Counterparts**	Drafting of the report	**Draft report to be sent to the Counterparts** ***by 13h00***	Counterparts review the draft report	**Internal reflection of comments**	Delivery of final draft report **EXIT MEETING**
10h00 - 12h00		National Policy and Framework								**Discussions with the Counterparts on the draft report**	
12h00 - 13h00		Lunch	Lunch	Lunch	Lunch	Lunch		Lunch		Lunch	
13h00 - 16h00		National Strategy	Concepts, Plans and technical solutions	Cost estimates and financing	Session reserved for further discussions if required/ drafting of the report	**Social event** Drafting of the report		Counterparts review the draft report		Finalising draft report	Departure of Team Members
16h30 - 17h30	18h00 Artemis team meeting	Team meeting	Team meeting	Team meeting	**Finalization of Suggestions and Recommendations**						
		Drafting of the report	Drafting of the report	Drafting of the report							

APPENDIX C: RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES

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 formulate a well-defined policy decision regarding spent fuel management options, specifically addressing the choice between reprocessing and direct disposal. Policy or policies should encompass all nuclear power plants and research reactors.
		R2	The Government should establish, without undue delay, a comprehensive geological disposal policy for the management of category B&C waste including all the necessary milestones and initiate as soon as possible the site selection process.
		R3	The Government should establish a policy for management of radium-bearing waste in a timely manner to enable the effective remediation of the existing exposure situation.
		R4	The Government should complete the process of establishing safety requirements and a licensing scheme specific to disposal facilities.

Area		R:Recommendations S: Suggestions G: Good Practices	Recommendations, Suggestions or Good Practices
2.	NATIONAL STRATEGY FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT	R5	The Government should ensure that waste streams that are non-conforming, have no clear end point or are waiting for a policy decision are included in the National Programme with their proposed associated management options.
		R6	ONDRAF/NIRAS should focus its main resources on solutions that are technically feasible and internationally acknowledged for the long-term management of category B&C waste of the Belgian inventory.
3.	INVENTORY OF SPENT FUEL AND RADIOACTIVE WASTE	R7	The Government should act upon an ONDRAF/NIRAS' proposal to revise the legal framework to incorporate additional provisions to allow the definition and the review of the required information for the reference programmes of the waste producers.
		R8	ONDRAF/NIRAS should include in the national inventory a category for radium-bearing waste from past industrial activities to make the radioactive waste inventory complete.
4.	CONCEPTS, PLANS AND TECHNICAL SOLUTIONS FOR SPENT FUEL AND RADIOACTIVE WASTE MANAGEMENT	GP1	The centralized management of the radioactive waste by Belgoprocess prior to disposal contributes to the minimization of waste and helps to optimize the interdependencies of the different waste management steps.
		S1	SCK CEN should consider extending its international cooperation through the EDF/DP2D Graphite Reactor Decommissioning Demonstrator, as this is a particularly timely opportunity.

Area		R:Recommendations S: Suggestions G: Good Practices	Recommendations, Suggestions or Good Practices
		GP2	The proposed approach for remediation of the radium-contaminated Umicore site in Olen is a very effective means for waste minimization.
5.	SAFETY CASE AND SAFETY ASSESSMENT OF RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT ACTIVITIES AND FACILITIES	R9	ONDRAF/NIRAS should develop the next safety case for geological disposal based on a reference host rock and also assess the range of alternative host rocks (in a stylised approach) to support a future site selection process.
6.	COST ESTIMATES AND FINANCING OF RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT	S2	The Government should consider enhancing the harmonization and justification of financial parameters to be used by all relevant nuclear actors in the determination of nuclear provisions (time frames, discount rates, inflation rates).
7.	CAPACITY BUILDING FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT – EXPERTISE,	R10	The Government should ensure adequate financial and human resources will be available for ONDRAF/NIRAS to fulfil its mission.
		S3	ONDRAF/NIRAS should consider exploring means to increase in-house staff resource in the safety case area, including actively recruiting and developing younger team members.

Area		R:Recommendations S: Suggestions G: Good Practices	Recommendations, Suggestions or Good Practices
	TRAINING AND SKILLS	**S4**	**The Government should consider developing and maintaining a national skills strategy for radioactive waste management.**

APPENDIX D: LIST OF ACRONYMS USED IN THE TEXT

ARTEMIS	Integrated Review Service for Radioactive Waste and Spent Fuel, Decommissioning and Remediation
ARM	Advance Reference Material
CNP	the Commission for Nuclear Provisions
FANC	the Federal Agency for Nuclear Control
IAEA	International Atomic Energy Agency
LLW	low-level waste
ILW	Intermediate-Level Waste
IRRS	Integrated Regulatory Review Service
HLW	High-Level Waste
ONDRAF/NIRAS	the Belgian National Agency for Radioactive Waste and enriched Fissile Material
RD&D	Research, Development, and Demonstration
SCK CEN	the Belgian Nuclear Research Centre
VLLW	very low- level waste
WAC	the waste acceptance criteria

APPENDIX E: IAEA REFERENCE MATERIAL USED FOR THE REVIEW

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[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).

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[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. SSR-4, IAEA, Vienna (2017).

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[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, INFCIRC/546, IAEA, Vienna (1997).

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Safety and Security Glossary, IAEA, Vienna (2022 interim edition).

[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).