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Alternative Disposal Options for High-Level Radioactive Waste

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Alternative Disposal Options

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Federal Office for the Safety of Nuclear Waste Management

- Project (2020-2023) funded by the Federal Office for the Safety of Nuclear Waste Management (BASE)*
- BASE reviews the proposals of the project managing company (BGE) and prepares a reasoned recommendation to the federal government for a site with the best possible safety. It includes a discussion of alternative disposal options
- Research: State of the art in science and technology for alternative disposal options for high level radioactive waste
- Focus on consequences for disposal. (Also, reactor safety and proliferation, but not addressed in this talk)
- 1st Phase 2020/2021. The report with all references on which this presentation is based will be published soon.

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Alternative Disposal Option for Highly Radioactive Waste

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Promising disposal option
Deep Geologic Repository

Conceivable disposal options
Long-Term Storage
Partitioning and Transmutation
Deep Borehole
Solid Packaged

Discarded disposal options
Deep Borehole
Liquid Waste Injection
Rock Melting
Deep Underground Melt Process
Deep Self Burial
Deep Rock Disposal
Solidified Waste in Situ Melting
Ocean
Dissolution
Deep Seabed
Suduction Trenches
Outer Space
Ice Sheets
Dissolution

Recommendation by the German Commission on the Storage of High-Level Radioactive Waste (Endlagerkommission) in 2015

Borehole Disposal

Borehole Disposal of nuclear waste

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- HLW disposal is usually planned using geological repositories
- HLW disposal using boreholes may provide an alternative to the construction of a mined repository
- Boreholes for HLW disposal may be drilled using off-the-shelve drilling technology
- By the use of boreholes HLW may be disposed of deeper within the earth‘s crust compared to a mined repository
- In the past a number of countries have developed borehole disposal concepts for HLW

The state of science and technology

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- Boreholes have been used for the injection of liquid low and intermediate level waste into sediment rocks at depths of a few hundred meters, at least since the 1960s, for example in the US and the former USSR
- Concepts for deep borehole disposal – implacement of waste containers in depths of up to 5000m – have been developed for example in Sweden (SKB) and the US (Sandia National Laboratories) since the 1980s. These plans have been abandoned
- Since 2016 development of a concept for a deep horizontal borehole repository in depths of about 1500m by the US based startup company
- No concept of borehole disposal of solid HLW has been put into operation so far

Possible use of borehole disposal facilities

- If developed to a state of industrial use, borehole disposal of HLW may become an option for nuclear waste disposal in the future
- The main advantage of borehole disposal is the provision of a greater distance between a HLW repository and the environment compared to mined repositories
- According to the IAEA, borehole disposal may be a viable and less expensive disposal solution for smaller inventories of HLW, compared to a mined repository
- The use of engineered barrier systems for the retention of radionuclides within a repository is highly limited within a borehole disposal system, compared to a mined repository

Borehole disposal of HLW in Germany

- Germany steps out of nuclear power generation by the end of 2022: HLW waste inventory is limited and well known
- In Germany HLW mainly consists of spent fuel and vitrified high level reprocessing waste
- Using drilling/borehole technology may not comply with the current German site selection law and require a change of legislation.
- Retrievability is currently precluded
- Vitrified waste packages may not be disposed of in boreholes in greater depths to date because of their diameter of 430mm: research and development would be required
- Small inventories of high-level waste from research, industry and medicine will probably be produced even after disposal of all German HLW waste in a mined repository – Borehole disposal may become a disposal option in the future

Long-term interim storage

Long-term interim storage of nuclear waste

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Dry storage at the surface or in the shallow sub-surface (tunnel concept) for hundreds of years (>300 y)

- Would allow to gain more time to develop a suitable final disposal option. Two options exist, either
- Continued use of the already existing onsite interim storage facilities (not designed for this so far) or the
- New construction of a long-term interim storage facility (more realistic) that would require
  - An active safety concept including maintenance and monitoring
  - To ensure the integrity of the radioactive inventories, transportability of the transport and storage casks and conditioning suitable for final waste management
  - To ensure the protection against external events

The state of science and technology

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- Degradation behavior of the inventories, in particular the high burn-up uranium and MOX fuel elements with high plutonium contents
  - Forecasts regarding the future condition of the inventories uncertain
  - New monitoring concepts challenging due to dry storage
- Specific repair concepts for the packaging/ repackaging/ reconditioning of the waste
  - Predictions on the interaction of ageing management with transportability and suitability of the transport and storage casks for a later disposing option uncertain
- New Building concepts
  - Future requirements of potential external impacts like climate change and civilization influences unknown
  - Forecasts on later requirements for a security concept uncertain

Possible use of long-term interim storage

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- HABOG in the Netherlands is designed to last for at least one hundred years. Its dry storage facilities can be renovated or replaced as needed to allow for a longer interim storage period. However, it does not have to store fuel assemblies from power reactors but predominantly vitrified waste canisters.
- Holtec International (HI) has submitted an application to the U.S. Nuclear Regulatory Commission (U.S.NRC) for construction and operation (for 40 years) of the HI-store CISF (Consolidated Interim Storage Facility) in Lea County, southeastern New Mexico. The area is geologically stable, has a dry and arid climate. The dry cask storage system to be used at this site will be a near-surface underground structure. Operation for more than 100 years possible.

Long-term interim storage of HLW in Germany

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- Active operation for hundreds of years. This also postpones the disposal issue indefinitely into the future with undetermined methods.
- Active Stewardship necessary: renovation of buildings, casks and reconditioning of inventories; Spare parts concepts, qualified specialist staff (operator, supervisor, technical support, R&D)
- New legal requirements for the financing and regulation of very long-term interim storage would be necessary
- Long-term interim storage is only an interim solution for the disposal of high-level radioactive waste and still requires a final disposal option.

Partitioning and Transmutation

Transmutation of nuclear waste

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- HLW can be treated using nuclear transmutation to reduce the actinide content in HLW and the requirements for final disposal.
- The HLW has to be partitioned to separate uranium, plutonium, other transuranic elements and fission products with chemical separation technologies.
- Fresh fuel assemblies are then manufactured from the separated transuranic elements.
- The fresh fuel assemblies are used in special transmutation reactors where they are irradiated to fission the transuranic elements they contain.
- After irradiation in a transmutation reactor, only a small fraction of the originally used transuranics is split. The process has to be repeatedly applied

The state of science and technology

- Partitioning and transmutation technologies are being developed since decades. But only organic solvent extraction technologies for uranium and plutonium, mixed-oxide plutonium bearing fuel and sodium cooled fast reactors have reached technical maturity.
- Other more advanced fuel cycle technologies such as minor actinide separation, pyrochemical separation technologies, minor actinide bearing fuels, molten-salt reactors or accelerator driven systems are being actively developed in a number of countries. The IAEA and OECD estimate that their development will still need substantial R&D efforts to reach technological maturity.

Possible use of partitioning and transmutation for HLW treatment

- P&T can reduce the actinide content in HLW significantly. However, actinides are immobile under reducing conditions in a repository. The long-term safety analysis of repositories is mainly determined by long-lived mobile fission products
- P&T does not obviate the need for a repository for high-level radioactive waste due to residual amounts of actinides because of separation efficiency, transmutation efficiency, specific waste types and time constraints. However, the required final storage area might be reduced somewhat.
- Since much more fission products and operational wastes are produced, additional repository space for intermediate and low-level radioactive waste is necessary.

Partinioning and Transmutation of HLW in Germany

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- P&T for Germany would require very high expenditures (dozens of reactors and a reprocessing plant) for very long periods of time (>100 years) with limited effectiveness (need for final storage).
- The responsibility for the disposal of nuclear waste would be transferred to future generations.
- P&T of actinides would not contribute significantly to dose reduction and therefore does not reduce isolation requirements. The leading isotopes for long term safety are long-lived mobile fission products.
- Change in social consensus on nuclear phase-out would be necessary.

Conclusions

Conclusions

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- The state of science and technology did not change substantially since 2015, when the German Commission on the Storage of High-Level Radioactive Waste last evaluated alternative disposal options. Only some minor developments were achieved in specific aspects of P&T, long-term interim storage and borehole disposal.
- The project will further deepen the research on the state of science and technology in some selected topics (e. g. horizontal boreholes, integrity of containers during long-term storage, molten salt reactors …) and actively scan the research on alternative disposal options.

See you hopefully next year!

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