

Future German R&D on HLW Disposal - 16519

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ABSTRACT

In 2009, after the General elections, the new German Government showed a relatively positive attitude towards a prolonged use of nuclear power. Power plant shut-down was planned for the year 2032. Nuclear power was considered as a sort of transition energy technology until the energy supply would take place by the use of renewable energy sources. This was in line with the legal framework and the political strategy of the energy turnaround. Then, 17 nuclear power plants (NPP) were operational.

The Fukushima incident heralded the sound of drastic changes in the German energy policy: Besides an intermediate stop of operation of reactors until a so-called stress test was accomplished, the general political decision was to phase-out nuclear earlier than planned and to implement faster the decisions regarding the energy transition policy. The shut-down of the last German nuclear power plant will occur in 2022. Accordingly, all the necessary legal changes were made.

A consensus about the appropriate waste management strategy for heat generating waste (spent nuclear fuel (SNF) and vitrified waste (HLW)) was still pending at this time. Public and political discussions on this subject continued as in the years before.

In July 2013, after intensive discussions, most of the parties represented in the German parliament agreed to eventually tackle the challenge of finding a repository by a consensual, transparent and science-based approach. This was to be codified in a law. In July 2013, the Site Selection Act passed the parliament. This law should pave the way for a new holistic process that addresses social, political, and scientific aspects of siting and the site selection process. The basics for this process should be provided by the "Commission Storage of Radioactive Waste Materials" which was established according this law.

Against this background discussions showed that scientific-technical R&D activities should be mirrored accordingly and R&D has to deal both with the future challenges of radioactive waste HLW disposal and related aspects.

Considering this the Federal Ministry for Economic Affairs and Energy (BMWi), which is responsible for non-site specific R&D, created the new Research Concept "Research for the management of radioactive waste", being fundamental and the frame for non-site specific R&D projects funded by BMWi. Key changes – mirroring the new requirements and different aspects – touch the issues: host rock research, i.e. all potential host rocks available in Germany are equally addressed and there is no prioritization, consideration of consequences of prolonged storage at NPP sites, alternative waste management strategies compared to direct disposal in a mined repository, and involvement of socio-technical aspects.

This paper intends to highlight the key changes, its consequences, and will give a brief overview on first initiated R&D activities.

INTRODUCTION

The frame governing the topic of German waste management and R&D activities is given by European and national requirements.

At European level the EC-Directive "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" [1], is normative and has to be implemented by national legislation of the EU member states.

At national level both the Atomic Energy Act (AtG) [2], which was especially amended to implement the requirements of the EC-Directive (i.a. an national waste management program, clear responsibilities, waste inventory), and the Site Selection Act [3] are forming the legal boundaries.

Besides these laws, the so-called National Waste Management Program (NaPro) [4], required in Article 14 (1) of the EC-Directive, is a further necessity. The Ministry of the Environment, Nature Conservation, Building and Reactor Safety (BMUB) is responsible for these laws and the NaPro.

When in July 2013 – after intensive and lively national discussions - the Site Selection Act was passed by the Bundestag (lower house of the German parliament) and the Bundesrat (upper house), it was considered as a very important national step towards a new and open way to deal with the controversially discussed and sometimes hotly debated issue of both radioactive waste management and the search for a suitable site hosting a suitable repository for German heat-generating waste. Despite concerns, the intra and inter partisan agreement and consensus paved the way for a legal basis for siting and the site selection process. It was commonly regarded as a joint effort to find a final solution for the management of highly radioactive waste in a common endeavor of the German society.

This is expressed in the objective of the Act to find a repository site by appropriate siting by a science-based and transparent process which guarantees the optimal safety for a compliance period of 1 M years in Germany, and for German radioactive wastes (SNF, HLW and some waste types not suitable for the Konrad repository) The Site Selection Act requires an unbiased as to the results site-selection process starting from a so called "white map". This means that all potential host rock types will be equally addressed and scrutinized and any priority for a special host rock type is removed.

In the law's articles important issues are addressed and regulated such as: establishment of the Commission "Storage of High-Level Waste Materials" (or Repository Commission) [5], responsibilities (implementer, regulator), involvement and participation of public bodies and the civil society, the siting procedure and site selection, and finally the financing of the process. The Repository Commission started its work more than one year ago having the task to address fundamental aspects of the disposal of esp. heat-generating radioactive waste and to review, substantiate and

further develop the existing requirements of the Site Selection Act. The aim is to give recommendations on and proposals for the following:

- Investigation and evaluation of relevant basic issues concerning the site selection procedure;
- Addressing past decisions concerning disposal;
- Information and public participation considering the transparency principle;
- Evaluation of the Site Selection Act, and
- Formulation of criteria and the basis for decision-making.

Especially the last point is important because it considers topics like direct disposal in a mined repository or other possibilities to manage radioactive waste, exclusion and selection criteria, minimal requirements, methodology for a preliminary safety case, and criteria for possible error correction measures (e.g. retrievability, reversibility, recovery).

The three working groups WG 1: Dialogue with civil society, public participation; WG 2: Evaluation (legal aspects); WG 3: Social and technological-scientific decision criteria, and error correction; will address these issues using external (national and international) expert opinions in public hearings.

The Repository Commission will present the results to the German parliament in a report that sets out recommendations by June 2016. This report will be the basis for the long-term strategy to dispose of particularly heat-generating radioactive waste in Germany.

According to schedule given by the Site Selection Act, the siting process is governed as follows: in 2023 there will be a proposal for sites for underground exploration and in 2031 the site selection procedure will be finalized and a site will be selected.

Concerning the Gorleben site – for decades the apple of discord - the Site Selection Act regulates the handling of the site explicitly in article 29. The Gorleben site will be included in a future selection process like any other possible site (or, in case of its unsuitability, excluded) but it is no reference site and there will be no preferential attention in any case. Operation takes place only concerning maintenance and servicing. Moreover, there will be no underground research laboratory, and the preliminary safety analysis (VSG) [6] is terminated.

Like all other EU member states, Germany had been called upon to draw up and submit a national nuclear waste management (disposal) program for all radioactive wastes by August 2015 in accordance with the EC-Directive. The program must mirror Germany's strategy to manage spent fuel and radioactive waste in a responsible and safe manner. The Federal Government decided about this program in time in August 2015. The implementation will take place within a change in the Atomic Energy Act.

The NaPro consists of a sort of summary report (so-called chapeau) with the programmatic overview and four report enclosures: 1) implementation concerning the EC-Directive, 2) joint convention report to IAEA, 3) inventory of nuclear wastes, and 4) report on financing the disposal of SNF and HLW.

Three issues are of special importance: Germany will install two final deep geological repositories (DGR), one for radioactive waste with negligible amounts of heat

(the Konrad repository, licensed for this type of waste, www.endlager-konrad.de), and one for esp. heat-generating radioactive waste. Some types of radioactive wastes that are not suitable for the Konrad Repository are to be disposed of in the latter one. For the R&D issue it is stated that by research and development activities the federal state has to provide for the scientific-technological expertise to realize a repository, to further develop the state of science and technology, to support, maintain and further develop the scientific-technological competence and the support of young scientists.

Responsibilities for research

The German state is responsible for providing repositories for radioactive waste (concerning the Atomic Energy Act). Accordingly, it is indispensable to have available all the necessary scientific-technical basics, the adequate know-how and the financial, institutional and human resources to adequately fulfill these requirements and demands. Sufficient knowledge and expertise of implementers, decision makers and stakeholders in general is a necessity as well in order to appropriately address all the issues with regard to waste management. Therefore, expertise and knowledge is to be provided by basic and applied research.

In Germany, the 6th Energy Research Program of the Federal Government "Research for an environmentally sound, reliable and affordable energy supply" still is the general framework for research, development, and demonstration (RD&D) activities [7]. It is the fundamental programmatic basis for the research policy, i.a. the nuclear safety research of the Federal Government, and is explicitly addressed in the NaPro and was created under the aegis of the Federal Ministry of Economic Affairs and Energy (BMWi).

In Germany three ministries are dealing with nuclear issues in their respective responsibilities: BMWi, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), and the Ministry of Education and Research (BMBF). Concerning their respective responsibilities and competences they operate on the basis of special research concepts being part of the 6th Energy Research Program.

Non-site specific R&D projects of applied basic science are funded by BMWi on the basis of its current research concept "Research on the Disposal of Radioactive Waste" (2015 – 2018) [8]. The Project Management Agency Karlsruhe operates on behalf of BMWi as a program manager (www.ptka.de). BMWi is supported by two subordinate authorities: the Federal Institute for Geosciences and Natural Resources (BGR, www.bgr.bund.de), the German Geological Survey, providing advice to the German Federal Government in all geo-relevant questions and, the Federal Institute for Materials Research and Testing (www.bam.de).

BMWi's funding activities are flanked by BMBF's projects in the areas nuclear safety research, waste management and radiation research. This type of research projects are focused on the education of young scientist. BMBF is responsible for basic research. Moreover, BMBF is also financing R&D in several areas of radioactive waste management within the frame of research activities of the Helmholtz-

Association, www.helmholtz.de, (Program "Nuclear Waste Management and Safety as well as Radiation").

The BMUB is financing activities to support internal needs with regard to regulatory tasks and is responsible for the national repository projects (Asse, Konrad, Morsleben, Gorleben) [9]. Subordinated authorities are the Office for Radiation Protection (www.bfs.de), which is presently the implementing body being responsible for the siting and the German repository projects, and the Federal Office for the Regulation of Nuclear Waste Management (www.bfe.bund.de), the German regulatory body.

DISCUSSION

Against the background of the new approach regarding the search for a final repository for highly radioactive waste and the work of the Repository Commission, it is clear that comprehensive support from science is needed. Moreover, it is particularly important to have undertaken broadly based research in order to find a responsible and honest solution for disposal that is fair for all parties concerned. An open minded approach towards ways of disposal and host rock types at the beginning of the process is highly recommended.

According to the Site Selection Act any prioritization of a special host rock is obsolete. The required unbiased as to results consideration of waste management and disposal options necessitate new approaches and the provision of the appropriate scientific-technical knowledge and adequate human resources. Therefore, BMWi has implemented the new political framework by introducing its research concept "Research on the Disposal of Radioactive Waste", which is the basis for R&D activities and the respective funding.

Major objectives

In all previous BMWi's research concepts, as well as in the new one, the following major objectives govern the R&D activities:

- Provision of the scientific and technical basis for building a final repository especially for heat-generating radioactive waste;
- Development of methods and techniques for the preparation of disposal, planning, construction, operation and closure of a repository;
- continually further developing the state-of-the-art in science and technology;
- Building, maintaining and further development of scientific and technological knowledge, skills and expertise, and
- Fostering the education and training of young scientists.

The research concept comprises issues of applied, non-site specific R&D and reflects different phases of a repository development. Therefore, generic activities, conceptual topics and R&D basics for site selection and technological developments are to be addressed. This must be done in by multi- and interdisciplinary work. Due to the changes and requirements given by legal boundary conditions and the demands of research it was deemed necessary to mirror research policy measures and to make

adoptions with regard to the content and completeness of the preceding research concept.

This lead to the inclusion of the following new topics with new fields of research and the consideration in the structure of the research concept:

1. Intensified host rock independent research, e.g. there is no prioritization of a special host rock type. Repository systems in all relevant host rock formations, i.e. rock salt, argillaceous clay, crystalline rock, will be investigated.

In general the research into host rocks will be continued, however focusing on the solution of scientific questions instead of focusing on the host rock type itself. Furthermore, in a more general way it is intended to initiate R&D activities focusing on the development of new or optimized repository reference concepts in all host rock formations.

Concerning rock salt the expertise and know-how in salt science and technology for realizing a repository in rock salt is very well advanced. Nonetheless there still is a demand for updated and complemented knowledge. However, the remaining necessary scientific activities must be performed appropriately and goal-oriented. For this purpose the outcomes of the preliminary safety analysis Gorleben must be used. Despite a sound and good knowledge and expertise gained during the past there is research demand that must be addressed in the years to come. It is planned to continue to meet the identified need for R&D on final disposal in salt domes. Besides domal salt, in Germany there are also rock salt formations in bedded salt. In the past this formation was actually never considered to host a repository for high-level waste even though bedded salt is used to host underground hazardous waste disposal facilities. Therefore it was decided to perform investigations in order to clarify conceptual questions. In this context, the cooperation with the United States is particularly valuable because of the tremendous expertise in WIPP [e.g. 10]. Therefore, continuing the cooperation with US is especially of high importance.

Concerning argillaceous rocks research actually started more than a decade ago as consequence of governmental decisions for a Gorleben moratorium and to intensify research into alternative host rock formations. In the meantime in Germany quite some expertise and knowledge has been accumulated concerning conceptual, technical, process related and safety issues by national R&D activities and intensive participation in international underground laboratories in Switzerland (Mont Terri) and France (Bure). It is planned to intensify research on clay. Besides addressing important topics like host rock characterization or THM-behavior, focus will especially be on all aspects dealing with safety considerations and evaluations. The existing cooperation in URLs will be continued.

With regard to crystalline rock – also a potential host rock type in Germany – past activities were reduced more or less on investigating the aspects of the engineered barrier system and groundwater modelling. However, because of the requirement to treat all potential host rocks equally, crystalline rock will also become important to address. First activities will focus on R&D supporting to clarify basic scientific

questions that allow evaluating the potential as host rock formation under German boundary conditions (i.a. BMUB's safety requirements, retrievability, and repository concepts relying on the integrity of the geological barrier vs concepts relying on the technical barrier). It is planned to take stock about the national knowledge base and to take into account all available international information (e.g. programs using crystalline host rock, esp. advanced countries like Sweden and Finland).

2. Considering prolonged interim storage periods with regard to the safety of waste and containers.

A high priority will be attributed to questions related to the prolonged intermediate storage times. This becomes necessary because in Germany the license of intermediate storage facilities (centralized storage facilities as well as NPP site storage facilities) of 40 years will expire before the commissioning of a DGR for heat-generating waste. Therefore it is deemed necessary to address questions concerning the behavior of fuel rods and the containers.

3. Considering alternative options for waste management compared to final disposal in mined repositories.

There are national discussions (i.a. within the Repository Commission) about alternatives to deep geological disposal in mined repositories, e.g. partitioning and transmutation or disposal in very deep boreholes. For several reasons it is unavoidable to address and discuss this topic. For this reason, there might be the idea of performing some R&D work to provide the knowledge for a balanced judgement.

4. Addressing socio-technical aspects in future R&D work as a new topic to involve social science in R&D.

Structure of the research concept

In BMWi's research concept the following research goals should be implemented by R&D activities and are mirrored in the concept's structure:

- Further development of instruments and of the methodology for the safety case;
- Scientific methodologies to characterize the geological conditions (without regarding activities for siting);
- Investigations of the repository system behavior and development or improvement of the system description (large scale demonstration experiments might be appropriate);
- Investigations concerning the technical feasibility and long-term behavior of repository components, as well as waste and containers under long-term interim storage conditions;
- Investigations concerning operational safety, and monitoring of the repository;
- Socio-technical questions, governance and public involvement;
- Involvement in activities optional to direct disposal (partitioning and transmutation, disposal in very deep boreholes); and
- Nuclear safeguards (esp. questions and tasks concerning waste management).

These goals are transferred into the structure that consists of R&D-Key topics, R&D-areas, and R&D-topics, the latter containing the most concrete topics for projects.

The structure of key topics is:

1. Waste and container
2. Scientific basis for site selection
3. Repository concepts and repository technology
4. Safety Case
5. Knowledge management and socio-technical issues
6. Safeguards

In more detail: for instance key topic 4 is subdivided into the four R&D-areas: Phenomena, processes and models, methodological basis for safety analysis, system analysis and tools for safety analysis, and supporting elements of the safety case (e.g. analogues).

International cooperation

In Germany it is generally accepted and acknowledged that international cooperation has been and will be an indispensable part in R&D activities on radioactive waste disposal. It is recognized that problems and scientific-technical challenges can be tackled better and more efficiently in joint undertakings. Moreover, it is valuable and practical to cooperate in international projects in order to foster the exchange between scientist, exchange knowledge and expertise, building networks, sharing the financial burden by performing joint projects, and use the expertise of national and international experts to solve common research tasks. Furthermore the cooperation offers opportunities to educate and train staff and young scientists. In the German case international cooperation is particularly important because there is no national underground research laboratory available; participation in international projects in URLs is indispensable. For this reason international cooperation plays an important role in BMWi's research policy and consequently appropriate research activities will be supported in the future. These activities comprise the cooperation in international joint (bilateral or multilateral) projects, for instance the successful cooperation with the United States, R&D activities in underground research laboratories (Switzerland (Grimsel Test Site, Mont Terri), France (Bure), and Sweden (HRL Äspö) Moreover the participation in international committees (e.g. IGDTP, [11], OECD/NEA) and respective R&D activities is envisaged.

New projects

With regard to the new strategy to address host rock specific R&D activities, two projects were initiated after the implementation of BMWi's research concept. This paper gives a very brief overview of the aims of each project. The first one is dealing with disposal in bedded salt and the second one is focusing on feasibility issues for a DGR in crystalline rock in Germany.

In order to compare the safety of repository systems in different host rocks methodologically requirements are necessary like conceptual ideas about the repository itself or a concept about how to demonstrate safety. For domal rock salt comprehensive DGR concepts, safety concepts, and safety demonstration concepts are available by the results of the preliminary safety analysis Gorleben and comparative activities. Concepts for clay either exist or are currently under investigation by appropriately BMWi-funded projects. [12].

Nevertheless for bedded salt this knowledge is still missing. Therefore, all the aspects and issues will be addressed by developing a generic repository concept, a safety concept and safety demonstration concept. In this joint project the expertise of four German organizations is concentrated, namely the Federal Institute for Geosciences and Natural Resources (BGR) representing the geological expertise, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS, www.grs.de), representing mainly the safety analysis expertise, DBE Technology GmbH (www.dbetech.de), representing the technology field, and Institute für Gebirgsmechanik (IfG, www.ifg-leipzig.de), representing rock and salt mechanic expertise. First results are expected beginning 2016.

The project focusing on a DGR in crystalline rock is similarly structured, e.g. a safety concept and a safety demonstration concept are to be developed. It is a joint project also performed by BGR, GRS, and DBE Technology GmbH combining the respective expertise.

The first objective is to evaluate if the BMUB-safety requirements for the disposal of heat-generating waste in a DGR [13] could be applied for a safety demonstration. This is not trivial because some requirements, esp. the concept of the so-called "containment providing rock zone (CPR)" are actually focusing at repositories in rock salt and clay where the geological barrier is of paramount importance. Therefore, it is particularly interesting how this concept can be applied and to study and evaluate the consequences. The second objective is to evaluate the possibility to apply DGR concepts in crystalline host rock (Sweden, Finland, Czech Republic, etc.) to German requirements and geological situations. The third objective is the development of a safety demonstration methodology taking into account geological information and finally, to evaluate the applicability of existing numerical tools necessary for performing a safety assessment. This project started after the implementation of the research concept as well; preliminary results will be available in 2016.

CONCLUSIONS

Because of the new legal framework and the developments regarding the DGR issue, it became necessary to react adequately by appropriate R&D activities. Consequently, BMWi, responsible for non-site specific R&D, took action and created the research concept "Research for the Management of Radioactive Waste (2015 - 2018)" as the new strategic tool. In this concept new key topics are implemented that account for the challenges to come, mainly in connection with the duration of the siting process, the commissioning of a possible repository for heat-generating waste or the unknown host rock formation, additional waste types, and discussions about other options to dispose of radioactive waste.

Broadly based R&D funding activities, in connection with international cooperation, will guarantee to tackle the new challenges.

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