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

MISSION

TO

GERMANY

COLOGNE, GERMANY

22 September to 4 October 2019

DEPARTMENT OF NUCLEAR SAFETY AND SECURITY
DEPARTMENT OF NUCLEAR ENERGY

ARTEMIS

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

REPORT OF THE

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

TO

GERMANY

Mission dates: *22 September to 4 October 2019*
Location: *Cologne, Germany*
Organized by: *IAEA*

ARTEMIS REVIEW TEAM	
Mr Patrick MAJERUS	ARTEMIS Team Leader (Luxembourg)
Mr Michael EGAN	Reviewer (Sweden)
Mr Patrice FRANÇOIS	Reviewer (France)
Mr Paolo GUI	Reviewer (Italy)
Mr Kai HÄMÄLÄINEN	Reviewer (Finland)
Mr Andrew PARKES	Reviewer (UK)
Mr Paul STANDRING	Reviewer (UK)
Mr John TAPPERT	Reviewer (USA)
Mr David BENNETT	IAEA Team Coordinator
Mr Patrick O'SULLIVAN	IAEA Deputy Team Coordinator
Ms Kristina NUSSBAUM	IAEA Admin. Assistant

IAEA-2019

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

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EXECUTIVE SUMMARY

At the request of the German Government, specifically the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), an IAEA Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS) mission to Germany was undertaken from 22 September to 4 October 2019. The objective of the ARTEMIS mission was to provide an independent international evaluation of Germany's National Programme for the responsible and safe management of spent fuel and radioactive waste (National Programme).

The mission was requested by the Government of Germany, specifically the Bundesministerium für Umwelt, Naturschutz und Nukleare Sicherheit, BMU (the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety), with the participation of the Gesellschaft für Zwischenlagerung mbH, BGZ (the Federal Company for Radioactive Waste Storage), the Bundesgesellschaft für Endlagerung mbH, BGE (the Federal Company for Radioactive Waste Disposal), the Bundesamt für kerntechnische Entsorgungssicherheit, BfE (the Federal Office for the Safety of Nuclear Waste Management), the Ministerium für Umwelt, Klima und Energiewirtschaft des Landes Baden-Württemberg, UMBW (the Ministry of the Environment, Climate Protection and the Energy Sector Baden-Württemberg), the Niedersächsisches Ministerium für Umwelt, Energie und Klimaschutz (the Lower Saxony Ministry of the Environment, Energy and Climate Protection), EWN Entsorgungswerk für Nuklearanlagen GmbH and its subsidiary KTE (publicly owned organisations for the decommissioning of nuclear facilities), Brenk Systemplanung GmbH, and the Gesellschaft für Anlagen und Reaktorsicherheit GmbH, GRS (limited liability Technical Support Organization, TSO, for plant and reactor safety).

ARTEMIS reviews are based on the IAEA Safety Standards and technical guidance, as well as international good practices. Germany requested this ARTEMIS review to fulfil its obligations under Article 14.3 of the Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community Framework for the Responsible and Safe Management of Spent Fuel and Radioactive Waste.

The ARTEMIS review put special emphasis on the following topics:

- restructuring of financial and waste management responsibilities;
- commissioning of the Konrad facility;
- site selection for a disposal facility for heat generating waste, including research, transparency and public engagement;
- decommissioning projects and strategy and associated waste management; and
- waste management implications of the retrieval from Asse II mine.

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

The ARTEMIS Review Team acknowledged and took advantage of the fact that the German regulatory framework and requirements had been reviewed during an IAEA Integrated Regulatory Review Service (IRRS) Mission to Germany in March 2019. Site visits took place to the Konrad facility and the Kerntechnische Entsorgung Karlsruhe.

Germany currently operates seven nuclear power reactors and seven research reactors. The country will end commercial nuclear power operations by the end of 2022. Germany has one NPP that has been permanently shut down, but which does not yet have a decommissioning

licence. It has another 25 NPPs and prototype reactors in decommissioning. Three NPPs and prototype reactors have been fully decommissioned and whose sites have been released from regulatory control.

Radioactive waste disposal has been or will be undertaken at three sites. The Morsleben disposal facility is being prepared for closure. The Konrad disposal facility is under construction and will receive waste with negligible heat generation (NHGW). A disposal facility for high level waste will be developed at a site to be selected according to the Site Selection Act. Radioactive waste retrieved from the Asse II mine and other NHGW that cannot be disposed of in the Konrad disposal facility are to be taken into account during the search for a HLW disposal facility.

The Konrad facility is scheduled to become operational in 2027. The site for the disposal facility for high level waste is to be determined by 2031. The disposal facility for high level waste is to be commissioned around 2050.

Germany has a long-standing and effective radiation protection history and a mature legal and regulatory framework for the safety of spent fuel and radioactive waste management. The recently restructured organizational framework which is set out in the National Programme contains the necessary elements for safety and programme implementation.

The ARTEMIS Review Team identified the support of the site selection process for a HLW disposal facility by the National Civil Society Board, NBG (Nationales Begleitgremium, an independent mediating body composed of public personages and citizens) as a Good Practice.

The ARTEMIS Review Team noted opportunities for improvement in relation to (i) monitoring progress of the many different projects comprising the National Programme, and (ii) achieving transparency in some reporting and regulatory processes.

The ARTEMIS Review Team considered that completion of the site selection process for a disposal facility for heat generating waste within the 12-year period to 2031 represents a significant challenge. The retrieval of waste from the Asse II mine will also be a significant challenge.

Recommendations and suggestions identified by the ARTEMIS Review Team included:

1. The Government should establish an improved process for monitoring progress in implementing the National Programme;
2. BGE, in consultation with BfE, as appropriate, should consider publishing the approach to applying site selection criteria for use in identifying a site for disposing of HLW;
3. BMU should consider including additional information in the radioactive waste inventory report;
4. BMU should update the cost assessment for the entire National Programme and should include the costs for waste retrieval from the Asse II mine;
5. The Government should analyse the risks and uncertainty associated with the costs of the National Programme;
6. The Government should consider enhancing the coordination of research, development and demonstration activities supporting the National Programme.

In summary, the ARTEMIS Review Team considered that Germany is in a good position to continue meeting high standards of safe and responsible management of radioactive waste and spent fuel, and identified recommendations and suggestions for further improvements. The ARTEMIS Review Team commended the German authorities and organizations involved in the design and implementation of the National Programme, as demonstrated by the deliberate actions taken, the professionalism displayed by all, and the commitment to safety in all its efforts.

I. INTRODUCTION

At the request of German Government, specifically the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the International Atomic Energy Agency (IAEA) organized an ARTEMIS review of the German Radioactive Waste and Spent Fuel Management programme.

The objective of the ARTEMIS Peer Review Service is to provide independent expert opinion and advice on radioactive waste and spent nuclear fuel management, decommissioning and remediation, based upon the IAEA safety standards and technical guidance, as well as international good practice.

Germany requested this ARTEMIS review to fulfil its obligations under Article 14.3 of the Council Directive 2011/70/Euratom of 19 July 2011 establishing a *Community Framework for the Responsible and Safe Management of Spent Fuel and Radioactive Waste* ("*Waste Directive*").

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

After a preparatory meeting in January 2019, and receipt and review of Advanced Reference Material in August of 2019, the ARTEMIS Review Team met with the German counterparts in September-October 2019 to complete its review of the German National Programme.

II. OBJECTIVE AND SCOPE

The objective of the ARTEMIS review was to provide an independent, international evaluation of the National Programme of Germany, in line with the obligations of the *Waste Directive*.

The review was organized by the Department of Nuclear Safety and Security and the Department of Nuclear Energy of the IAEA. The German programme was evaluated against the relevant IAEA Safety Standards and proven international practice and experiences by an international peer review team selected by the IAEA.

In accordance with the Terms of Reference for the review agreed between the IAEA and the German authorities, the ARTEMIS review considered all types of radioactive waste and spent fuel in Germany and special emphasis was given to the following topics:

- restructuring of financial and waste management responsibilities;
- commissioning of the Konrad facility;
- site selection for a disposal facility for heat generating waste, including research, transparency and public engagement;
- decommissioning projects and strategy and associated waste management; and
- waste management implications of the retrieval from Asse II mine.

In developing the TOR, it was agreed to exclude from the ARTEMIS review consideration of residues from mining and milling and Naturally Occurring Radioactive Material (NORM) in accordance with the *Waste Directive*.

III. BASIS FOR THE REVIEW

A) PREPARATORY WORK AND IAEA REVIEW TEAM

At the request of the Government of Germany, a preparatory meeting for the ARTEMIS Review was held at the offices of the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, in Cologne, Germany, during 16 and 17 January 2019. The preparatory meeting was attended by the ARTEMIS Team Leader, Mr Patrick Majerus, the IAEA Coordinator, Mr David Bennett, the IAEA Deputy Team Coordinator, Mr Patrick O'Sullivan and the German Counterpart Liaison Officer, Mr Thomas Pissulla of BMU, and colleagues from BMU, BfE and GRS.

The preparatory meeting comprised discussions on:

- the Terms of Reference for the ARTEMIS review of the German programme to fulfil obligations from article 14.3 of the *Waste Directive*; 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 of planning for the the ARTEMIS review mission to Germany in September - October 2019.

Germany provided the IAEA and the ARTEMIS Review Team with Advance Reference Material (ARM) for the review in August 2019.

B) REFERENCES FOR THE REVIEW

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

C) CONDUCT OF THE REVIEW

An Initial Meeting of the ARTEMIS Review Team was held at the Hotel Landhaus Gut Keuchhof in Cologne on Sunday, 22 September 2019. This meeting was led by the ARTEMIS Team Leader, Mr Patrick Majerus, supported by the IAEA Coordinator, Mr David Bennett, and the IAEA Deputy Coordinator, Mr Patrick O'Sullivan. The National Counterpart Liaison Officer, Mr Thomas Pissulla of BMU was present at the initial ARTEMIS Review Team meeting, in accordance with the ARTEMIS guidelines, and described the logistical arrangements for the mission.

The ARTEMIS Entrance Meeting was held at the offices of GRS in Cologne, Germany, on Monday, 23 September 2019, with the participation of the ARTEMIS Review Team and senior management and staff from the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the Federal Company for Radioactive Waste Storage (BGZ), the Federal Company for Radioactive Waste Disposal (BGE), the Federal Office for the Safety of Nuclear Waste Management (BfE), Brenk Systemplanung GmbH and staff from GRS. Opening remarks were made by Mr Wolfgang Cloosters of BMU, by Mr Patrick Majerus, the ARTEMIS Team Leader, and by Mr David Bennett of IAEA. Mr Thomas Pissulla presented an overview of the German radioactive waste and spent fuel management programme and the main findings from a self-assessment performed by the German organizations in response to an ARTEMIS questionnaire.

During the ARTEMIS Review Mission, a review was conducted of all of the topics identified in the Terms of Reference in accordance with the agreed review scope. The overall aim of the review was to provide the German Government and authorities with recommendations and suggestions for improvement and, where appropriate, to identify good practice. The ARTEMIS Review Team performed its review according to the mission programme in Appendix B.

The ARTEMIS Exit Meeting was held on Friday, 4 October 2019. Opening remarks were made by Mr Thomas Pissulla of BMU. A presentation of the results of the Review Mission was given by the ARTEMIS Team Leader, Mr Patrick Majerus. Closing remarks were made on behalf of the IAEA by Mr Peter Johnston, Director of the Division of Radiation, Transport and Waste Safety, Department of Nuclear Safety and Security. Closing remarks on behalf of BMU were made by Mr Wolfgang Cloosters.

An IAEA press release was issued.

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

1.1. NATIONAL POLICY

German position

Waste management policy is compiled in the National Programme for the responsible and safe management of spent fuel and radioactive waste (National Programme). The National Programme consists of an overarching document giving a programmatic overview of German waste management policy and four appendices: the supporting information is given in the report for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention), the report on implementation of the *Waste Directive*, together with separate reports on the radioactive waste inventory as well as on the costs and financing of the management of spent fuel and radioactive waste. Key legislation for the national radioactive waste management policy includes the Atomic Energy Act (AtG), the Radiation Protection Act (StrSchG) and Site Selection Act (StandAG).

In short the radioactive waste management policy is as follows:

- Production of nuclear energy will be terminated in the year 2022 at the latest. Delivery of spent fuel to Reprocessing has been banned since 2005. Decommissioning of Nuclear Power Plants (NPPs) will follow the strategy - required by law - of immediate dismantling.
- Management of radioactive waste shall be carried out in a safe manner within German national responsibility and disposal has to be done in Germany. Undue burdens and obligations for future generations have to be avoided.
- The Morsleben disposal facility is being prepared for closure.
- There will be two further disposal facilities, one for radioactive waste with negligible heat generation (NHGW) and one for high level radioactive waste (HLW).
- Deep geological disposal is the chosen option for waste disposal. Development of the deep borehole disposal concept, further, long interim storage as well as partitioning and transmutation are observed and tracked. Other options are ruled out.

The AtG sets the following principles that the National Programme for the responsible and safe management of spent fuel and radioactive waste takes into account:

- by means of design, operational and decommissioning procedures of nuclear facilities, including the recycling of material, the generation of radioactive waste shall be limited to what is reasonably feasible with respect to activity and volume;
- the mutual dependency of separate steps during generation and management of spent fuel and radioactive waste shall be taken into account;
- spent fuel and radioactive waste shall be disposed of safely, taking into account passive safety with regard to long-term safety;
- measures shall be implemented taking into account the graded approach to safety;
- the costs of spent fuel and radioactive waste management shall be borne by the waste producers; and
- a decision process based on facts shall be applied and documented for all steps of spent fuel and radioactive waste management.

The National Programme will be regularly reviewed and updated in accordance with the Waste Directive 2011/70/EURATOM, the supporting documentation will also be updated regularly. Germany will periodically, and at least every 10 years, arrange for a self-assessment of the national framework, competent regulatory authority, national programme and its

implementation, and invite international peer review for these topics (see Article 14.3 Waste Directive). The National Programme has to be accepted by the federal cabinet and it will be presented to parliament and public. The next update for the National Programme in the aforementioned sense will be in 2025 and it will be a major one since all nuclear power plants will be permanently shut down and the site selection process will be well underway.

Responsibility for the execution of the German National Programme currently rests with individual public and private licence holders, each of whom reports separately to competent authorities in line with their responsibilities as nuclear licensees. BMU has overall responsibility for drafting the National Programme on behalf of the Federal Government.

ARTEMIS observation

The IAEA Fundamental Safety Principles (SF-1) and Governmental, Legal and Regulatory Framework for Safety (GSR Part 1 (Rev.1)) define the following principles for radioactive waste management: minimization of the amount of waste produced, interdependences of the waste management steps, safety of waste management, graded approach, polluter pays and documented and fact based decision making. All of these principles are established in the AtG to be taken into account for the National Programme.

Based on the ARM and discussions during the review meeting, the ARTEMIS Review Team concluded that the national policy for spent fuel and radioactive waste management established in Germany is comprehensive. It covers existing and future nuclear facilities and installations, as well as industry, science and medical sectors.

The ARTEMIS Review Team requested information on the background to Germany's policy of deep geological disposal for all radioactive waste. It was told by the counterpart that this is based on an earlier political decision.

1.2. MONITORING THE PROGRESS OF THE NATIONAL PROGRAMME

German position

The majority of projects connected to radioactive waste management in Germany are complex licensing or construction projects where the progress cannot easily be quantified. For those projects means like milestone trend analyses are commonly used to monitor their progress. Usually this is performed within each of the organizations involved and the BMU is informed about the progress through frequent reports, e.g. in the framework of standing committees or dedicated meetings or written progress reports.

However, there are cases where the concept of key performance indicators (KPIs) can be applied.

It is foreseen to emplace more than 10,000 m^3 of product controlled radioactive waste per year into the Konrad facility. To achieve this, there must be a sufficient number of product controlled waste packages available. Hence, the product controlled volume/year will be a good KPI. Consideration of the absolute numbers (the volume of existing product controlled waste packages per year) already indicates that the process is not as successful as it should be, as the numbers are stagnating over the last years.

For the site selection process milestones are defined in the law. To measure the progress towards safe disposal the milestones and steps defined in the site selection process according to the StandAG are used. The Act also contains the respective responsibilities as well as required documentation e.g. results, working progress, evaluations and assessments from the involved organisations.

In line with the fundamental objective of transparency in the area of radioactive waste management in Germany, the StandAG sets clear and substantial requirements, deliverables, and timelines for the information and involvement of the public in the site selection process.

ARTEMIS observation

Based on the ARM and the ensuing discussion during the review mission, the ARTEMIS Review Team did not see a process for regular short term review of the National Programme, in terms of monitoring the achievement of project milestones or overall performance against estimated costs, or in terms of updates to the programme to reflect changing circumstances.

Progress of the projects related to decommissioning and safe management of radioactive waste and spent fuel are monitored separately by BMWi, BMBF, Länder authorities, BfE and BMU based on reporting by the implementers, each according to its area of competence. The ARTEMIS Review Team did not see a process to oversee and monitor the progress of the programme as a whole, or to manage interdependencies between its different components.

The key performance indicators presented in the self-assessment report are mainly associated with the dates of major milestones for long-running decommissioning and radioactive waste management projects. Although it is recognized that the projects themselves will be monitored by the executing organisations, the ARTEMIS Review Team considers that long term milestones do not facilitate progress monitoring of the overall programme and its interdependencies in the shorter term (e.g. on a yearly basis).

Publication of a detailed roadmap for near term activities (e.g. those related to completion of the construction of the Konrad facility or the early phases of the site selection programme for the disposal facility for HLW), and establishing more detailed targets linked to interim steps, would support regular progress monitoring at the programme level. A near term roadmap and measurable indicators could also be considered for waste conditioning and subsequent acceptance of waste packages by BGZ, as well as completion of decommissioning of individual NPPs by the utilities and subsequent release of the associated sites from regulatory control.

Defining a process and associated responsibility at federal level for progress monitoring of the National Programme would strengthen the ownership and implementation of the policy and strategy. Furthermore, making the outcome of this process publicly available would also increase transparency[1] and credibility of the programme for all parties. Two examples of where this approach would add value are:

- There is a strong interdependency between storage and conditioning facilities for radioactive waste retrieved from the Asse II mine and the retrieval of the waste from the mine;
- The decision to proceed with the disposal of radioactive waste at the Konrad facility was confirmed in 2007, however the current estimate for the commencement of operations is 2027. The commencement of operations will allow removal of NHGW from a number of sites, moving those sites closer to release from regulatory control

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Energy Basic Principles, IAEA Nuclear Energy Series NE-BP, IAEA, Vienna (2008).

with associated benefits to the operator and the public. This is another example of where interdependencies between radioactive waste management activities may usefully be re-assessed.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *To ensure effective delivery of the National Programme, regular monitoring of overall performance, including the achievement of targets, is important. The current approach sets only longterm milestones for project implementation. This does not make the underpinning plans transparent.*	
(1)	**BASIS: GSR Part 2 Requirement 4 states that** *"Senior management shall establish goals, strategies, plans and objectives for the organization that are consistent with the organization's safety policy. […]* *4.3. Goals, strategies, plans and objectives for the organization shall be developed in such a manner that safety is not compromised by other priorities.* *4.4. Senior management shall ensure that measurable safety goals that are in line with these strategies, plans and objectives are established at various levels in the organization.* *4.5. Senior management shall ensure that goals, strategies and plans are periodically reviewed against the safety objectives, and that actions are taken where necessary to address any deviations."*
(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.* *Decommissioning of facilities and the safe management and disposal of radioactive waste shall constitute essential elements of governmental policy and the corresponding strategy over the lifetime of facilities and the duration of activities [3, 7]. The strategy shall include appropriate interim targets and end states."*
(3)	**BASIS: SSG-16 para. 2.89 states that** *"The government should inform all interested parties regarding decisions on the implementation of a nuclear power programme, including the long term national and international commitments to maintain nuclear safety and the necessity of measures such as establishing new organizations, building new national infrastructure and making financial provision for radioactive waste management and spent fuel management. Information should be provided to the public, local governments, committees representing local interests, industry, news media, non-governmental organizations and neighbouring States."*
(4)	**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."*
R1	**Recommendation: The Government should establish a process to monitor regularly the progress of the national decommissioning and radioactive waste**

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
	and spent fuel management programme, including the associated costs, timeframes and interdependencies between projects.
S1	**Suggestion: Given the long timescales of the projects, the Government should consider establishing additional shorter-term interim targets as key performance indicators.**

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

German position

Legislation for the safe radioactive waste management

The legislative framework in Germany for the use of nuclear energy and radiation protection is described in fig. 1.

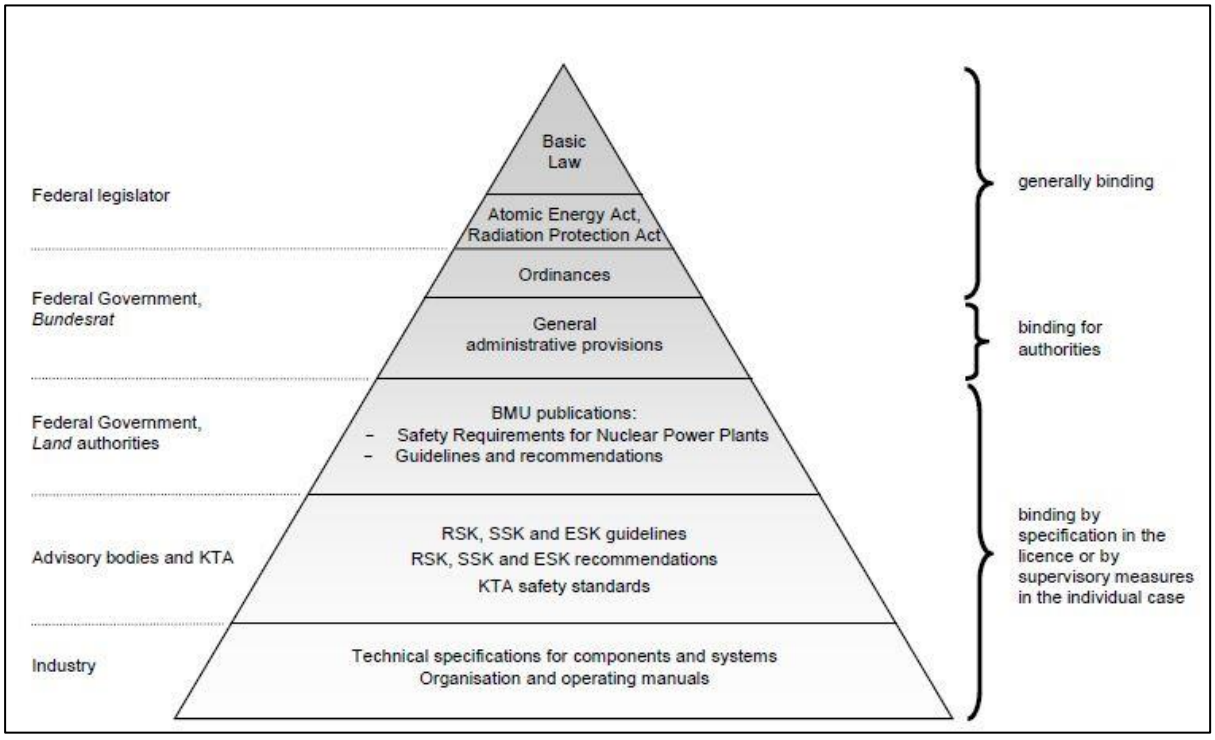

Figure 1. Hierarchy of the national regulations and the issuing organizations

The framework has been updated recently and one key change was the implementation of the updated site selection act (StandAG) which describes the actors and their roles and tasks, public participation, the site selection process and major steps and criteria to be used in identifying a site for the disposal of heat generating waste. The aim of the StandAG is to identify a site with best possible safety on a timeframe of one million years. Criteria to be used in selecting the site are divided in to four categories: exclusion criteria, minimum requirements, geoscientific weighting criteria and planning-scientific weighting criteria.

The StandAG also sets time frame for the site selection by aiming at a decision on the site to be taken by 2031. Alongside the disposal of heat generating waste, the suitability of the same site

will also be considered for disposal of those NHGW that are not destined for disposal to Konrad. If the site also fulfils the requirements for NHGW and disposal at the same site can be achieved without impairing the safety of the facility for heat generating waste, the StandAG allows for the possibility of disposal of NHGW at the site.

Three ordinances, giving more details for the site selection process, are being prepared in support of implementation of StandAG. These ordinances define the safety requirements for the disposal facility, requirements for preliminary safety analyses and requirements for the documentation of disposal activities. It is expected that these will be supplemented in due course with more detailed regulations and guidelines.

Advisory bodies can also publish guidelines and recommendations. In the field of radioactive waste management, the Entsorgungskommission, ESK (Nuclear Waste Management Commission), an independent advisory body to BMU, is the key advisory body. Their guidelines describe the state of the art relating to radioactive waste management technology in Germany. Additionally some Kerntechnischer Ausschuss, KTA (Nuclear Safety Standards Commission), rules are used as appropriate. The Länder regulatory bodies have implemented specific ESK guidelines as part of binding regulations for facilities under their supervision.

Responsibilities and roles

The national framework for decommissioning and for radioactive waste and spent fuel management has been restructured quite recently in Germany. On the regulatory side, each federal state has its own safety regulator, as previously, and BMU as the topmost regulator has the overall supervisory authority concerning legality and appropriateness. As part of the restructuring a new regulator, BfE, was formed at the federal level for the regulatory oversight of the spent fuel and radioactive waste management. On the implementer side two new companies, BGE and BGZ were formed. Responsibilities of the different organizations are identified in figure 2. The Federal Parliament will make the decision on the site. This ends the step of site selection. After that, the facility has to be licensed by BfE.Transfer of responsibility from the NPP operators to BGZ for storage of NHGW that meets the criteria for disposal to Konrad will take place at the beginning of 2020. In conjunction with the restructuring of the national framework, arrangements for funding were also reorganized. Since responsibility for implementation of storage and disposal of radioactive waste and spent fuel from the NPPs was transferred to the federal state, the accruals of the utilities that had been set aside for waste storage and disposal were transferred to a federal fund.

Activity	Operator	Licensing authority	Supervisory authority	Legal basis
Decommissioning (including of NPPs)	Utilities	Land authority	Land authority	§ 7 AtG
Storage of (spent) nuclear fuel	BGZ, EWN	BfE	Land authority	§ 6 AtG
Storage of other radioactive material	Various companies	Land authority	Land authority	§ 12 StrlSchG
Waste treatment	Various companies	Land authority	Land authority	§ 12 StrlSchG
Transport of (spent) nuclear fuel	Various companies	BfE	Land authority	§ 4 AtG

Activity	Operator	Licensing authority	Supervisory authority	Legal basis
Transport of other radioactive material	Various companies	Land authority	Land authority	§ 27 StrlSchG
Cask approval	Various companies	BAM, BfE; for radioactive waste also product control by BGE	– (not applicable)	GGBefG, Acceptance criteria for disposal facility
Site selection	BGE (implementer)	– (not applicable)	BfE	StandAG
Disposal	BGE	BfE/ Land authority	BfE	§ 9b AtG

Figure 2. Responsibilities for decommissioning and spent fuel and radioactive management

ARTEMIS observation

The role of BfE in the site selection process was discussed during the mission. The IRRS mission earlier had raised and made a suggestion on the issue (Suggestion 2 in section 1).

Based on the English translation of the StandAG, the ARTEMIS Review Team had a similar view on the process as that taken by the IRRS review team. During the ARTEMIS review mission, the counterpart explained to ARTEMIS Review Team that, in the last stage of the site selection process, BGE as implementer will be required to submit a comparison of at least two sites with a clear recommendation to BfE regarding the site with best possible safety. BfE shall examine the proposal and then submit a reasoned site proposal to BMU. The counterpart emphasized that BfE does not itself select the best site from the sites proposed by BGE. Its role is to review the proposals of BGE from a safety point of view and take into account all private and public interests and the results of the public participation in making its recommendation to government.

Since both review teams have had difficulties in understanding the German system based on the StandAG, it may be useful for the counterpart to consider how to communicate this in a clear way to relevant stakeholders during the site selection process.

2. NATIONAL STRATEGY FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT

2.1. SCOPE

German position

Germany's National Strategy for radioactive waste management can be summarized as follows:

- NHGW will be disposed of in the Konrad facility, which has a licensed capacity of about 303,000 m³ and which is about to start operation in 2027;
- This includes basically all radioactive waste with NHGW which will have been created by the end of the Konrad operation period, especially all suitable radioactive waste from the decommissioned nuclear facilities (except spent fuel and high level waste); this waste is to be conditioned to meet the Konrad acceptance criteria;
- Radioactive waste from research, medical and industrial application have to be transferred for storage to Land collecting facilities, which are responsible for the conditioning for disposal in the Konrad facility;
- NPPs and other nuclear facilities will be decommissioned following the method of immediate dismantling;
- Large components, like steam generators, may be decay-stored; if necessary they will be conditioned for disposal in the Konrad facility;
- The radioactive waste currently located in the Asse II mine is to be retrieved;
- Spent fuel and high level radioactive waste from reprocessing will be dry-stored until their disposal in a disposal facility for HLW;
- The site with the best possible safety for HLW will identified by a three phase site selection process;
- Depleted uranium (if declared as radioactive waste), NHGW which does not meet the acceptance criteria of the Konrad facility, radioactive waste retrieved from the Asse II mine, and radioactive waste arising after the closure of the Konrad facility might be disposed at the disposal site selected according to StandAG, if this is possible without undue impairment of the safety of HLW disposal.
- Disused radioactive sources are either recycled via their manufacturer or collected for disposal via the Land collecting facilities.

2.2. MILESTONES AND TIMEFRAMES

German position

Milestones for the Morsleben facility are as follows:

- Finalisation of all application documents through BGE by 2026;
- Plan approval through Land Sachsen-Anhalt by 2028;
- Closure of the Morsleben disposal facility (tbd).

Milestones for Konrad are as follows:

- Selection of site for the central reception storage facility (ZBL, Zentrales Bereitstellungslager) by 2019;
- Shut down of all NPPs by 2022;
- Start of operation of the Konrad facility by 2027;
- Completed decommissioning of all NPPs by 2045;
- Completed decommissioning of all other nuclear facilities (tbd);
- Conditioning and product control of all LLW and ILW which have been generated during operation and decommissioning of the NPPs for disposal in Konrad (tbd);
- Conditioning and product control of all LLW and ILW from other origins in Germany (research, Land collecting facilities) for disposal in Konrad (tbd);
- Closure of the Konrad facility (tbd).

Milestones for the Asse II mine are as follows:

- Completion of the safety preparedness measures for the precaution against foreseeable major events;
- Completion of the exploration drilling into the emplacement chamber (fact finding);
- Sinking of a new recovery shaft and building a new recovery mine;
- The planning, licensing and construction of a buffer storage, conditioning and storage facility;
- Start of retrieval of the radioactive waste from the Asse II mine – target date 2033;
- End of retrieval (tbd);
- Closure of the Asse II mine (tbd).

For the HLW the milestones have been defined as follows:

- Publication of subareas by 2020;
- Site selection by 2031;
- License for the HLW disposal facility (tbd);
- Start of operation of the HLW disposal facility by 2050;
- Licensing and construction of a dedicated entrance storage facility for the spent fuel and HLW from reprocessing at the site of the HLW disposal facility (tbd);
- Clearance of the existing on-site and off-site storage facilities for spent fuel and HLW from reprocessing (tbd);
- Conditioning and product control of spent fuel and HLW from reprocessing to meet acceptance criteria for the HLW disposal facility (tbd);
- Closure of the HLW disposal facility (tbd).

ARTEMIS observation

Site selection

The StandAG sets out the siting process for the disposal facility for HLW and spent fuel and specifies four types of criteria which BGE will apply:

- Exclusions;
- Minimum requirements;
- Geoscientific weighting;
- Planning-scientific weighting.

It is understood that these criteria will be applied along with preliminary safety analyses during a three phase site selection process to identify the site with the best possible safety for HLW:

1. a) Application of criteria to identify sub areas;
   b) Preliminary safety analyses and re-application of criteria for the sub areas to identify siting regions;
2. Surface-based investigation of siting regions, preliminary safety analyses and re-application of criteria to identify sites;
3. Underground investigation of at least two sites, preliminary safety analyses and re-application of criteria to select disposal site.

The ARTEMIS Review Team notes that the geoscientific weighting criteria are very specific and that information is unlikely to be available for the rocks and geological settings for much of the country during Phase 1 of the process. The application of these criteria to the areas left after the application of the exclusion criteria and the minimum requirements in a way that allows meaningful comparison of different areas with regards to the safety of a disposal facility is challenging. Similarly the application of preliminary safety analyses based on generic safety cases to sub areas in order to identify sites is also challenging.

The ARTEMIS Review Team notes that the 12 years to 2031 set in the StandAG to undertake this siting process, which includes geophysical investigations and deep borehole drilling at multiple sites and underground investigations at a minimum of two sites, is significantly challenging.

BGE and BfE clearly recognize these technical and timescale challenges and are considering how the criteria and preliminary safety analyses can be applied and assessed through the three phases. The ARTEMIS Review Team suggests that the approach to applying site selection criteria should include flexibility to develop the methodology for phases 2 and 3 as the process develops.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *BGE's understanding of how their approach to applying the four types of site selection criteria may change during the three site selection phases has not yet been made clear.*	
(1)	**BASIS: SSG-14 Appendix 1 Siting of Geological Disposal Facilities, para. I.5 states that** *"The key geoscientific criteria that will be used in support of judgements concerning the potential suitability of a site should be developed by the operator, in accordance with national regulatory requirements. Such criteria might include requirements or preferences for the host rock and surrounding geosphere, e.g. tectonic setting, rock characteristics and groundwater properties. From these criteria, screening guidance should be established for the selection of suitable areas and host rocks and later for the selection of the preferred site(s). It is recognized that, as knowledge improves, the criteria, or any limits placed on the criteria, may change during the siting process."*
S2	**Suggestion: BGE, in consultation with BfE, as appropriate, should consider publishing the approach to applying the site selection criteria during all three phases in advance of the interim report on sub areas.**

The policy for the NHGW that will not be disposed of in the Konrad facility is disposal at the site of the facility for HLW. It is noted that the site selection criteria for the facility for HLW were not chosen to consider the requirements on the geosphere for NHGW, which may in some respects be more onerous than those for HLW. It is considered likely that the geoscientific weighting criteria could be used by BGE in a manner that identifies sites with the potential to host all of this radioactive waste.

The ARTEMIS Review Team understands that BGE are considering how this could be undertaken and that BMU are currently consulting on draft Statutory Ordinances provided for in the StandAG including:

- Safety requirements for the disposal of HLW (§ 26);
- Requirements for preliminary safety analyses (§ 27).

It is understood that the underground investigations during Phase 3 will focus on providing only the geoscientific information that allows the identification of the site. It is noted that sufficient time should be included in the programme before the construction of underground facilities to establish baseline environmental conditions at the site.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *The site selection process aims to identify the site with the best possible safety for the disposal of HLW. Since the requirements on the geosphere of NHGW may be different from those for HLW, the site selection process may not identify the best site for both types of waste.*	
(1)	**BASIS: GSR Part 5 Requirement 2 states that** *"[…] The policy and strategy shall be appropriate for the nature and the amount of the radioactive waste in the State […]* *3.6 The national strategy for radioactive waste management has to outline arrangements for ensuring the implementation of the national policy. It has to provide for the coordination of responsibilities. It has to be compatible with other related strategies such as strategies for nuclear safety and for radiation protection."*
S3	**Suggestion: BGE, in consultation with BfE, as appropriate, should consider assessing whether the requirements on the geosphere for NHGW are different from those for HLW and, if they are, taking them into account in the approach to applying the siting criteria.**

Public involvement during site selection

BGE and BfE recognize the importance of communicating their work on site selection in an accessible manner to a wide range of non-technical stakeholders. BfE have started to consider the range of material that they will need to produce to achieve this and are in the process of commissioning work to gain stakeholder perspectives. This approach is fully supported by the ARTEMIS Review Team.

The site selection procedure is accompanied by the National Civil Society Board, NBG (Nationales Begleitgremium). This board is composed of public personages and selected citizens. It has been set up as an independent body, with its own staff and financial resources.

The ARTEMIS Review Team believes that the National Civil Society Board will contribute as a mediating body to enhance public confidence with regard to the site selection process.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *The site selection procedure is accompanied by the National Civil Society Board. This board is composed of public personages and selected citizens.*	
(1)	**BASIS: GSR Part 1 (Rev. 1)Requirement 36 states that** *"The regulatory body shall promote the establishment of appropriate means of informing and consulting interested parties and the public about the possible radiation risks associated with facilities and activities, and about the processes and decisions of the regulatory body."*
GP1	**Good Practice: The use of the National Civil Society Board as a mediating and independent body to accompany the site selection process.**

Asse II mine

The German strategy is to retrieve the radioactive waste from the Asse II mine and to consider and assess whether it can safely be disposed of at the disposal facility site selected according to the StandAG. BGE plans to discuss the plan for retrieval in a conference in 2020 with international experts, especially experts with experience in clean-up-processes of repositories. This is fully supported by the ARTEMIS Review Team.

Clause 57b (2) of the AtG (Lex Asse) states:

> '*The retrieval shall be discontinued, if its performance is not acceptable for the population and the employees for radiological or other safety-relevant reasons. This is especially the case, if compliance is not possible with the dose limits pursuant to § 5 of the Radiation Protection Ordinance of 20 July 2001 as lately amended by article 5, para. (7) of the Act of 24 February 2012 or if it is not possible to guarantee mining safety.*'

BGE has considered the specific conditions that could make a discontinuation of retrieval unavoidable but have not formally shared these with relevant stakeholders. Such safety relevant conditions may include for instance the daily rates of brine inflow or certain geomechanical conditions in the mine. Sharing these considerations at an early stage with relevant stakeholders would facilitate efficient decision making if such conditions occur.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *BGE has considered the conditions that would lead them to recommend that retrieval of waste from the Asse II mine be discontinued but has not made these public.*	
(1)	**BASIS: SSG-23 para 4.99 states that** *"Transparency requires openness, communication and accountability. This implies that the safety case and safety assessment should be documented in a clear, open and unbiased way that, for example, recognizes both the features of the disposal system that provide safety benefits and the uncertainties. The aim should be to provide a clear picture of what has been done in the assessment, what the results and uncertainties are, why the results are what they are, and what the key issues are, in order to inform decision makers. To increase transparency, it may also be appropriate to make the safety case documentation available to the public and to ensure that it is prepared in a manner and at a level of detail that is suitable for the intended audience."*
S4	**Suggestion: BGE should consider publishing the safety-based conditions that would lead them to recommend that retrieval of waste from Asse II mine be discontinued.**

3. INVENTORY OF SPENT FUEL AND RADIOACTIVE WASTE

German position

In Germany radioactive waste is classified either as:

- Waste with negligible heat generation (sometimes referred to in Germany as 'Negligible-, or 'Non-Heat Generating Waste'), NHGW, a waste category, which arose out of the planning work for the Konrad disposal facility, and which restricts emplaced waste packages to those that would lead to a maximum 3K increase in wall temperature on average; and
- Heat Generating Waste (sometimes referred to in Germany as 'High Level Waste').

A further distinction is made in the AtG (Section 2, para 1) between nuclear fuel and other radioactive substances and, in line with most Member States, there is a system for clearance of materials as laid out in StrlSchV.

The basis of the classification system is the national policy that all radioactive waste will be disposed of in a deep geological disposal facility. As a result, the system differs from the internationally adopted system, as described in IAEA Safety Standards Series No. GSG-1, which describes waste in terms of its activity levels and half-lives. A comparison between the two classification systems is provided in fig. 3.

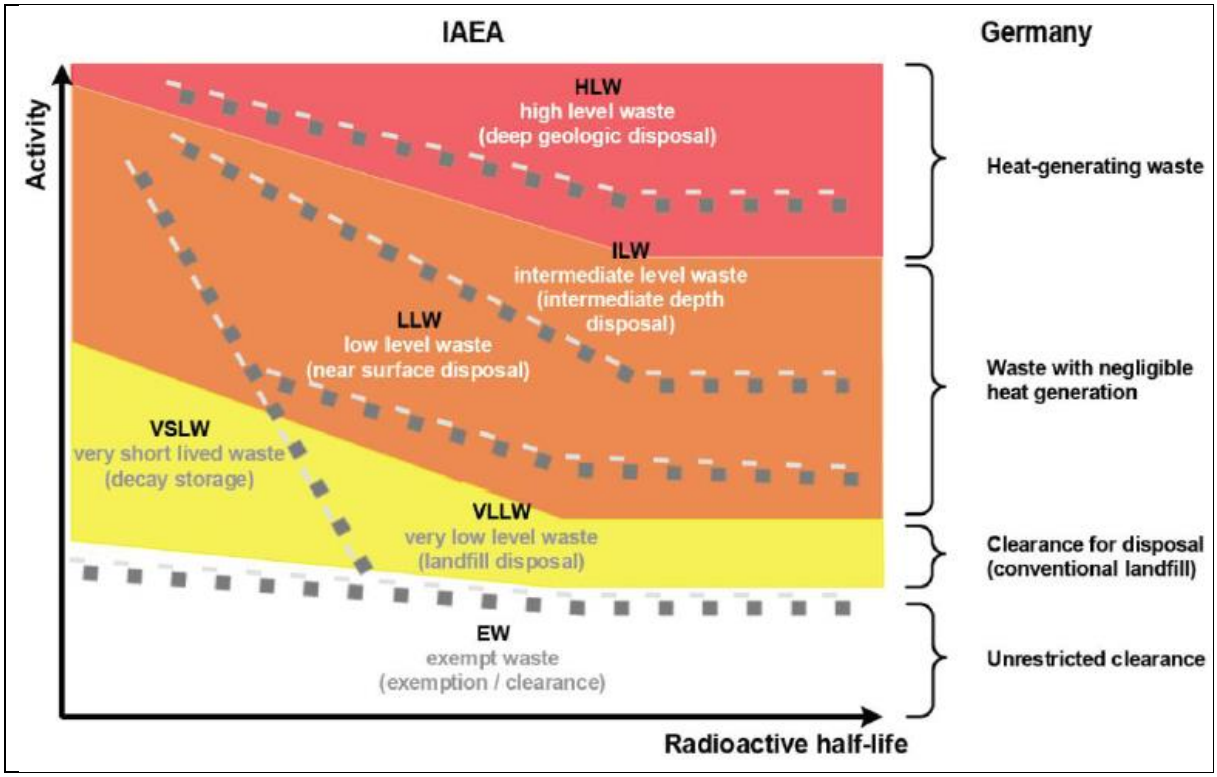

Figure 3. Comparison of radioactive waste classification system used in Germany with the international classification system given in IAEA Safety Standards Series No GSG-1 (2009) courtesy of BMU

As required by the AtG (Section 2c) an inventory of spent fuel and other radioactive waste is compiled as part of the National Programme.

On an annual basis there is a requirement under the Nuclear Waste Disposal Ordinance (Section 1) for radioactive waste producers to provide information to the Länder Authorities. Under the AtG (Section 2c (4) and 9i) there is an additional provision for the BMU to get information about the inventory of all kinds of radioactive waste for the inventory report of the National Programme and the periodic reporting to the European Commission every three years. The Länder collect this information for the BMU. The collected information is updated by GRS (spent fuel) and BGE (other radioactive waste) on BMU's behalf, and reported via BMU's website. Under Section 2c (3) of the AtG the inventory is reported as part of the National Programme in terms of actual arisings and estimates of future arisings. Further, the inventory should state the amount and location of spent fuel and radioactive waste by classification.

Estimates for future spent fuel arisings are based on reactor accountancy lives which are fixed under the AtG as given in Appendix 3 and future estimates of NHGW from reactor decommissioning operations are based on 5000 m^3 average per Light Water Reactor (LWR) NPP and 45 m^3 per year per LWR NPP of conditioned waste from ongoing power reactor operations. The basis of these figures, for example the 5000 m^3 assumption for radioactive waste generated during an NPP decommissioning project was estimated by the ESK and is based on experiences from past and current NPP decommissioning projects. Estimations for each individual project are made by the operator and are described in the safety report for the licensing procedure for decommissioning.

The processes for developing the inventories for NHGW and HGW are shown in figs 4 and 5 Governance and assurance of the data being provided to BMU is the responsibility of the Länder authorities.

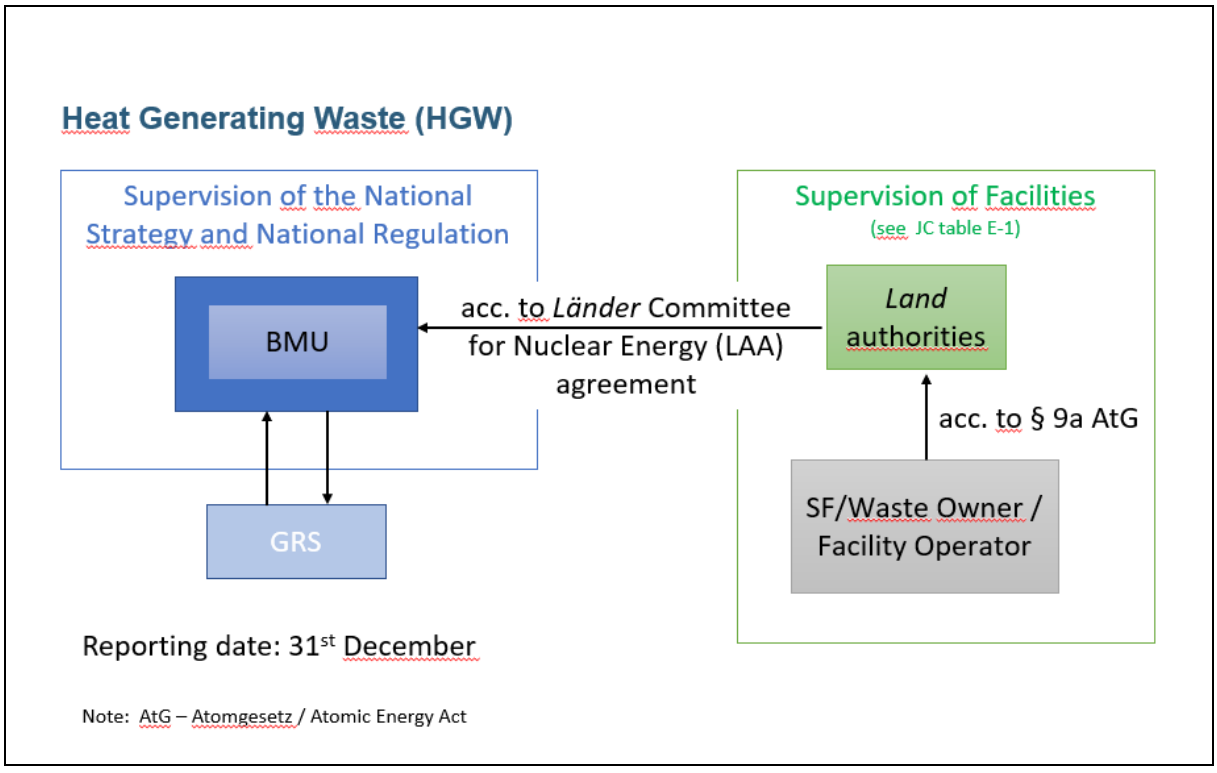

Figure 4. Reporting process for heat generating waste

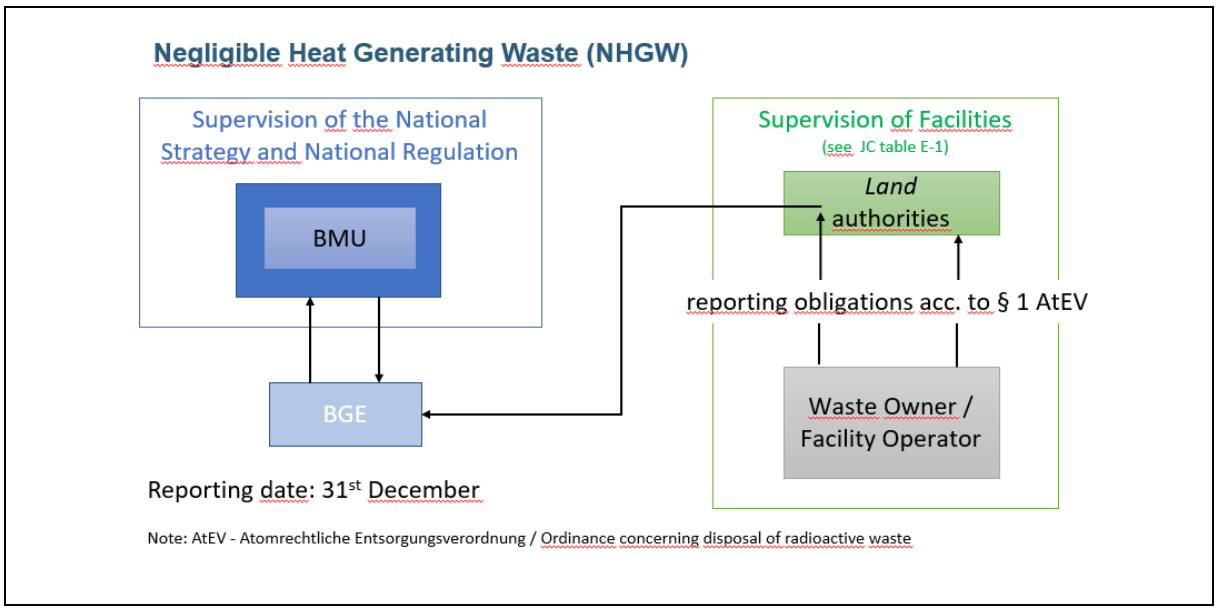

Figure 5. Reporting process for NHGW

The inventory (a sub document of the National Programme) was last published in August 2018[2] covering the period up to 31 December 2017. The inventory is updated annually and reported (every 3 years) to fulfil the requirements of the *Waste Directive* and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention).

ARTEMIS observation

The requirement to produce and keep a radioactive waste inventory is laid down in the AtG and BMU routinely publishes the inventory as is required by the Act and obligations under the *Waste Directive* and the Joint Convention.

In comparison to current practice in countries with similarly large and complex inventories, the level of detail provided in the published radioactive waste inventory for NHGW is limited to numbers and volumes of conditioned waste packages and weights of unconditioned waste (inorganic, organic and miscellaneous waste). There is no information on quantities and volumes, conditioning factors/processes or conditioning assumptions and characterization for individual waste streams[3]. Such information is, however, collected and available to the Länder Authorities. There is also no detailed information in the inventory report regarding future projections. This leads to questions over transparency in relation to how these waste streams are being managed.

As a mechanism for improving transparency with respect to inventory reporting, additional information could be provided that gives a description of the main types of radioactive waste by location as well as the inventories for each of this waste in terms of current and projected weight or volume of unconditioned waste, total activity, the current conditioned and projected waste volumes, and total number of packages. The ARTEMIS Review Team suggests that consideration should also be given to providing data on radioactive material that is not currently

[2] Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, Verzeichnis radioaktiver Abfälle (Bestand zum 31. Dezember 2017 und Prognose), Cologne, August (2018).
[3] A waste stream is the complete flow of the same type of waste from source to disposal. For example, spent fuel storage racks, ion exchange resins would typically be considered waste streams.

declared as radioactive waste, but may be in the future.

The ARTEMIS Review Team also see value in using inventory reporting to monitor changes over time, i.e. comparison with previous inventories, as a mechanism for demonstrating the outcomes of waste minimization initiatives. In making this suggestion, the ARTEMIS Review Team recognizes that there is a degree of stability around the total volume of lifetime arisings of spent fuel and other radioactive waste. Incentives to power plant owners to introduce further efficiencies below the already agreed radioactive waste volumes allocated at the Konrad facility for their decommissioning waste arise primarily in relation to reducing the investment cost of packaging. Such cost savings need on the other hand to be balanced against the associated treatment costs and, where relevant, those associated with achieving clearance. As far as the remaining operational nuclear power plants are concerned, there are also incentives to minimize spent fuel volumes as well as investment costs (fuel purchase, spent fuel casks) by optimizing the strategy for fuel that is loaded to the reactor at end of life.

The ARTEMIS Review Team also considers the availability of detailed inventory information to be beneficial to organisations (EWN, BGZ, BGE and BfE) beyond those identified in Figures 4 and 5. For example, it may be of particular value in relation to designing and assessing the safety of radioactive waste management facilities and activities.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *The level of detail provided in the inventory for NHGW is limited to numbers and volumes of conditioned waste packages and weights of unconditioned waste (inorganic, organic and miscellaneous waste); there is no information on quantities and volumes, conditioning factors/processes or conditioning assumptions and characteristics for waste streams.*	
(1)	**BASIS: GSR Part 3 Requirement 31, para. 3.131 (e) states that** *"Registrants and licensees, in cooperation with suppliers, as appropriate:* *Shall maintain an inventory of all radioactive waste that is generated, stored, transferred or disposed of;"*
(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."*
S5	**Suggestion: To improve transparency on how waste streams are being managed, BMU should consider including additional information and description on NHGW in future revisions of the radioactive waste inventory report.**
S6	**Suggestion: BMU should consider making greater use of the radioactive waste inventory to monitor changes in the inventory over time and demonstrate waste minimization.**

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

4.1. DECOMMISSIONING PROJECTS AND STRATEGIES

German position

The phase-out of nuclear energy production in Germany allows for a comprehensive planning for the decommissioning and associated management of radioactive waste. The German approach for all radioactive waste coming from fuel cycle activities is deep geological disposal. In the case of spent fuel and vitrified waste from reprocessing activities, dry storage in dual purpose casks in a storage building is the adopted interim storage solution pending the availability of a HLW disposal facility. The concept of interim storage of spent fuel under dry conditions in heavy duty transport/storage casks was first proposed in the 1970s. The first such storage system in Germany was loaded with High Temperature Reactor (HTR) fuel in 1992; the first such system for LWR fuel in Germany was loaded in 1995. For NHGW the proposal is to use on-site storage prior to consigning it directly to the Konrad facility, when it becomes available, or via a centralized interim storage facility.

Decommissioning of NPPs and management of related radioactive materials and waste

The German policy for decommissioning is to implement the immediate dismantling strategy of all NPPs. An overview of the status of the already undergoing and foreseen NPP decommissioning projects shows that some decommissioning projects are in the final phase of dismantling. The final phase of decommissioning mainly comprises the decontamination of building structures and the site, and clearance measurements to prepare for release from regulatory control.

Würgassen, Stade, Obrigheim and Greifswald have already reached the final phase of decommissioning. The decommissioning of Obrigheim NPP is expected to be completed by 2023. For the Würgassen NPP, the release of the remaining buildings and the site from regulatory control can not yet be completed because low and intermediate level radioactive waste will remain at the site until they are ready for transport. According to the present strategy, the waste may only be removed after commissioning of the Konrad facility (i.e. 2027 at least). Transfer to other storage facilities is under investigation.

Würgassen, Obrigheim and Stade are sites where there is no decay storage for clearance, no on-site storage of spent fuel and where only on-site storage of NHGW will remain under operation after the completion of decommissioning projects. These on-site stores of NHGW will be transferred with effect from 1 January 2020 to the new publicly owned storage company (Gesellschaft für Zwischenlagerung mbH (BGZ)) founded in 2017.

To facilitate the emplacement of solid radioactive waste at Konrad facility, a central reception storage facility (ZBL) operated by BGZ will be sited and constructed at a maximum distance of 200 km from the Konrad site and will be connected to it via railway. The centralized ZBL storage facility is expected to be commissioned in 2027 and operated by BGZ. A working group involving radioactive waste producers is led by BGE in order to address the waste producers' needs in the future when Konrad facility will be in operation, by 2027.

Clearance of radioactive materials and substances

The Radiation Protection Ordinance (StrlSchV) amended 29 November 2018 clarifies the conditions for an unrestricted clearance of radioactive substances, based on the criterion of 10 µSv/y. Unrestricted clearance does not require any definitions regarding the future use, disposal or possession of the substances and goods to be cleared, or their transfer to third parties. It provides specific guidance and acceptance criteria for which the future use, utilization, disposal or possession of the substances and goods to be cleared, or transferred to third parties. Various specific clearance options are available to allow clearance of buildings, materials and soil areas. The implementation of the clearance process for a NPP under decommissioning is done on a case-by-case basis where the controlled area is not the only area to be considered as it is recognized that checks have to be performed on other areas having singularities to be addressed.

ARTEMIS observation

The ARTEMIS Review Team observes that there has been significant progress in decommissioning projects in the past years and that the decommissioning of some NPPs will be completed within the next ten years. At that time, for some of these sites, only radioactive waste storage facilities managed by BGZ will remain in operation. The remaining time until the start of operation of Konrad facility should be sufficient to allow BGZ to prepare all the waste packages to be removed from those sites without undue delay to the ZBL centralized storage facility. The capacity of the ZBL central storage facility (60 000 m^3 of RAW) is significant in regards to the amount of NHGW to be generated by the decommissioning of each NPP, estimated to be around 5 000 m^3 per reactor.

The ARTEMIS Review Team observes also that the implementation of the clearance process of radioactive materials generated by NPPs under decommissioning is done on a case-by-case basis where the controlled area (i.e. defined in compliance with the radiation protection requirements) is not the only area to be considered and where checks have to be performed on other specific areas. The preferred option of the final end state of German NPPs is to clear the buildings from regulatory control and to terminate the decommissioning licence.

The ARTEMIS Review Team notes that the conditions to enable the entire release of some NPP nuclear sites from regulatory controls should be met within the next ten years.

The commissioning and operation of the ZBL centralized storage facility, operated by BGZ, will provide the necessary flexibility to facilitate the emplacement of the NHGW to the Konrad facility. Regarding other radioactive waste producers, in particular Kerntechnische Entsorgung Karlsruhe (KTE) which will generate around 25% of Konrad waste. The ARTEMIS Review Team considers that the ZBL centralized storage facility could also be used to accept NHGW from all radioactive waste producers.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *ZBL will be constructed to store radioactive waste coming from BGZ's on-site NHGW storage facilities before the waste is emplaced in the Konrad facility. The ZBL facility is scheduled to be commissioned in 2027. The ZBL centralized storage facility could also be used to accept NHGW from all waste producers.* *Sites where only remain radioactive waste stored in on-site storage facilities operated by BGZ and where decommissioning of NPP is completed should be removed to ZBL to enable the entire sites to be released from regulatory controls within the next decade.*	
(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."*
S7	**Suggestion: The Government should consider taking benefit from the construction and operation of the ZBL by enabling this facility to accept NHGW from all waste producers and thereby increasing flexibility within the National Programme for radioactive waste management.**
S8	**Suggestion: BGZ should consider using the ZBL facility in order to remove all waste from sites where, after completion of decommissioning, only NHGW storage facilities will remain under operation to enable the entire sites to be released from regulatory controls.**

4.2. PREDISPOSAL MANAGEMENT OF SPENT NUCLEAR FUEL

German position

All NPP decommissioning projects follow the strategy of immediate dismantling and it is assumed that all nuclear power plants will have been decommissioned by 2045.

As stated in the National Programme, the national policy for the management of spent fuel and radioactive waste implies that all radioactive waste generated in Germany is stored until its disposal. For high level waste, it is expected that the deep geological disposal facility will be under operation in 2050. In this context, it cannot be ensured that the spent fuel will be removed from the on-site and centralized storage facilities within the 40 years of licensed period and re-licensing of casks will be necessary.

Maintenance areas will be kept in the storage facilities to allow for the external repair of casks. The opening of casks is not currently provided for in the repair concept for storage casks. Therefore, no hot cell or backup solution is required at the present time and none is included in the design of existing storage facilities or in the designs of future storage facilities to be operated in Germany by BGZ and EWN.

EWN has decided to plan and construct a replacement storage facility for the spent fuel containers currently stored in Hall 8 of the centralized storage facility Zwischenlager Nord, ZLN. This new facility is known as the Ersatztransportbehälterlager, ESTRAL. Of the 74 Castor casks currently stored in Hall 8, the first was closed in 1996, the last in 2011. EWN applied for a licence for the ESTRAL facility consistent with the 40-year storage period per cask,

considering the date of closure of the last cask, i.e. until 2051. This facility is in the early phases of licensing.

ARTEMIS observation

The ARTEMIS Review Team observes that German operators will have to extend the 40-year licence period of the spent fuel storage casks. In the meantime, no contingency solutions will be available in order to manage any abnormal situations giving rise to a need to inspect spent fuel loaded in the container casks (ageing of cask containers, damage during handling or during transport of spent fuel casks, etc.).

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *After completion of NPP decommissioning there will be no infrastructure that can be used to deal with damage to the body of spent fuel casks which requires unloading the spent fuel elements for reconditioning.*	
(1)	**BASIS: SSG-15 para. I.51 states that** *"Inclusion of a hot cell in the design of a dry spent fuel storage facility should be considered to allow for unloading the cask and subsequent repackaging of the fuel or repairs."*
S9	**Suggestion: The Government should consider identifying a contingency plan for the repair of storage casks and the removal of spent fuel elements in case of damage.**

The ARTEMIS Review Team observes that the licence duration for all dry storage facilities for spent fuel, including the currently ongoing licensing procedures (e.g. ESTRAL), is not consistent with the schedule for HLW disposal.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *It cannot be ensured that the HLW disposal facility will be available in time to accept the spent fuel from the planned ESTRAL storage facility which is only envisaged to be licensed until 2051.*	
(1)	**BASIS: GSR Part 5 Requirement 6 states that** "*Interdependencies 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."*
S10	**Suggestion: EWN should consider designing the new ESTRAL storage facility to have a lifetime consistent with the planned availability of the HLW disposal facility which is not expected to begin operation before 2050.**

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

5.1. STATUS OF SAFETY CASES FOR THE FACILITIES NEEDED FOR THE SAFE MANAGEMENT, AT ALL STAGES, OF ALL SPENT FUEL AND RADIOACTIVE WASTE

German position

Nuclear and Radiation Protection Law in Germany requires that the construction and operation of nuclear facilities, as well as the handling of radioactive substances, are subject to regulatory approval. Regulatory approval for nuclear facilities involves licensing according to the Nuclear Licensing Procedure Ordinance (*Atomrechtliche Verfahrensverordnung*) or according to comparable regulations to a similar effect. Among other things, this ordinance sets out general expectations (§ 3(1)) relating to the provision of information on the facility and its systems, the scope of safety assessments as well as relevant limits, controls and conditions in the form of precautions taken to assure safety.

In the Self-Assessment Report it is noted that no single document for any given facility reflects the full scope of requirements for a safety case as described in IAEA guidance documents, but that the various components of a safety case are represented in documentation developed in the context of licensing and supervisory procedures. In this respect, Germany considers that the requirements of IAEA Fundamental Safety Principles (SF-1) in relation to the assessment of safety, as well Generic Safety Requirements relating to the functions of the regulatory body (GSR Part 1) and the purpose of safety assessment (GSR Part 4), are fulfilled.

Operations at nuclear power plants and nuclear fuel cycle facilities

NPPs and facilities for the production of nuclear fuels are licensed according to § 7 of the AtG. These licenses may encompass, by decision of the licensing authority, steps for the management of SF and operational waste. Licensing and supervision are carried out by the competent authority in the Land where the facility is located. On-site dry storage facilities for SF are in general licensed according to § 6 AtG, while § 12 of the Radiation Protection Act (StrlSchG) offers the legal base for licensing other radioactive waste management facilities like conditioning or storage facilities not covered by the NPP licence (see below). This applies to the seven nuclear power plants currently remaining in operation as well as the Krümmel power plant, which is currently in post-operational phase. Licensing and supervision of nuclear power plants and nuclear fuel cycle facilities are carried out by the competent authority in the Land where the facility is located.

Decommissioning of nuclear facilities, including related radioactive waste management activities, are subject to a related licensing procedure under § 7(3) AtG. The issuing of a licence for decommissioning is subject to the requirements of the Nuclear Licensing Procedure Ordinance, requiring supporting safety assessments and related controls and conditions. Licensing and supervision are carried out by the corresponding Länder authorities. Technical guidelines relating to safety under different phases of decommissioning have been prepared by the ESK.

Dry storage of spent nuclear fuel

Longer-term dry storage of spent nuclear fuel is undertaken using storage casks at dedicated facilities at the sites of twelve nuclear power plants, as well as at AVR Jülich and the central storage facilities at Ahaus, Gorleben and Greifswald. Except for ZLN at Greifswald (storage

for vitrified high-level waste from WAK) Gorleben is currently the only store for vitrified high-level waste from reprocessing, although future shipments from the La Hague and Sellafield facilities are planned to be sent to Biblis, Brokdorf, Isar and Philippsburg. Such storage is licensed under § 6 of the AtG. There is also a separate package design approval according to the Dangerous Goods Transport Act for each type of storage cask, based on a safety assessment for transport, that is not linked to any specific facility. A certificate of conformity with this design approval is necessary before a specific cask may be loaded. There is typically interdependency between the licensing procedure for spent fuel storage and the safety case for the adjacent nuclear power plant(s) on the same site. The licensing authority is BfE, taking into account specific recommendations of the ESK, while supervision is performed by the competent authority in the Land where the facility is located.

ESK carried out additional stress tests for all German storage facilities for spent fuel and heat-generating radioactive waste following the events in Fukushima in 2011. The results indicated a robust protection strategy, primarily based on the physical integrity of the casks.

The licensing period for all existing fuel storage facilities (typically 40 years) will expire between 2034 (Gorleben) and 2047 (Brokdorf, Unterweser, Philippsburg, Isar). As well, due to the storage licenses, the storage period for each cask is limited to 40 years beginning with the closure of the primary lid after loading. These licenses will need to be extended in view of the fact that a dedicated disposal facility for HLW is not expected to be available before 2050. According to § 6(5) AtG, licence extensions of on-site storage facilities (central storage facilities as Ahaus, Gorleben and Greifswald are not affected) are permitted only on imperative grounds and require referral to the German Bundestag. Renewed safety verifications, particularly in relation to the physical condition of the storage casks and their inventory, including consideration of transportability, will be required from BGZ and EWN in support of applications to extend the licence period. Evidence to support safety assessments necessary for life extension of storage arrangement will depend in part on information obtained through national research programmes.

Treatment and storage facilities for NHGW

Radioactive waste treatment facilities for materials with low fissile material content are subject to licensing under the § 12 Radiation Protection Act (previous § 7 Radiation Protection Ordinance (*Strahlenschutzverordnung*)) if they are not otherwise covered by nuclear site licences (e.g. at nuclear power plants or fuel cycle facilities). Some waste treatment facilities are licensed under § 9 Atomic Law to be able to handle the waste coming from nuclear research sites or fuel cycle facilities, e.g. WAK, Siemens MOX or JRC-ITU. In addition to certain research and commercial radioactive waste treatment facilities, these include the radioactive waste collection and interim storage facilities operated by the Länder on behalf of small radioactive waste producers (hospitals, industry and education) within their territories. Licensing and supervision are both undertaken by the competent authority in the Land where the facility is located.

With the reorganization in Germany of responsibilities for nuclear waste management, BGZ will take over operation of storage facilities for NHGW originating from NPPs, and will also take over ownership of waste packages originating from NPPs that have been conditioned for the Konrad disposal facility according to §§ 2, 3 of the Waste Management Transfer Act (*Entsorgungsübergangsgesetz*). The responsibility for waste processing up to this point will remain with the utilities who can use dedicated conditioning facilities, mobile facilities or installations at their facility sites.

All current disposal facilities operated by BGE, are subject to plan approval by the Länder Authority according to § 9b AtG, unless the site has been determined by federal law (i.e.

geological disposal facility for HLW), in which case the licensing authority is BfE. After Commissioning of the Konrad Repository, BfE will be also licensing authority for this site, e.g. for modification-licenses. The licensing procedure takes account of guidelines and recommendations from ESK. No new licensing will be required for the transfer of storage facilities to BGZ. Storage is undertaken under the supervision of the competent authority of the Land in which the facility is located.

Asse II mine

Disposals of radioactive waste took place to the Asse II mine between 1967 and 1978. Subsequently, the mine was used until 1995 as a research facility for development and demonstration of techniques for radioactive waste emplacement. Since 1988 saline waters have been observed to be percolating into the mine.The major problem in the mine is the very large volumes of open drifts and chambers and the closeness of the chambers to the adjoining rock. Also the chamber themselves are becoming unstable through the rock movement (some of the roofs between chambers have already collapsed), leading to the risk of an uncontrollable inflow of brine due to enhanced damage zones. Originally operated according to mining law, the Asse II mine has been operated under nuclear law since 2009. The facility has no licence (nor safety case) for the disposal of radioactive waste, and the policy of retrieval of waste from the facility became legally binding (unless radiological or other safety-related risks make such measures unjustifiable) through amendment to the AtG (§ 57b) in 2013.

Morsleben disposal facility for radioactive waste

The ERAM facility (Morsleben) is the only operational disposal facility for radioactive waste in Germany. No emplacement of waste has taken place at the ERAM since 1998, but it has remained open under the terms of its original permanent operating licence, which was equated with a plan approval following German reunification. The terms of the original licence required renewal every five years, and the facility has been the subject of a series of retrofitting measures and corresponding amendment licences in accordance with federal law.

Konrad facility

The Konrad national disposal facility for NHGW received plan approval according to § 9b AtG for construction and operation in in 2002, taking into account requirements for safety demonstration in accordance with the Nuclear Licensing Procedure Ordinance. Conversion of the former mine into a disposal facility started in 2007 following a series of administrative delays and the facility is not currently operational. Nevertheless, the operator (BGE) voluntarily initiated in 2017 a comprehensive review of safety requirements to assess the potential implications of changes in the state of the art in science and technology since 2002. Updated assessments completed to date confirm the results obtained at the time of plan approval in respect of long-term safety performance.

Periodic safety review

All operational facilities involved in the management of spent fuel and radioactive waste function fall under the terms of appropriate licences according to the requirements of the AtG and the Radiation Protection Act. The licences and plan approvals are supported by safety demonstrations in accordance with defined licensing procedures. Since amendment to the AtG (§ 9h in combination with § 19a(3)) in 2015, periodic safety reviews have been required for all licensed facilities at intervals of 10 years from the start of active operation. Periodic safety reviews are also required for decommissioned nuclear facilities under the deferred dismantling strategy. Guidelines have been developed by ESK for the performance of periodic safety reviews and on technical ageing management for storage facilities for spent fuel and heat-generating radioactive waste.

ARTEMIS observation

The ARTEMIS Review Team observes a clear division of responsibilities in relation to safety assessment and its review with respect to licensing processes. The safe management of radioactive waste and spent fuel in Germany in current facilities, including the Konrad facility that is currently being prepared for operation, is supported by appropriate and, where necessary, updated safety documentation according to requirements defined by nuclear licensing procedures. Regulatory requirements and processes relating to the role of safety assessment in nuclear facility licensing were extensively reviewed during the IRRS Mission to Germany in March 2019.

The ARTEMIS Review Team notes that the IRRS mission made an observation relating to the lack of formal internal guidance on review and assessment related to decisions taken by the regulatory authorities, both at federal level and by relevant competent authorities from the Länder. Moreover, the IRRS team noted that requirements for periodic safety review were not applied to decommissioning activities (e.g. for more recent nuclear power plant closures) that are the subject of immediate dismantling, and recommended that such a requirement be established (Recommendation 5, section 6). Nevertheless, the IRRS team raised no specific concerns relating to compliance of authorising procedures with IAEA safety requirements regarding to the role of safety assessment in the context of licensing for spent fuel storage or other radioactive waste management facilities. The ARTEMIS Review Team draws no different conclusion.

The ARTEMIS Review Team understands that BfE and BMU recognize the importance of ensuring that the process of periodic safety review (in particularly for the spent fuel storage facilities under BfE's licensing control) becomes well-established, that schedules for such reviews will be defined and adhered to, and that the licensing authority carries out corresponding integrated safety assessments. It is expected that similar schedules will need to be developed for those facilities under the control and supervision of the Länder Authorities.

5.2. PROCESS FOR DEVELOPING AND MAINTAINING A SAFETY CASE AND/OR SUPPORTING SAFETY ASSESSMENTS

German position

Regulatory authorities and operators in Germany recognize that the development of safety cases supported by safety assessments plays a role that extends beyond that of providing some of the material that is required to be submitted in support of a licence application. Performing safety assessments, in particular for radioactive waste disposal facilities, is seen as being part of a system of self-learning that builds understanding through an iterative process of the key components of the disposal system and its safety case. Such activity also contributes to concept development and optimisation, as well as to identifying research needs and priorities. Although this is critical for the operating organisations, which bear the burden of responsibility for radiological protection and safety, even regulatory bodies such as BfE and the competent authorities in the Länder consider an independent capacity to perform safety assessment at some level, as an essential part of the regulatory toolkit. This capacity may exist in-house or via the support of TSOs, and is used to development understanding of, as well as independently verifying, material submitted by the licensee or prospective licensee.

The maintenance of existing safety cases and supporting safety assessments is a task for each of the radioactive waste processing and storage facilities identified above, up to the point where they are finally released from licensing control under the AtG. More particularly, however, safety case development is a critical aspect of the development, operation and closure of geological disposal facilities (particularly in relation to long-term radiation safety considerations) as well as the retrieval of radioactive waste from the Asse II mine (from an operational safety perspective). Some specific considerations identified by the German counterpart in relation to these facilities are identified below.

Asse II mine

Planning for the retrieval of the radioactive waste from the Asse II mine is based on developing a necessary understanding of the current state of the mine and its future evolution, as well as the methods and techniques that could be used to gain access to and ultimately retrieve the radioactive waste. Only situations presenting unacceptable risk from a mine safety or radiological exposure perspective will be considered as suitable grounds for discontinuing the retrieval programme. According to § 57b of the AtG the retrieval (as well as related measures carried out prior to closure) does not require a Plan approval (i.e. licensing by the competent authority in Lower Saxony) However, operational safety considerations are paramount in the planning and ultimate execution of retrieval operations. Plans for realizing retrieval are being developed by BGE and will be shared with the supervisory and licensing authorithies (BfE and NMU) as well as with local stakeholders as they evolve. The radiation exposure associated with the retrieval (at each individual step) can be assessed with the detailed retrieval plans. During the entire retrieval process, the general principles and requirements of radiation protection are strictly observed.

Morsleben disposal facility for radioactive waste

Closure planning was never part of the operating licence granted for the ERAM facility at Morsleben. In order to finally close the disposal facility it will be necessary to obtain plan approval from the competent Land authority of Saxony-Anhalt. Application documents for closure, together with a post-closure safety assessment, were originally submitted by the former operator in 2009. This led to a prolonged administrative process, culminating in a review and statement by ESK in 2013 regarding the compliance of the long-term safety case that had been developed for the facility with state of the art in science and technology. Since then, the former operator and now BGE have worked with contractors to update the post-closure safety case to reflect modern standards approaches to safety assessment (e.g. with respect to the management of uncertainties) as well as determining design criteria to be applied for the installation and performance of closure barriers. The present stage of development work in relation to the safety case is aimed at gaining assurance in the comprehensive closure concept and preparing for the submission of revised application documents for plan approval in 2026.

Konrad facility

As noted above, the operator voluntarily initiated in 2017 a comprehensive review of safety assessments relating to both the operational and long-term safety performance of the Konrad facility. Outcomes of this process to date confirm the primary assumptions that underlie the definition of waste acceptance criteria for waste packages (for the most part based on operational safety considerations) and the post-closure radiological safety assessment undertaken prior to plan approval in 2002. The latest version of waste acceptance criteria for the facility was defined in 2014 and is currently under revision. It is planned that a further ‘as-built’ update to safety assessment documentation will be prepared ahead of disposal of the first active waste packages, relying in part on the outcomes of non-active commissioning of the facility’s systems and components. Any necessary licence amendments reflecting modifications

to the original reference design as well as changes in regulations will be taken into account. According to the plan approval, a final post-closure safety assessment, as well as concrete verification of emplacement and backfilling operations, must be provided prior to approval of the final operational and closure plan.

Site selection

The site selection procedure associated with development of a geological disposal facility in Germany for HLW waste is defined in the Site Selection Act (*Standortauswahlgesetz*). The process as defined in the act is based primarily on the application of specified geological criteria based on increasingly detailed levels of available information. Nevertheless, proposals have been published by BMU for two ordinances in support of implementation of the Act, These cover: (i) safety requirements for disposal (*Endlagersicherheitsanforderungsverordnung*), and (ii) requirements for carrying out preliminary safety investigations in the site selection procedure (*Endlagersicherheitsuntersuchungsverordnung*). It is noted that these requirement are not related to a licensing procedure but anyway constitute a legal requirement. At the same time, BGE, which is responsible for implementing the procedure, plans to be using safety assessments alongside the legally-defined procedures under the Site Selection Act in order to guide comparison and development of disposal facility concepts for different geological formations, as well as to assess the potential for disposal of NHGW in suitable formations that might ultimately be judged the best possible for disposal of heat-generating waste. The regulatory authority, BfE, is also developing competence in performance assessment for geological disposal of heat generating waste, in order to guide verification and assessment of safety analyses undertaken by BGE.

ARTEMIS observation

The German perspective on the various roles of safety cases and supporting safety assessments outside the formal licensing process is consistent with the perspectives expressed in IAEA safety guides (see for example IAEA SSG-23, para. 4.20–4.21). The ARTEMIS Review Team considers that the scope of work being undertaken, or planned to be undertaken, in relation to developing, maintaining and examining safety cases and supporting safety assessments is appropriate.

To be of full value, it is important that there should be a measure of flexibility in developing and using safety assessments alongside the development of plans for geological disposal, in a way that is not constrained by delivery against specific regulatory or legal requirements. For example, it will be a significant challenge for BGE to make appropriate use of safety assessments as part of a site selection process that is driven almost exclusively by prescribed geological criteria. Generic assessments based on general concepts for alternative geological environments, built on assumptions owing to sparse data, need to be undertaken in a way that informs and guides the process defined in legislation, rather than adding unnecessary and potentially confusing detail.

The potentially large number of separate configurations of concept and geological environment to be assessed will also potentially present challenges for consistency in how the assessments are made and the results interpreted in the context of site selection. Questions may arise, for example, when deciding how to define a disposal concept, which disposal concepts to consider, which disposal concepts to associate with which types of geology. There will also be challenges regarding how to assess and compare, on an objective basis, the safety of combinations of disposal concepts and geologies at the regional, sub regional, or site based level, during the three phases of the site selection process.

BGE suggested in discussions during the ARTEMIS mission that the emphasis of such assessments, particularly at an early stage, is likely to be on developing understanding and guiding programmes for site exploration, rather than direct comparisons of safety assessments for different disposal concepts at different sites. The ARTEMIS Review Team considers this to be an appropriate approach.

The ARTEMIS review team anticipates that safety and performance assessment will need to be undertaken to support concept understanding, selection and development. The ARTEMIS Review Team is aware that the German programme has previously conducted research and safety assessments on various disposal concepts and has considerable knowledge and experience that can be brought to the new site selection process. It will be challenging to undertake such safety assessment work, in the context of concept development, in parallel with the prescribed site selection process. Documentation by BGE of its approaches and plans for disposal concept development, including their relationship to safety assessments and safety case development, would be an appropriate basis for commencing early regulatory dialogue with BfE on these matters.

The ARTEMIS Review Team notes the role that has been played over the years by the ESK, an independent advisory body to BMU, in preparing guidelines reflecting state-of-the-art considerations for the safe storage and management of spent fuel as well as the storage and disposal of radioactive waste. It is understood the specific role to be played by ESK guidance in relation to site and concept selection for the disposal facility for heat-generating waste remains to be determined.

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

German position

Financing of spent fuel and radioactive waste management in Germany is based upon the polluter-pays principle. According to §9a Para. 1 of AtG, the facility operators are responsible for making provisions for management of waste resulting from their activities, both in the case of commercial NPPs and public sector facilities. Cost estimation and financing procedures differ between the private and public sectors.

BMU is responsible for defining Germany's National Programme, which was published in 2015 in line with the requirements of the *Waste Directive*. The Programme describes how national strategy for a responsible and safe management of spent fuel and radioactive waste is implemented and periodically reviewed (at least once every ten years from the date of first preparation - 23 August 2015 or in the case of decisive changes).

The National Programme includes: (§ 2c Para. (2) 8, 9 AtG):

'8.) an assessment of the costs of the national waste management programme and the underlying basis and assumptions for that assessment including a presentation of the profile over time of the anticipated cost trend;

9.) the financing schemes in force.'

The abovementioned information is reported in the 'Report on the cost and financing of the disposal of spent fuel and radioactive waste' (Cost Report) and is based on data provided by facility operators.

The first 'Cost Report' was published in 2015 and is currently under revision. The report provides cost estimates and financing schemes differentiated according to public and private sectors. Estimated disposal costs are provided for existing or planned disposal facilities.

Requirements on specific cost estimating methodologies to be applied in Germany are not prescribed in nuclear legislation, and in practice the estimating procedures differ depending on the radioactive waste producer/facility, and on whether the operator belongs to the private or public sector.

Financing within public sector (e.g. for nuclear research centres, research reactors and publicly-owned reactors) is generally based upon an arrangement in which the Federal Government and/or the relevant Land bears all costs in a fixed proportion; some exceptions apply where public-private partnerships occur (e.g. WAK, THTR 300). Financing of waste disposal takes place in compliance with EndlagerVlV and financing regulations according to the Site Selection Act.

Radioactive waste generated by the non-nuclear industry, medical, research and education must be delivered to the Land collecting facilities for its long term management. These facilities, operated by the Länder, are financed by fees charged to operators upon waste acceptance according to §21a Para. 2, Clause 2, of AtG. The fees are intended to cover all expenses associated with the subsequent management of the waste, applying the cost recovery principle. Additional costs (e.g. due to the unavailable disposal facility and old radioactive waste stocks) resulting from operation of the facilities will be paid by the relevant Land and then reimbursed by the Federal Government. A percentage of fees levied by the Land collecting facilities is related to radioactive waste disposal and is paid directly to the Federal Government (cf. EndlagerVlV).

After the phase-out decision in 2011, significant changes in the field of radioactive waste management financing in the private operator sector have been applied.

In 2017 the Act on the Reorganisation of Responsibility in Nuclear Waste Management (*Gesetz zur Neuordnung der Verantwortung in der kerntechnischen Entsorgung*) came into force together with the Waste Management Fund Act (*Gesetz zur Errichtung eines Fonds zur Finanzierung der kerntechnischen Entsorgung* - EntsorgFondsG) and the Waste Management Transfer Act (*Gesetz zur Regelung des Übergangs der Finan-zierungs- und Handlungsplichten für die Entsor-gung radioaktiver Abfälle der Betreiber von Kernkraftwerken (Entsorgungsübergangsgesetz)*. These Acts regulate the transfer of obligations for financing and responsibility for storage and disposal of radioactive waste from commercial NPP operators to the state-owned company BGZ. This transfer of responsibilities took effect following the payment of contributions stipulated in the EntsorgFondsG (€24.1 billion - basic amount including a risk premium). In 2018 the Waste Management Fund was created using the payment from the NPP operators to the Federal State; the Fund collects, deposits and disburses the funds in accordance with the EntsorgFondsG.

Following the payment of the contributions to the Waste Management Fund by the commercial NPP operators, then, according to the Act on the Reorganisation of Responsibility in Nuclear Waste Management, the operators are responsible only for decommissioning and dismantling of their own facilities, as well as for processing and packaging of radioactive waste in line with acceptance criteria established by BGE; they are no longer responsible for the costs of storage of conditioned waste packages or for disposal. Accordingly, they remain responsible for determining the amounts of necessary provisions to meet their remaining responsibilities in accordance with the Commercial Code.

BGZ financing is provided from the State Budget and, on an annual basis, reimbursed by the Fund for the Financing of Nuclear Waste Management. Financial arrangements for establishment of disposal facilities for radioactive waste are managed according to Disposal Prepayment Ordinance (EndlagerVlV) and commercial operators' liabilities have been transferred to the Fund.

There are other nuclear fuel cycle facilities or nuclear installations that are commercially operated (e.g. Urenco plant, ANF) and for which the residual waste costs are not covered by the Waste Management Fund Act (EntsorgFondsG). The operators of these facilities are required to set aside financial provisions for future disposal of residual waste in geological formations in accordance with commercial law.

ARTEMIS observation

The German legal framework for management of spent fuel and radioactive waste is well defined and implements the polluter-pays principle. National regulations for the waste management process ensure that roles and liabilities are identified and establish a mechanism to ensure that adequate financial resources are set aside to cover future obligations associated with safe decommissioning and waste management.

With reference to the Cost Report, part of the National Programme, the ARTEMIS Review Team notes that the report does not reflect current progress in the implementation of the National Programme and does not provide a complete overall cost assessment. As examples, the ARTEMIS Review Team has been informed that costs for Asse II mine waste retrieval and ZBL facilities are not included. A cost estimate for ZBL is available but has not been published while the cost estimate for the radioactive waste retrieval process from the Asse II mine is not yet available.

Cost figures are provided in 2012/2013/2014 prices and are based on a legal framework that has been largely superseded by the Act on the Reorganisation of Responsibility in Nuclear Waste Management of 2017 and subsequent regulations.

The Konrad facility cost estimate does not reflect the updated project schedule (expected operation in 2022 and postponed to 2027) and the cost estimate for the disposal facility for HLW does not consider the impact of outcomes from Commission on Storage of High-Level Radioactive Waste.

The ARTEMIS Review Team recommends that BMU should update the cost assessment for the National Programme in the Cost Report, in order to include all the activities foreseen and provide a complete overview of the costs.

It was also noted that the cost figures provided in the Cost Report in some cases have a different basis and assumptions. In order to provide consistency between such estimates prepared by different operators, the ARTEMIS Review Team considers that BMU should implement a common reporting approach (assumptions and basis). BMU should also consider updating the Cost Report more frequently (less than 10 years) with additional details on assumptions and cost breakdowns. More detail would both improve document clarity and transparency.

With reference to Asse II mine waste, the ARTEMIS Review Team recognizes the significant challenges associated with the project and the efforts being made in the preparation of the specific plan on how to realize the retrieval of radioactive waste. This plan, to be published by BGE towards the end of 2019, will however not include the costs of retrieval. Currently, BGE estimates the costs for the preparatory activities planned from 2019 to the beginning of retrieval in 2033 at around € 3.35 billion (+/- 30 %).

Despite the challenge of developing cost estimates for the radioactive waste retrieval activity, the ARTEMIS Review Team considers that such cost information is needed to provide a full understanding of the challenges associated with implementation of the project in accordance with current legal requirements.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *The 2015 Cost Report, part of Germany's National Programme, does not reflect current progress in the implementation of the National Programme and does not include a complete overall cost assessment (e.g. retrieval of Asse II mine waste, ZBL).*	
(1)	**BASIS: GSR Part 1 (Rev. 1) Requirement 10, para. 2.33 states that** *"Appropriate financial provision shall be made for:* *(a) Decommissioning of facilities;* *(b) Management of radioactive waste, including its storage and disposal;* *(c) Management of disused radioactive sources and radiation generators;* *(d) Management of spent fuel."*
(2)	**BASIS: GSR Part 6 Requirement 9, para. 6.2 states that "***The cost estimate for decommissioning shall be updated on the basis of the periodic update of the initial decommissioning plan or on the basis of the final decommissioning plan. The mechanism used to provide financial assurance shall be consistent with the cost estimate for the facility and shall be changed if necessary."*
(3)	**BASIS: GSR Part 6 Requirement 4, states that** *"Responsibilities of the government for decommissioning* *The government shall establish and maintain a governmental, legal and regulatory framework within which all aspects of decommissioning, including management of the resulting radioactive waste, can be planned and carried out safely. This framework shall include a clear allocation of responsibilities, provision of independent regulatory functions, and requirements in respect of financial assurance for decommissioning. […]* *— Establishing a mechanism to ensure that adequate financial resources are available when necessary for safe decommissioning and for the management of the resulting radioactive waste."*
R2	**Recommendation: BMU should update the cost assessment for the national waste management programme in the Cost Report, based on a consistent approach across all activities, including waste retrieval from Asse II mine.**
S11	**Suggestion: BMU should consider updating the Cost Report more frequently (less than 10 years) with additional details on assumptions and cost breakdowns.**

With reference to the cost estimation process, cost estimates are developed by facility operators in both the public and private sectors. For private sector operators a specific presentation was made by RWE Nuclear on their estimating process: bottom-up techniques are applied and risks are included. Uncertainties and risks are assessed by probabilistic and deterministic approaches. Nuclear sector specific cost increases for inflation are applied.

The NPP operators are regulated under commercial law and are obliged to report once a year

to BAFA[4] the amount of their provisions to cover their future liabilities, including forecasts of expenses in future years.

Cost estimates in the public sector are developed by operators according to the requirements of the responsible authority/shareholders. A specific presentation was made by KTE on their cost estimation process.

The ARTEMIS Review Team notes that risk and uncertainty analyses are not undertaken as part of the cost assessment for all public sector components of the National Programme. Information provided to the team showed differences in Project Cost Estimate (PCE) calculations: for example, in the case of KTE uncertainty and risk analysis and cost escalations are not included in their PCE.

In addition, according to the ARM documentation and the discussion during the meeting, there are areas of cost estimation, in particular for the public sector storage and disposal activities, which are subject to high levels of uncertainty. For example, the Konrad, Morsleben and HLW disposal facility cost estimates appear to be very preliminary with significant uncertainty.

Taking into account that the public sector includes several types of operators (universities, public companies and non-profit companies) and that not all estimates include uncertainty and risk evaluation, the ARTEMIS Review Team considers that the Government should analyze risk and uncertainty when updating the cost assessment for the whole of the National Programme.

With reference to the funding system in Germany and the redefinition of radioactive waste management responsibilities after the phase-out, the new arrangements provide increased security in financing in the long term due to the split of provisions for waste storage and disposal from the financial stability of the private operators. The ARTEMIS Review Team notes that, notwithstanding the risk premium paid by private operators, the Government still faces a risk that the cost of storage and disposal of radioactive waste will be greater than the money accumulated in the Fund. This is because costs estimates and interest rate risk are difficult to assess over such a long time frame.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *Risk and uncertainty analyses are not undertaken as part of the cost assessment for all public sector components of the radioactive waste and spent fuel management programme.*	
(1)	**BASIS: GSR Part 1 (Rev. 1) Requirement 10, para. 2.33 states that** *"Appropriate financial provision shall be made for:* *(a) Decommissioning of facilities;* *(b) Management of radioactive waste, including its storage and disposal;* *(c) Management of disused radioactive sources and radiation generators;* *(d) Management of spent fuel."*
(2)	**BASIS: GSR Part 6 Requirement 9, para. 6.2 states that** *"The cost estimate for decommissioning shall be updated on the basis of the periodic update of the initial decommissioning plan or on the basis of the final decommissioning plan.*

[4] Bundesamt für Wirtschaft und Ausfuhrkontrolle

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
	The mechanism used to provide financial assurance shall be consistent with the cost estimate for the facility and shall be changed if necessary."
(3)	**BASIS: SSG-47 para. 6.5 states that** *"The cost estimate for decommissioning should cover all actions required to plan and perform the decommissioning. There will be additional costs for other actions, which might be included as part of the decommissioning, depending on the national legal framework. These typically include financing for the management of waste from operation, pre-decommissioning actions during the transition phase, waste storage and disposal, and spent fuel management."*
(4)	**BASIS: SSG-47 para. 6.8 states that** *"With regard to the accuracy and associated uncertainties of the decommissioning cost estimate, there are typically three types of cost estimate made during the lifetime of the facility:* • *An order of magnitude estimate — this type of cost estimate can be utilized prior to receiving the operating licence and is based on the initial decommissioning plan.* • *A budgetary estimate — this type of cost estimate is based on the data provided in revisions of the decommissioning plan.* • *A definitive estimate — this type of cost estimate can be utilized after the completion of detailed planning of the decommissioning actions, and is based on the data provided in the final decommissioning plan and in the associated working level documentation (procedures)."*
(5)	**BASIS: SSG-47 para 6.10 states that** *"Cost estimates and financial provisions should be reviewed periodically and should be adjusted as necessary to allow for proper consideration of inflation and other factors, such as technological advances, waste management costs or regulatory changes, especially in the case of a deferred dismantling strategy where decommissioning might be completed only decades after shutdown of the facility."*
R3	**Recommendation: The Government should analyse risk and uncertainty when updating the cost assessment for all public sector components of the radioactive waste and spent fuel management programme.**

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

German position

The Federal Government ensures that the requirements for experts that are responsible for the safety of spent fuel and radioactive waste within the national framework are met with regard to education and training. The public vocational training system in Germany allows for the recruitment of skilled workers, foremen, technicians, engineers and scientists with the prerequisite technical background. This is usually documented by state-approved certificates and proof of expertise and skills are furnished on the basis of the relevant guidelines on technical qualification. Expertise is demonstrated in a number of ways, including meeting educational and training requirements, completing the initial qualification and additional training, the acquiring of practical experience and, depending on the intended area of work, passing required examinations. Technical qualifications are renewed by attending courses and training at specified intervals. The training and further qualification of expert staff of authorities and authorised expert organisations is, for example, the objective of the training events offered by the GRS within the framework of its seminars. There are seminars on various relevant topics including fundamentals of reactor physics, nuclear fuel supply and radioactive waste management, prominent events/incidents/accidents in nuclear facilities, International Nuclear Event Scale (INES) User Manual of the IAEA, fundamentals of radiation protection, radiation emergency preparedness, external hazards, regulatory supervision of the operation of nuclear reactors, legal and technical nuclear standards, selected topical issues of the nuclear licensing and supervisory procedure, fire protection in nuclear power plants, operation management of nuclear power plants, and decommissioning of nuclear facilities.

In order to maintain the necessary expertise in the areas of nuclear technology and radiation protection, the Alliance for Competence in Nuclear Technology (Kompetenzverbund Kerntechnik (KVKT)) of German research institutes was founded in March 2000 in association with the Energy Research unit of the Helmholtz Association of German Research Centres (HGF), which brings together research facilities in the area of nuclear safety. The Alliance for Competence in Nuclear Technology coordinates tasks in the area of reactor safety and disposal research and contributes to maintaining the competence through analysing the training situation and future staffing needs. In addition to the education and training programmes of Germany, the education and training opportunities offered by the European Nuclear Safety Training and Tutoring Institute (ENSTTI), are available to all staff members of the authorities and technical expert organisations. Participation in national and international conferences and initiatives (e.g. OECD-NEA, IAEA, WENRA) also serve to increase the knowledge and exchange of experience.

With regards to the regulator, public service employees are required to have relevant academic qualifications and to have passed the corresponding examinations. Moreover, the competent regulatory body conducts scientific research in the areas of planning, approval, and supervision of federal facilities for the safekeeping and disposal of radioactive waste, the management of radioactive waste, the transport and storage of radioactive substances and waste and the nuclear safety. The BfE Research Strategy defines sustainable, long-term competence building as one of the key objectives of its research activities. This not only includes measures for competence building within BfE but also measures for external competence building in research institutes, universities and TSOs. Newly recruited staff members take part in the knowledge transfer of the nuclear licensing and supervisory authorities. They receive training on the basis of individual plans. Each individual’s on-the-job training plan comprises different training and further qualification measures in all relevant technical and legal areas. This ensures that newly

employed personnel are trained to fulfil their nuclear safety related tasks. Additionally, experienced staff are obligated to maintain or develop their knowledge and skills and keep their technical qualification continuously up to date.

With regards to the operators, the licence holder is required to provide for and maintain adequate human resources. All licence applications for construction, operation, decommissioning or a major modification are accompanied by the proof of the qualification of the responsible persons and staff engaged in the operation of the facility, and are reviewed by the regulator. Furthermore, the license holder is obliged to provide education and further training of their personnel. The safety management system must ensure that persons are only entrusted with tasks for which they are trained and competent. This applies to all levels of responsibility. Clear requirement profiles are prepared for all activities with safety relevance, including the criteria against which the respective competencies are to be assessed. This includes documentation of how the specific incumbents of the positions fulfil these requirements. For every safety-relevant task, an adequate number of suitable individuals must be available.

ARTEMIS observation

Although Germany has taken the decision to phase out nuclear power, expertise will be needed for many decades to support decommissioning and management of radioactive waste and spent fuel. Presentations were provided on Germany's approach to preserve expertise and build capacity in the areas of nuclear safety and radiation protection. Based on the present Coalition Agreement, BMU, BfE, BfS, BGE, BGZ and KTE, in coordination with the Federal Ministry of Education and Research (BMBF) and the Federal Ministry for Economic Affairs and Energy (BMWi) began developing a concept for the preservation of specialist knowledge and development of competence for the operation, dismantling and safety of nuclear facilities as well as for storage and final disposal. There is the possibility that the concept could be later expanded to include other parties such as EWN and the Länder.

The approach being pursued involves an assessment by each organization against a number of "pillars". The pillar structure is based on the IAEA's Strategic Approach to Education and Training in Nuclear Safety 2013–2020 and consists of: Education and training; Further education and training; Knowledge base; Committee work and networks; Research and development. The assessment also includes a demand analysis of identified key competencies for each organization (e.g. safety analysis and concepts, execution of site selection procedure, supervision of site selection, public participation, etc) which will inform future staffing needs and allow strategic investments to develop and maintain critical skills. This demand analysis extends to the medium term (2031) and long term (2050) which represent key milestones in the HLW geological disposal facility programme. The result of this project is expected in mid-2020. It was noted that this effort is responsive to a suggestion (S4, section 1.8) from the recent IRRS review, specifically that, '*The government should consider establishing a comprehensive plan, in consultation with relevant parties, for the project on German competence needs during future decades.*'

Through this effort, a number of initiatives regarding the preservation of expertise and knowledge management have been initiated or are contemplated. Examples include: using mentoring programmes to support personal and professional development opportunities; supporting employee exchanges to provide experiences in different parts of the company; capturing lessons learned and expertise from expert staff before they enter retirement; as well as developing a new BGZ Academy for the Management of Radioactive Waste. There is also an ongoing initiative at BGE to establish a Knowledge Archive for the disposal of radioactive

waste. This is being done by gathering all available research reports and scientific publications dealing with the disposal of radioactive waste in geological formations and scanning them to create a digital database. Text analysis software enhances accessibility and the ability to conduct document queries. However, according to § 38 StandAG, the BfE is responsible for permanently storing data and documents that are or might become relevant for the storage and disposal of radioactive waste. The ARTEMIS Review Team understands that details will be specified by an Ordinance. Germany also intends to maintain its strong commitment to participation in international organizations as a mechanism to maintain expertise and build capacity. This includes participation in the CNS and JC review process, numerous standing committees with the IAEA and NEA, WENRA, and others. Germany also has bilateral arrangements with a number of countries including France, Switzerland, Austria, and many others. While the ARTEMIS Review Team recognizes that some of these activities are at an early stage, the overall approach is found to be reasonable and appropriate.

BGE indicated that approximately 50% of their staff will be eligible to retire within the next 10 years. The corresponding value for BGZ was 42% and some other organizations are expected to have similar profiles. The nuclear phase out policy could potentially make recruiting replacement staff challenging if they do not see a viable career. It was also noted that the mining sector had declined in Germany and care would also be needed to maintain this competency. To date, the various organizations indicated they have been successful in obtaining and retaining suitable candidates. However, continued vigilance into the future will be necessary.

Finally, the team had an opportunity to meet with one of the NPP operators to discuss building and maintaining capacity as they transition from operations to decommissioning. The German system allows for the continued employment of all operating staff of the NPP after the cessation of power operations. Provisions are made for appropriate training for the existing staff to prepare for decommissioning activities. The ARTEMIS Review Team notes that the activities and focus of a facility undergoing decommissioning are very different from that of an operating NPP and that changing the safety culture and mindset of the workforce can be a challenge and requires repeated reinforcement.

Research activities

Another theme discussed was engagement with universities and research institutions as a means to develop capacity and recruit new staff. Activities being undertaken or explored include: supporting academic education by offering lectures on regulatory topics or subject matters for theses; establishing additional professorships for nuclear safety research; establishing graduate schools for disposal; cooperating with universities for the establishment of degree programmes for ‘Nuclear Safety‘ or ‘Mining with focus on disposal‘; conducting periodical fora or conferences for developing and evaluating research programs; establishing a collaborative research centre for special topics concerning disposal, etc. The ARTEMIS Review Team was informed that approximately € 90 M was expended each year on nuclear safety research with approximately € 40 M of that total being associated with waste management projects and € 14 M supporting students and young scientists. These funding levels in the federal budget have been generally stable over the last several years. It was noted that the various waste management organizations, as well as ministries independently sponsored research activities. Recognizing that the regulator must retain an independent capability, there appears to be an opportunity to strengthen and further enhance the coordination of research, development and demonstration activities to ensure they are commensurate with the needs of waste management operators and regulators.

RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES	
Observation: *The various organizations involved in radioactive and spent fuel management independently pursue research programmes.*	
(1)	**GSR Part 1 (Rev. 1) Requirement 10, para 2.32 states that** *"The government shall make provision for appropriate research and development programmes in relation to the disposal of radioactive waste, in particular programmes for verifying safety in the long term."*
(2)	**GSR Part 1 (Rev. 1) Requirement 10, para 4.45 states that** *"In the process of its review and assessment of the facility or activity, the regulatory body shall take into account such considerations and factors as: ….* *(15) Relevant research and development plans or programmes relating to the demonstration of safety;"*
S12	**Suggestion: The Government should consider enhancing the coordination of research, development and demonstration activities for the management of spent fuel and radioactive waste to ensure they are commensurate with the needs of waste management operators and regulators.**

APPENDIX A: TERMS OF REFERENCE

1. Introduction

On 1 June 2017, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany requested the IAEA to organize and carry out, in the second half of 2019, an Integrated Review Service for Radioactive Waste and Spent Fuel, Decommissioning and Remediation (ARTEMIS) Review of the national programme and framework of Germany, as required of all EU Member States by 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.

2. Objective

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

The review, organized in the IAEA by the Department of Nuclear Safety and Security and the Department of Nuclear Energy, will be performed on the basis of the relevant IAEA Safety Standards and proven international practice and experiences, by an international peer review team selected by the IAEA.

3. Scope

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

Special emphasis should be given to the following topics:

- restructuring of financial and waste manangement responsibilities;
- commissioning of the Konrad facility;
- site selection process for the new disposal facility, including research, transparency and public engangement;
- decommissioning projects and strategy and associated waste management; and
- waste management implications of the retrieval from Asse II mine.

It was agreed to exclude residues from mining and milling as well as NORM in accordance with the 2011/70/Euratom directive.

Results from the 2019 IRRS mission to Germany will be taken into account as far as possible.

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 National Counterpart for the considered scope of the review, with a focus on the national programme, as well as the results of self-assessment, which should be based on the provided questionnaire.

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

6. Modus operandi

The working language of the mission will be English.

The National Counterpart is the Federal Ministry for the Environment, Nature Conservationand Nuclear Safety. The National Counterpart Liaison Officer for the review is Mr Thomas Pissulla.

- Self-assessment questionnaire: available to Germany as of 16 April 2018
- Preparatory Meeting: 16 to 17 January 2019, Cologne, Germany
- Reception of documents: end of June 2019 (including results of self-assessment)
- Peer review mission: 22 September to 4 October 2019
  - Sunday: arrival of experts and their meeting
  - Monday to Friday: interviews/exchange/discussion with Counterpart(s) on the basis of preliminary analysis and drafting of recommendations and suggestions
  - Saturday-Sunday: drafting and delivering of the draft report (Review Team)
  - Monday: site visits, fact checking by Counterpart(s)
  - Tuesday-Wednesday: discussions – finalization of draft report
  - Thursday: preparation of the final presentation and press release, executive summary (German national holiday)
  - Friday: Exit meeting

7. International peer review team

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

- Eight qualified and recognized international experts from government authorities, regulatory bodies, waste management organizations, and technical support organizations with experience in the safe management of radioactive waste and spent fuel;
- Two IAEA staff to coordinate the mission. The Coordinator of the ARTEMIS review, Mr David Bennett of the Waste and Environmental Safety Section is from the Department of Nuclear Safety and Security. The deputy coordinator, Mr Patrick O'Sullivan of the Waste Technology Section is from 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.

The peer review team will be led by a Team Leader from the review team. The Team Leader will be assisted by a Deputy Team Leader, also from the review team. 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 in advance of 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 the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

9. Funding

The peer review will be funded by Germany. 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 peer review were paid to the IAEA as voluntary contribution.

If the actual costs of the peer review exceed the initial voluntary contribution, Germany agrees to cover such additional costs to the IAEA. In the same way, if the actual costs are inferior to the initial voluntary contribution, excess will be refund to Germany.

Germany agrees with these Terms of Reference by accepting necessary arrangements.

Signed on behalf of IAEA: Dr David Bennett, IAEA, Vienna, 28.02.2019

Signed on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany: Dr Thomas Pissulla, BMU, Bonn, 18.02.2019

APPENDIX B: MISSION PROGRAMME

Time	Sun 22 Sept	Mon 23 Sept	Tue 24 Sept	Wed 25 Sept	Thurs 26 Sept	Fri 27 Sept	Sat 28 Sept	Time	Sun 29 Sept	Mon 30 Sept	Tues 1 Oct	Wed 2 Oct	Thurs 3 Oct	Fri 4 Oct
09:00		Entrance Meeting	National Strategies & Programmes	Costs & Financing	Capacity Building	Review Team finalize draft Suggestions & Recommendations	Report drafting. Draft Executive Summary & Press Release	09:00	Report drafting & delivery of draft report to Counterparts	Site Visit(s) and Review of draft report by Counterparts	Review of draft report by Counterparts. Free time for Review Team	Discussion of draft report with Counterparts to agree final wording	German National Holiday, Free time for Review Team	Exit Meeting
10:00								10:00						
11:00								11:00						
12:00		Lunch	Lunch	Lunch	Lunch	Lunch		12:00				Lunch		
13:00								13:00						
14:00	Initial Team Meeting at hotel	National Policy Framework	Waste and Spent Fuel Inventory	Concepts, plans and technical solutions	Safety Demonstration	Presentation of draft Suggestions & Recommendations to Counterparts		14:00			Discussion of draft report with Counterparts	Discussion of draft report with Counterparts to agree final wording		
15:00								15:00						
16:00								16:00	Travel for Site Visit(s)					
17:00								17:00					Social event (17:00 meeting at Main train station)	
18:00		Review team meeting	Review team meeting	Review team meeting	Review team meeting	Review team meeting		18:00						
19:00		Report drafting at hotel	Report drafting at hotel	Report drafting at hotel	Report drafting at hotel	Report drafting at hotel	City tour & dinner	19:00			Report drafting at hotel	Meeting at hotel to finalize the ES and Press Release, and to develop a presentation on Final Draft Report		
20:00								20:00						
21:00								21:00						
22:00								22:00						
23:00								23:00						

APPENDIX C: RECOMMENDATIONS AND SUGGESTIONS

Area		R:Recommendations S: Suggestions G: Good Practices	Recommendations, Suggestions or Good Practices
1.	**NATIONAL POLICY AND FRAMEWORK FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT**	R1	The Government should establish a process to monitor regularly the progress of the national decommissioning and radioactive waste and spent fuel management programme, including the associated costs, timeframes and interdependencies between projects.
		S1	Given the long timescales of the projects, the Government should consider establishing additional shorter-term interim targets as key performance indicators.
2.	**NATIONAL STRATEGY FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT**	S2	BGE, in consultation with BfE, as appropriate, should consider publishing the approach to applying the site selection criteria during all three phases in advance of the interim report on sub areas.
		S3	BGE, in consultation with BfE, as appropriate, should consider assessing whether the requirements on the geosphere for NHGW are different from those for HLW and, if they are, taking them into account in the approach to applying the siting criteria.
		GP1	The use of the National Civil Society Board as a mediating and independent body to accompany the site selection process.
		S4	BGE should consider publishing the safety-based conditions that would lead them to recommend that retrieval of waste from Asse II mine be discontinued.

Area		R:Recommendations S: Suggestions G: Good Practices	Recommendations, Suggestions or Good Practices
3.	**INVENTORY OF SPENT FUEL AND RADIOACTIVE WASTE**	S5	To improve transparency on how waste streams are being managed, BMU should consider including additional information and description on NHGW in future revisions of the radioactive waste inventory report.
		S6	BMU should consider making greater use of the radioactive waste inventory to monitor changes in the inventory over time and demonstrate waste minimization.
4.	**CONCEPTS, PLANS AND TECHNICAL SOLUTIONS FOR SPENT FUEL AND RADIOACTIVE WASTE MANAGEMENT**	S7	The Government should consider taking benefit from the construction and operation of the ZBL by enabling this facility to accept NHGW from all waste producers and thereby increasing flexibility within the National Programme for radioactive waste management.
		S8	BGZ should consider using the ZBL facility in order to remove all waste from sites where, after completion of decommissioning, only NHGW storage facilities will remain under operation to enable the entire sites to be released from regulatory controls.
		S9	The Government should consider identifying a contingency plan for the repair of storage casks and the removal of spent fuel elements in case of damage.
		S10	EWN should consider designing the new ESTRAL storage facility to have a lifetime consistent with the planned availability of the HLW disposal facility which is not expected to begin operation before 2050.
6.	**COST ESTIMATES AND FINANCING OF RADIOACTIVE WASTE**	R2	BMU should update the cost assessment for the national waste management programme in the Cost Report, based on a consistent approach across all activities, including waste retrieval from Asse II mine.

Area		R:Recommendations S: Suggestions G: Good Practices	Recommendations, Suggestions or Good Practices
	AND SPENT FUEL MANAGEMENT	S11	BMU should consider updating the Cost Report more frequently (less than 10 years) with additional details on assumptions and cost breakdowns.
		R3	The Government should analyse risk and uncertainty when updating the cost assessment for all public sector components of the radioactive waste and spent fuel management programme.
7.	**CAPACITY BUILDING FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT – EXPERTISE, TRAINING AND SKILLS**	S12	The Government should consider enhancing the coordination of research, development and demonstration activities for the management of spent fuel and radioactive waste to ensure they are commensurate with the needs of waste management operators and regulators.

APPENDIX D: LIST OF ACRONYMS USED IN THE TEXT

BfE	Federal Office for the Safety of Nuclear Waste Management (*Bundesamt für kerntechnische Entsorgungssicherheit*)
BfS	Federal Office for Radiation Protection (*Bundesamt für Strahlenschutz*)
BGE	Federal Company for Radioactive Waste Disposal (*Bundesgesellschaft für Endlagerung mbH)*
BGZ	Federal Company for Radioactive Waste Storage (*BGZ Gesellschaft für Zwischenlagerung mbH*)
BMBF	Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (*Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit*)
BMWi	Federal Ministry for Economic Affairs and Energy (*Bundesministerium für Wirtschaft und Energie)*
ERAM	Morsleben disposal facilty (*Endlager für radioactive Abfälle Morsleben*)
ESK	Nuclear Waste Management Commission (*Entsorgungskomission*)
ESTRAL	*Ersatztransportbehälterlager*
EWN	*EWN Entsorgungswerk für Nuklearanlagen GmbH*
GRS	*Gesellschaft für Anlagen- und Reaktorsicherheit gGmbH*
HLW	High Level Waste (sometimes referred to as Heat Generating Waste)
HTR	High Temperature Reactor
IAEA	International Atomic Energy Agency
KTA	Nuclear Safety Standards Commission (*Kerntechnischer Ausschuss*)
KTE	*Kerntechnische Entsorgung Karlsruhe GmbH* (part of EWN Group)
LWR	Light Water Reactor
NBG	National Civil Society Board (*Nationales Begleitgremium*)
NHGW	Waste with negligible heat generation (sometimes referred to as Negligible or Non Heat Generating Waste)
NPP	Nuclear Power Plant
UMBW	Ministry of the Environment, Climate Protection and the Energy Sector Baden-Württemberg (*Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg*)
WENRA	Western European Nuclear Regulators Association
ZBL	Central reception storage facility (*Zentrales Bereitstellungslager*)
ZLN	Interim storage north (*Zwischenlager Nord*)

APPENDIX E: IAEA REFERENCE MATERIAL USED FOR THE REVIEW

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Fundamental Safety Principles, Safety Fundamentals No. SF-1, Vienna (2006).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Governmental, Legal and Regulatory Framework for Safety, General Safety Requirements No. GSR Part 1 (Rev. 1), Vienna (2016).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Leadership and Management for Safety, General Safety Requirements No. GSR Part 2, IAEA, Vienna (2016).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for Facilities and Activities, IAEA Safety Standards Series No. GSR Part 4, IAEA, Vienna (2009).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Radioactive Waste, IAEA Safety Standards Series No. GSR Part 5, IAEA, Vienna (2009).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Facilities, IAEA Safety Standards Series No. GSR Part 6, IAEA, Vienna (2014).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Disposal of Radioactive Waste, IAEA Safety Standards Series No. SSR 5, IAEA, Vienna (2011).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Fuel Cycle Facilities, IAEA Safety Standards Series No. NS-R-5 Rev. 1, IAEA, Vienna (2014).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Energy Basic Principles, Nuclear Energy Series, NE-BP, Vienna (2008).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Radioactive Waste Management and Decommissioning Objectives, Nuclear Energy Series, NW-O, Vienna (2011).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Fuel Cycle Objectives, Nuclear Energy Series, NF-O, Vienna (2013).

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Policies and Strategies for Radioactive Waste Management, IAEA Nuclear Energy Series No. NW-G-1.1, IAEA, Vienna (2009).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Policies and Strategies for the Decommissioning of Nuclear and Radiological Facilities, IAEA Nuclear Energy Series No. NW-G-2.1, IAEA, Vienna (2012).

[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Policy and Strategies for Environmental Remediation, IAEA Nuclear Energy Series No. NW-G-3.1, IAEA, Vienna (2015).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, IAEA International Law Series No. 1, IAEA, Vienna (2006).

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Glossary – Terminology used in Nuclear Safety and Radiological Protection, IAEA, Vienna (2018).

[18] Official Journal of the European Union No. L 199/48 from 2nd Aug 2011, COUNCIL DIRECTIVE 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste, Brussels (2011).

APPENDIX F: SITE VISITS

Site visit to Kerntechnische Entsorgung Karlsruhe (KTE)

A site visit to KTE was organized for two experts of the ARTEMIS Review Team. This visit provided the opportunity to gain an overview of the decommissioning and waste management projects that are being conducted at the site. Significant progress has been made on most of the decommissioning projects. With the notable exception of the FR2 Research Reactor, which is currently under Safe Enclosure and for which decommissioning will start later, these projects should be completed in the mid-2030s.

Regarding radioactive waste management, storage capacity will have to be increased to facilitate the eventual transfer of packaged radioactive waste to the Konrad disposal facility. This transfer is expected to take some 40 years.

A new storage building is under construction to allow KTE to sort waste packages that are eventually to be sent to the Konrad disposal facility. Significant efforts are being made to reduce the volume of radioactive waste to be disposed of. The ARTEMIS Review Team was told by KTE that, by volume, only some 10% of the materials from decommissioning will be managed as radioactive waste. The balance is cleared.

Loading of drums of radioactive waste into an ISO container at the KTE storage facility (*courtesy of KTE*)

Waste treatment facility at KTE site (*courtesy of KTE)*

Site visit to the Konrad radioactive waste disposal facility

A site visit to the Konrad radioactive waste disposal facility was organized for eight experts of the ARTEMIS Review Team. This visit provided the opportunity to gain an overview of the preparations being made in the Konrad mine for the disposal of radioactive waste with negligible heat generation.

The Konrad mine is a former iron ore mine. Iron ore extraction ceased in the 1970s. A Plan Approval for the disposal facility was granted in 2002; this was subsequently challenged in court before being finally confirmed in 2007. Although construction works began in 2007, radioactive waste emplacement has not yet begun. Given this background, the ARTEMIS Review Team was interested to understand the work being undertaken and why the schedule for radioactive waste emplacement had been delayed.

BGE explained that the long term safety of the disposal facility will largely be provided by the geology and, in particular, by the thick clay formations above the iron ore in which the disposal facility will be situated. Conditions underground are very dry. Given this, BGE is currently working to ensure and improve aspects related to operational safety (e.g. installing structural components to a standard that will enable safe waste emplacement over the facility's projected operational lifetime; installing fire protection). The old buildings will be removed and new facilitites constructed. Additional activities include installing new hoists and cages, and replacing all wooden and old iron structures in the shafts. The new north hoist should come into operation in 2022. The annual budget for work at Konrad is currently approximately €200 million.

Project delays have arisen for several reasons. Many of these are typical of large-scale public projects, but some are specific to the unique nature of the project, which involves converting old mine workings at considerable depth into a radioactive waste disposal facility. For example, it has been difficult to refurbish the old mine shaft while also operating the mine at the same time. The connection of the new disposal facility to shaft number 2 has been especially challenging, and the construction of large diameter tunnels, including in some cases the enlargement of the diameter of the former mine tunnels, generally requires extensive engineering measures to manage the high rock stresses at depth. The large size of the tunnels relates to much larger containers, handling equipment and vehicles used when handling radioactive waste compared with the infrastructure formerly used during mining operations. Further significant project difficulties have arisen due to arrangements for contract management. The requirements for nuclear safety are stricter than the regulations for mining safety. It has been difficult to find contractors with suitable capabilities and experience in both mining/tunnelling and radioactive waste management/nuclear safety.

A view of disposal facility excavations at Konrad illustrating the large diameter of the tunnels, and showing the use of extensive rock support in the form of rock bolts and iron mesh (*courtesy of BGE*).