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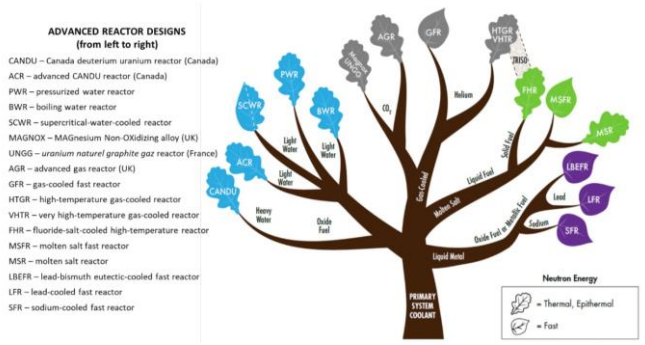
Deep Borehole Disposal Could Be a Viable Path for Managing the Back-end of the Fuel Cycle

The Electric Power Research Institute (EPRI) has released a technical report that identifies and evaluates some of the most important elements for planning, siting, licensing, and implementing deep borehole storage and disposal for spent nuclear fuel (SNF) and high-level radioactive waste (HLW) co-located with an operating advanced nuclear power plant. The study aims to determine if co-locating a small deep borehole repository with an advanced reactor (AR) is feasible. AR concepts include liquid metal-cooled fast reactors, fluoride salt-cooled high-temperature reactors, small modular reactors using liquid metal, helium or liquid salt. The image below, from the report, is titled, "Family tree of nuclear reactor technology organized by primary system coolant with dominant neutron energy indicated by leaf shape."



The key components assessed include regulatory considerations, physical site characteristics, spent fuel and waste package specifications, operations, safety analysis, public acceptance, strategic partnerships, risk management, and schedule and budget. Some highlights of the report are reviewed below.

The prospect of being able to store or dispose of spent fuel or HLW at the reactor site where the waste is generated could provide a more socially acceptable, but still technically credible, alternative to offsite to geological disposal in a mined centralized repository. A realistic solution for nuclear waste disposal from current and future advanced reactors is a necessary prerequisite for establishing public confidence and acceptance of the deployment of future reactors. Co-locating a deep borehole repository with an AR provides "flexibility not available under the existing SNF regime."

Although progress towards the implementation of a permanent disposal facility for spent fuel and HLW continues in many countries around the world that have commercial nuclear power plants, to date, none have been commissioned and only one is under construction – in Finland. The US operates the Waste Isolation Pilot Plant (WIPP) for defense related transuranic waste, but it is not authorized to accept spent nuclear fuel. The authors note that "Lack of progress on permanent disposition paths for the current nuclear operating fleet could present a serious obstacle for deployment of a new generation of ARs. Providing more disposal options could reduce uncertainties and risks relative to the adoption and deployment of new nuclear energy technologies. In this context, borehole disposal offers a valuable alternative for the permanent dispositioning of AR nuclear waste."

Geologic disposal of spent fuel and HLW in a mined repository is a decades-long project, is expensive, has many infrastructure requirements, and significant institutional involvement. For these reasons, and others, mined geologic repositories are being pursued at the national scale in countries with large inventories of spent fuel and HLW. A smaller, single or multiple borehole repository could serve a broader set of customers, which could include:

- Nations without a commercial nuclear power program but with relatively small inventories of spent research reactor fuel or other forms of HLW
- Nations or utilities with a small number of commercial nuclear power plants
- Nations or utilities seeking to deploy commercial nuclear power plants for the first time
- Nations or vendors seeking scalable modular disposal capacity for HLW resulting from reprocessing operations
- Nations or entities seeking disposal of "problematic radioactive waste inventories ineligible for near surface disposal."

By co-locating a deep borehole repository with an AR, the site characterization efforts could be streamlined into a single approach. For the study, a generic site in the southeastern United States was selected.

Assumptions – One AR with its own dedicated disposal facility is assumed, with the spent fuel from that reactor disposed of at its own on-site disposal facility and no import or export of spent fuel to or from other locations. The spent fuel

is assumed to be similar in size and characteristics to pressurized water reactor (PWR) spent fuel from a large light water reactor (LWR), even though most advanced reactor fuel is expected to be discharged in smaller size forms, so the assumption of PWR fuel is a conservative assumption.

The reactor would discharge spent fuel over a 20-year period, resulting in 2,100 assemblies containing 1,000 metric tons of heavy metal (MTHM). The operator would procure 100 multipurpose canisters (MPCs) that have a capacity of 21 spent fuel assemblies each. Disposal is assumed to be in a horizontal borehole 1 kilometer deep and 1.5 kilometers in length in a sedimentary rock such as shale. One spent fuel assembly is placed in a disposal canister, and each borehole holds 210 disposal canisters, resulting in a total of 10 boreholes for the disposal of all of the spent fuel from the reactor. One disposal borehole is operational at all times, and three canisters per day are emplaced, five days per week, 50 weeks per year, until all the spent fuel is emplaced.

Regulatory challenges – The report also includes regulatory options and challenges for advanced reactor spent fuel disposition in the US, with each of five options discussed in detail. One option is to develop a new regulatory framework, although the authors note that this option would take at least five years to complete under a best-case scenario. In addition, before work on this framework could even begin, Congress would have to authorize it, which, based on "The last decade of inaction on SNF dispositioning following defunding of the Yucca Mountain project suggest this will not be an easy task." Furthermore, any new NRC regulations likely would be challenged in court, adding to the length of time a new framework could be put into place and take effect.

Another option would be to add a specific chapter on borehole disposal in a new advanced reactor regulation. This approach is similar to establishing a whole new disposal regulation, but "with the potential advantage of removing the disposal rulemaking effort from the fraught history of the national spent fuel conversation to the more positive context of advanced reactors, with expanded stakeholders in the disposal rulemaking effort."

Other options discussed are (1) surface storage until removal of spent fuel for offsite disposal at a permanent repository; (2) disposal under 10 CFR Part 60; (3) Disposal under 10 CFR Part 63. Part 60 contains the regulations on disposal of HLW in geologic repositories, and Part 63 contains the regulations on disposal of HLW in a geologic repository at Yucca Mountain, Nevada.

Licensing deep borehole disposal technology in other countries outside the US in conjunction with an AR would face many of the same challenges as it would in the US.

One option explored in the study is borehole storage with an intent to confirm disposal. The US has an established regulatory framework for spent fuel storage at reactor sites in independent spent fuel storage installations (ISFSIs). The authors contend that "it is feasible that a deep borehole could be licensed for storage under the existing rule without the need for additional rulemaking." Engagement with the NRC would be needed to advance this concept.

Licensing borehole technology as storage would not be a permanent disposal solution, but if the on-site facility had renewable 40-year license within existing regulations, that would be an "important first step toward the permanent solution that would allow the subsequent steps to proceed in an adaptively staged manner…" It also fits well with recommendations for an adaptive/phased approach.

Two important components of the "storage with intent to confirm disposal are that retrievability of the spent fuel in the boreholes is a requirement throughout the process, and the reactor operators would still enter into a contract with the Department of Energy to ensure a disposal facility is available in case the borehole route is not ultimately chosen."

Industry Calendar

- February 24-25, 2021
  Nuclear Decommissioning & Waste Management
  Hilton London Tower Bridge
  https://www.wplgroup.com/aci/event/nuclear-decommissioning-waste-management-summit/
  London, UK
- March 7-11, 2021
  WM Symposia
  https://wmsym.org
  Online
- March 8-11, 2021
  NRC Regulatory Information Conference
  https://nrc.gov/public-involve/conference-symposia/ric/
  Online
- May 10-13, 2021
  International Conference on Fast Reactors and Related Fuel Cycles
  https://iaea.org/events/fr21
  Beijing, China
- June 7-11, 2021
  Sixth International Conference on Geological Repositories (ICGR)
  https://www.oecd-nea.org/confdb/confdb/conf?id=432
  Sirkus Hall of Pasasitorni Helsinki, Finland
- August 21-26, 2021
  IMNN & ESARDA Joint Annual Meeting
  https://www.inmm.org/inmmesarda2021
  Austria Center Vienna
  Vienna, Austria
- November 30 – December 2, 2021
  WNE – World Nuclear Exhibition 2021
  https://www.world-nuclear-exhibition.com
  Paris Nort Villepinte, Paris, France

Details are available at:
https://www.uxc.com/c/data-industry/Calendar.aspx

Key findings (paraphrased)

- No technical showstoppers are identified for further consideration of deep borehole disposal co-located with future deployments of ARs
- Greater flexibility and optionality emerge from scenarios in which onsite disposal options for AR spent fuel are available
- The horizontal variant of borehole technology evaluated in the study offers unique benefits for applications where waste package retrievability is a priority, such as for interim, fully-reversible storage prior to closure for permanent disposal
- The applicable US regulation for geological disposal of spent fuel, 10 CFR 60, is obsolete and represents a barrier for near-term implementation of deep borehole disposal in the US; however, a potential path exists through 10 CFR 72
- Establishing and maintaining support from the public, regulators, and other stakeholders is "foundational" for the implementation of a decentralized, onsite borehole solution tailored for future AR
- "Given the lack of viable alternatives to centralized mined repositories, which have proven costly and challenging to deploy in many countries, further evaluation and demonstration of deep borehole technologies could yield a valuable enabling option for the commercialization of advanced nuclear power plants in the United States and globally."

The report was sponsored by EPRI but prepared by Deep Isolation, Auburn University, and J Kessler and Associates, LLC. Reference: Feasibility of Borehole Co-Location with Advanced Reactors for Onsite Management of Spent Nuclear Fuel. EPRI, Palo Alto, CA: 2020. 3002019751. the report is available here: https://www.epri.com/research/products/000000003002019751

Top Story

US Nuclear Waste Fund balance was $45.1 billion at the end of September 2020

According to an audit report of the Department of Energy's Nuclear Waste Fund (NWF) as of the end of fiscal year (FY) 2020, the fund balance at the end of the fiscal year was $45.1 billion, compared to $43.5 billion at the end of FY 2019. As of September 30, 2020, the US Treasury securities held by the NWF were $42.6 billion and had a fair value of $54.3 billion, compared to $49.3 billion at the end of FY 2019.

DOE estimates the remaining liability associated with the partial breach of the Standard Contract as of September 30, 2020 was $30.6 billion (compared to $28.5 billion at the end of FY 2019).

Owners and generators of civilian spent nuclear fuel entered into contracts with DOE for disposal services and for payment of fees to the NWF. There are two types of fees: (1) a one-time charge per kilogram of heavy metal (KGHM) contained in spent fuel existing prior to April 7, 1983; and (2) a one mill per kWh fee on all net electricity generated and sold on and after April 7, 1983. Since there is no disposal program, the US Court of Appeals for the District of Columbia Circuit ruled in 2014 that the fee be set to zero. The proposal took effect on May 16, 2014. No kWh fees have been assessed or collected since then.

The contracts provided for three options for payment of the one-time spent fuel fee:

- Payment of the amount due plus interest from April 7, 1983 in 40 quarterly installments with the final payment due on or before the first delivery of spent fuel to DOE
- Payment of the amount due plus interest in a single payment any time prior to the first delivery of spent fuel to DOE
- Payment of the amount due any time before June 30, 1985, or two years after contract execution, in the form of a single payment with no interest due.

Litigation – DOE entered into more than 68 Standard Contracts with utilities, which DOE has "partially breached" (only partially breached because DOE intends to honor the contract at some point in the future). To date, 41 suits have been settled involving utilities that collectively own 80 percent of the nuclear reactors. Under the terms of the settlements, the taxpayer-funded Judgment Fund has paid $6.3 billion to the utilities for delay damages they have incurred through September 30, 2020. In addition, 63 cases have been resolved by 55 final unappealable judgments and 8 voluntary withdrawals with no damages. Forty-seven of the cases resulted in a total of $42.3 billion in damages that have been paid by the Judgment Fund as of September 30, 2020. Eight of the unappealable judgments resulted in an award of no damages.

An additional 16 cases were still pending in the Court of Federal Claims at the time of the audit. In most cases, the only outstanding issue to be litigated is the amount of damages to be awarded. Industry has estimated that remaining damages for all utilities with which DOE has contracts would ultimately be at least $50 billion. DOE believes that estimate is "highly inflated" and that the disposition of the 96 cases is estimated to be $39.2 billion as of September 30, 2020. Deducting the $8.6 billion already paid, the remaining liability is estimated to be approximately $30.6 billion; however, this estimate assumes that DOE will begin removing spent fuel from reactor sites by FY 2023, and that acceptance will begin no later than the timeframes contained in the *Nuclear Waste Policy Act* and the Yucca Mountain license application.