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Department of Energy issues Draft Environmental Impact Statement for High-Assay Low-Enriched Uranium (HALEU)

The Department of Energy has issued for public comment an Environmental Impact Statement (EIS) for acquiring high-assay low-enriched uranium (HALEU). [1]

The Department of Energy wants to encourage commercial producers to invest in the necessary fuel cycle infrastructure and gear up production to provide the expected amount of HALEU needed for commercial use or demonstration projects.

The production of HALEU under DOE's proposed action is acknowledged by DOE to require the following:

- Uranium mining and milling
- Conversion of uranium ore into uranium hexafluoride
- Uranium enrichment to HALEU
- Deconversion of uranium hexafluoride to oxides or metal
- HALEU storage
- Transportation of uranium between activity locations

The use of HALEU will also involve fuel fabrication, and its use in nuclear reactors will generate spent nuclear fuel that require continued storage and either disposal or reprocessing.

All of these activities for HALEU involve the poisoning the workers, the public and the environment with radioactive materials. Some of the poisoning happens sooner, some of it later.

The Department of Energy and other nuclear boosters are making several incorrect claims:

1. Myth: *Nuclear energy is needed to combat climate change*. In fact, nuclear energy is too slow to deploy and also so expensive, that it impedes the ability to combat climate change.
2. Myth: *Nuclear energy is affordable.* In fact, the construction costs alone make nuclear energy unaffordable. But the cost of spent nuclear fuel storage for decades and who

[1] Department of Energy, *Draft Environmental Impact Statement for Department of Energy Activities in Support of Commercial Production of High-Assay Low-Enriched Uranium (HALEU)*, DOE/EIS-0559, March 2024. https://www.energy.gov/ne/haleu-environmental-impact-statement Public comment is open until April 22, 2024 and comments may be sent to HALEU-EIS@nuclear.energy.gov

knows for how long, and the cost of nuclear fuel disposal also must be considered. The cost of spent nuclear fuel disposal is being low-balled by the Department of Energy, and reported by the Government Accountability Office as though the cost estimates had any credibility. The Department of Energy has no program to site any repository and continues to have no plan to site one (or more). The costs of the repositories we already need, will be the burden of future generations. The Department of Energy and nuclear boosters love to say that reprocessing spent nuclear fuel is the solution, but they don't admit the cost of reprocessing let alone the radiological pollution and resulting waste to dispose of. And when reprocessing might be conducted on certain spent nuclear fuel, they don't admit that how the bulk of the spent nuclear fuel will remain, still needing disposal.

3. Myth: *Nuclear energy has a small footprint*. The land where many nuclear reactors have operated is increasingly becoming the permanent dumping ground for radioactive materials. Also, the spent nuclear fuel is stranded at nuclear reactor sites and as spent nuclear fuel in dry storage degrades and the casks or canisters degrade, this spent nuclear fuel poses increasing storage and transportation safety challenges. The routine airborne releases and the groundwater releases depend on the reactor type, but can be spread far and wide, entering the food chain and entering our bodies. Accidents involving a nuclear reactor, spent fuel in a pool or in dry storage, transportation accidents, or sabotage can involve permanent contamination of vast areas of land. Spent nuclear fuel disposal will also require large repositories and even with reasonably expected performance of the repository, will trickle out radioactive contamination for over a million years.

4. Myth: *Nuclear energy is needed for reliable base-load power*. In fact, the nuclear reactors expected to use HALEU like the TerraPower Natrium, a liquid-metal cooled fast neutron reactor, have a record of frequent and long outages. And high-temperature gas-cooled reactors, like X-energy wants to build that also use HALEU, also have a poor operating record. The Fort St. Vrain reactor in Colorado was a high-temperature gas-cooled reactor that had frequent maintenance problems. The reality is that fossil-fueled plants will remain online to provide power for these unreliable so-called "advanced" nuclear reactors.

5. Myth: *Nuclear energy is clean*. In fact, with routine activities from mining, milling, fuel fabrication, nuclear reactor operation, fuel reprocessing, and radioactive waste disposal, nuclear energy has caused countless radiologically contaminated sites across the U.S. Cancer rates can be shown to increase near every operating nuclear reactor. [2] Radiological releases contaminate air, soil, and water and enter the food chain. The radioactive particles enter our bodies, in chronic exposures, and especially harm women, children and the unborn developing child. [3] Accidents involving nuclear material are

[2] Jay M. Gould with members of the Radiation and Public Health Project, Ernest J. Sternglass, Joseph U. Mangano, and William McDonnell, *The Enemy Within – The High Cost of Living Near Nuclear Reactors – Breast Cancer, Aids, Low Birthweights, and Other Radiation-Induced Immune Deficiency Effects*, Four Walls Eight Windows, 1996. ISBN 1-56858-066-5. See pages 131 and 281.

[3] "Health Risks from Exposure to Low Levels of Ionizing Radiation BEIR VII – Phase 2, The National Academies Press, 2006, http://www.nap.edu/catalog.php?record_id=11340 The BEIR VII report reaffirmed the conclusion of the prior report that every exposure to radiation produces a corresponding increase in cancer risk. The BEIR VII report found increased sensitivity to radiation in children and women. Cancer risk incidence figures for solid tumors for women are about double those for men. And the same radiation in the first year of life

> excluded from home and auto insurance policies. The Price-Anderson Act liability coverage will not necessarily cover damages at all for consolidated spent nuclear fuel storage, transportation or reactors smaller than 100 megawatts. [4]

When nuclear boosters promote nuclear energy as "small footprint," they tend to leave out the space required for spent nuclear fuel disposal as well as other radioactive waste disposal. **The U.S. already has over twice as much spent nuclear fuel (existing now or expected to be produced from currently licensed reactors) than was allotted for the Yucca Mountain repository.**

The Department of Energy mischaracterizes the magnitude of the unsolved technical challenges for finding a permanent solution to the radioactive waste problem posed from nuclear energy. The Department of Energy's recent "Liftoff" document implies that the spent nuclear fuel problem isn't a big problem because the volume of spent nuclear fuel "is quite small" and stating that the volume of spent nuclear fuel "could fit on a single football field at a depth of less than 10 yards." [5]

The fact is that the Department of Energy was needing 41 miles of waste emplacement tunnels (or drifts) at the proposed Yucca Mountain repository as limited by law to 70,000 metric tons of spent nuclear fuel. And this assumed repackaging and positioning the waste to limit the thermal heat load. [6] The football field analogy is highly misleading. And the U.S. already will have about 140,000 metric tons of spent nuclear fuel to dispose of, even without any new reactors going online.

Typical commercial nuclear spent fuel was enriched to less of 5 percent enriched. HALEU is expected to be enriched to at least 19.75 and less than 20 weight percent uranium-235. **The use of high-assay low-enriched uranium (HALEU) inherently means enriched uranium-235 is more available for diversion to nuclear weapons and creates nuclear material security problems.** So much for being "secure."

The higher enriched HALEU fuels will require disproportionately more space in a disposal repository. HALEU would be used to make TRISO fuels proposed for high-temperature gas-cooled reactors and for the fuel for the TerraPower Natrium liquid-metal fast reactor.

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for boys produces three to four times the cancer risk as exposure between the ages of 20 and 50. Female infants have almost double the risk as male infants.

[4] See the October 2023 Environmental Defense Institute article, "Will the public be compensated for a radiological release from a spent nuclear fuel storage or transportation accident" Liability coverage ranges from about $13 billion to zero dollars."

[5] Department of Energy webpage, Pathways to Commercial Liftoff: Advanced Nuclear, March 2023. https://www.energy.gov/lpo/articles/sector-spotlight-advanced-nuclear See page 35.

[6] U.S. Department of Energy, *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, DOE/EIS-0250F-S1D, October 2007. https://www.energy.gov/sites/prod/files/EIS-0250-S1-DEIS-Summary-2007_0.pdf

The TRISO fuel would be more difficult to reprocess than many other fuels because of various silicon impurities and high loadings of carbon fines, [7] and no process has been developed to reprocess TRISO fuel. The cost of reprocessing, the airborne polluting while reprocessing, the extra radioactive waste generated by reprocessing [8] and the weapons material theft are problems with reprocessing spent fuel.

Similar TRISO spent fuel languishes in the U.S. Fort St. Vrain spent nuclear fuel and also in Germany, and remains costly to store decades after the reactors were shuttered. So much for being "affordable." There may be safety advantages to the TRISO fueled Xe-100 reactor, but information isn't available to make much of an assessment.

The Department of Energy conducted a study completed in 2023 about Xe-100 reactor impacts on a repository, but that report, mentioned at the August 2023 Nuclear Waste Technical Review Board Meeting, is still withheld from the public. [9] Apparently, the waste disposal characteristics of Xe-100's spent fuel are not something the public should be told about.

The difficulty in disposal of TRISO fuel and reactor internals will depend on whether or not the graphite can be disposed of with the spent fuel and whether or not the graphite exceeds Class-C low-level radiative waste criteria. In addition, when the carbide in TRISO fuel is exposed to water, flammable gases are generated, which may be significant. Also, the more highly enriched the fuel, above 3 to 5 percent, additional measures may be needed to ensure criticality control after disposal, particularly if the fuel is separated from the graphite blocks. [10]

X-energy's design is for a 60-year reactor design life and for an 80-year spent fuel storage design. X-energy is stating that **"X-energy has engaged with the DOE to strategize their acceptance of all spent fuel within the 80-year period."** [11] **But this statement is no guarantee that there will be a permanent repository in 80 years.**

The Bill Gates TerraPower Natrium reactor would also use HALEU fuel but its spent nuclear fuel may require processing prior to placement in a repository. The metallic sodium-bonded fuel may require treatment to remove metallic sodium. [12] That reprocessing, dry pyro-processing, will

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[7] Charles W. Forsberg and David L. Moses, Oak Ridge National Laboratory, *Safeguards Challenges for Pebble-Bed Reactors Designed by People's Republic of China*, ORNL/TM-2008/229, November 2009.

[8] *Blue Ribbon Commission on America's Nuclear Future, Report to the Secretary of Energy*, 2012.

[9] Brady Hanson, Pacific Northwest National Laboratory, Laura Price, Sandia National Laboratory and others, *Report of the Back-End Management of Advanced Reactors (BEMAR) IPT on the X-energy's Xe-100 Reactor,* April 25, 2023, Revision 1. CUI Categories: SP-EXPT-SP-PROPIN/PRIVILEGE. Report front cover only was provided at the August 2023 NWTRB meeting presentation by Ned Larson, Department of Energy.

[10] Laura Price, Sandia National Laboratories, *Using Past Experience to Inform Management of Waste from Advanced Reactors and Advanced Fuels*, SAND2022-10873C, 2022. https://www.osti.gov [2004321.pdf]

[11] X-energy, Letter from X-energy to U.S. Nuclear Regulatory Commission, "Submittal of X Energy, LLC (X-energy) Xe-100 White Paper Slide Deck, 'Spent Fuel Management White Paper,'" 2023-XE-NRC-002, January 10, 2023. https://www.nrc.gov/docs/ML2301/ML23011A324.pdf Project No. 99902071.

[12] Ned Larson, Department of Energy, Office of Nuclear Energy, "Back-end Management of Advanced Reactors (BEMAR)," U.S. Nuclear Waste Technical Review Board Public Meeting, Idaho Falls, Idaho, August 30, 2023.

be costly and will release radionuclides to the skies. Pyroprocessing has been conducted only on a small scale, and have left radioactive waste yet to be disposed of.

Advanced reactor designs using HALEU fuels may differ substantially from existing commercial spent nuclear fuels currently stored. The Natrium reactor, X-Energy reactor, and a variety of others are being proposed. The Department of Energy is eager to encourage any and all proposed reactors. **And for each reactor and its fuel design and use, the HALEU fuels may need different handling, storage, transportation and disposal options. These new fuels present a challenge to Department of Energy research programs that are supposed to provide a technical basis for storage and disposal. DOE acknowledges that it has fallen behind and expects to only fall further and further behind.** [13]

The DOE's EIS contains disinformation about the dismal state of DOE's spent nuclear fuel disposal program. The HALEU EIS includes one paragraph to address disposal of spent nuclear fuel. Paragraph 3.7.33 states:

> "The program for a geologic repository for SNF at Yucca Mountain, Nevada, has been terminated. However, DOE remains committed to meeting its obligations under the Nuclear Waste Policy Act to dispose of SNF (DOE, 2022). In the interim, as described above, SNF is being safely stored."

It is correct that the proposed and never granted a license-to-construct repository at Yucca Mountain was defunded in 2010. But the statement that "DOE remains committed to meeting its obligations under the Nuclear Waste Policy Act to dispose of SNF" references a **footnote** in an Environmental Impact Statement for the Versatile Test Reactor (DOE/EIS-0542).

That VTR EIS footnote states:

> "DOE remains committed to meeting its obligations to manage and, ultimately dispose of spent nuclear fuel."

Isn't it odd that the only way DOE could offer any statement of its commitment to dispose of commercial spent nuclear fuel was to refer to a footnote in another EIS for a research reactor that does not generate commercial spent nuclear fuel, stating only the DOE remains committed to meeting its obligations to manage and, ultimately dispose of spent nuclear fuel?

Saying that the DOE remains committed to meeting its obligations under the Nuclear Waste Policy Act to dispose of SNF is as empty as the promise DOE made, in the Standard Contract with electric utilities that operated commercial nuclear reactors, that DOE would begin taking ownership of commercial spent nuclear fuel in 1998.

There is no reason to have confidence that the DOE has a commitment to meet its obligations under the Nuclear Waste Policy Act. The Department of Energy, despite promising to open a spent nuclear fuel repository by 1998, and then by 2010, has utterly failed to do so. Furthermore,

[13] Ned Larson, Department of Energy, Office of Nuclear Energy, "Back-end Management of Advanced Reactors (BEMAR)," U.S. Nuclear Waste Technical Review Board Public Meeting, Idaho Falls, Idaho, August 30, 2023.

the Department of Energy's proposed conceptual design for the Yucca Mountain repository was incomplete and technically unsound. It had assumed disposal in canisters that were not being used by commercial nuclear utilities, it assumed technically unsound corrosion rates to length the time to container failure, it squashed water infiltration rates through the repository to lower the trickle out of radionuclides and it assumed titanium drip shields would be installed despite no way to actually install them.

The Department of Energy publishes an annual report of the inventory of commercial spent nuclear fuel and Government-owned spent nuclear fuel. [14] The Department of Energy makes the disclaimer in its report of spent nuclear fuel inventory, including:

> "No inferences should be drawn from this report regarding future actions by DOE, which are limited both by the terms of the Standard Contract and Congressional appropriations for the Department to fulfill its obligations under the Nuclear Waste Policy Act including licensing and construction of a spent nuclear fuel repository."

The DOE's draft HALEU EIS misrepresents the DOE's spent fuel management and disposal problem. The DOE's draft HALEU EIS ignores the unsolved existing spent nuclear disposal problem, and ignores the messes DOE made, starting decades ago and still has not cleaned up, like the DOE's Hanford site in Washington state. There are many contaminated sites at basically every location the Department of Energy conducted any activity associated with nuclear reactors or their fuel.

The Department of Energy, in 2014, had to cease collecting fees for geologic disposal, because DOE has no repository program. Now in 2024, DOE still has no program for geologic disposal. The DOE has **continued to ignore the Nuclear Waste Policy Act** in its proceeding to attempt to cite consolidated interim storage. The DOE has **continued to ignore the Nuclear Waste Policy Act** with regard to the limit on the amount of spent fuel that can be disposed of at Yucca Mountain, 70,000 metric tons, and the U.S. is on track to create about twice that with the already generated or expected to be generated spent nuclear fuel.

And finally, let us address the claim in the DOE's HALEU EIS that "SNF is being safely stored." By DOE's own experts, the safety of long-term storage of spent nuclear fuel currently **lacks adequate technical basis**. And the problem is compounded by the higher burnup fuels being used by commercial nuclear utilities.

The Department of Energy acknowledged the gaps in the technical basis for continued storage of spent nuclear fuel, first in 2012. [15] Then in 2019, an additional gap was identified that was the lack of technical basis for understanding what the radiological consequences of a spent

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[14] Department of Energy, Prepared by Office of Nuclear Energy, *Spent Nuclear Fuel and Reprocessing Waste Inventory: Spent Fuel and Waste Disposition*, PNNL-33938, FCRD-NFST-2013-000263, November 2022. https://www.osti.gov/biblio/1974547 (Inventory ending calendar year 2021.)

[15] B. Hanson et al., *Gap Analysis to Support Extended Storage of Used Nuclear Fuel*, FCRD-USED-2011-000136, For the Department of Energy, January 2012.

nuclear fuel canister breach would be. [16] **Each new fuel type from the use of HALEU will require additional research regarding the storage and disposal of the fuel. The Department of Energy acknowledges that it is already behind in researching the technical basis for fuel already in storage.** [17] Read more about DOE's lack of timely and adequate research for long-term storage of spent nuclear fuel in this newsletter.

The Department of Energy's Draft Environmental Impact Statement for HALEU issued in March 2024 [18] lists the two proposed consolidated "interim" storage sites granted licenses by the NRC: Holtec International in Lea County, New Mexico and Interim Storage Partners, Andrews, Texas. [19] [20] **The DOE failed to mention that both New Mexico and Texas have passed bills prohibiting consolidated storage of spent nuclear fuel.** The DOE also failed to mention that the court in Texas found that NRC did not have the authority to authorize away-from-reactor consolidated storage because Congress made requirements in the Nuclear Waste Policy Act that the NRC ignored. The Environmental Impact Statements for those facilities is limited to the NRC licensing period for those facilities, and what happens over time as spent nuclear fuel degrades and storage canisters are breached, is not evaluated.

The Department of Energy is promoting its consent-based siting of consolidated interim [forever] storage parking lot dumps without citing one or more geologic repositories. [21]

The Department of Energy admitted at the August 2023 NWTRB meeting that it planned to give information to the newly forming "consortia" of universities, businesses and others and that citizens would not have access to the information given to the consortia. **Importantly, the communities being bribed and connived into hosting "temporary" interim consolidated storage sites would NOT have access to the information shared with the consortia.** The Department of Energy's approach to siting consolidated interim storage was to proceed with no planning for obtaining a permanent geological repository or for obtaining reprocessing capability. The DOE understands the imperative to withhold the truth about the risks and health

[16] M. Teague et al., *Gap Analysis to Guide DOE R&D in Supporting Extended Storage and Transportation of Spent Nuclear Fuel: An FY2019 Assessment*, For the Department of Energy, SAND2019-15479R, 2019.

[17] Ned Larson, Department of Energy, Office of Nuclear Energy, "Back-end Management of Advanced Reactors (BEMAR)," U.S. Nuclear Waste Technical Review Board Public Meeting, Idaho Falls, Idaho, August 30, 2023.

[18] Department of Energy, *Draft Environmental Impact Statement for Department of Energy Activities in Support of Commercial Production of High-Assay Low-Enriched Uranium (HALEU)*, DOE/EIS-0559, March 2024. https://www.energy.gov/ne/haleu-environmental-impact-statement Public comment is open until April 22, 2024 and comments may be sent to HALEU-EIS@nuclear.energy.gov

[19] U.S. Nuclear Regulatory Commission, *Federal Register*, Vol. 86, No. 178, "Interim Storage Partners, LLC; WCS Consolidated Interim Storage Facility; Issuance of Materials License and Record of Decision," September 17, 2021. This is the consolidated storage facility proposed for Andrews County, Texas. (The consolidated storage facility could store up to 40,000 metric tons heavy metal.)

[20] U.S. Nuclear Regulatory Commission, *Federal Register*, Vol. 88, No. 92, "Holtec International; HI-STORE Consolidated Interim Storage Facility," May 12, 2023. (The consolidated storage facility could store up to 100,000 metric tons heavy metal.)

[21] Department of Energy, Office of Nuclear Energy, *Consent-Based Siting Process for Federal Consolidated Interim Storage of Spent Nuclear Fuel*, April 2023.

harm of storing spent nuclear fuel for unknown decades to come. **The DOE stated that it would use carefully filtered messaging in order to persuade the community's leaders.**

The DOE stated that consortia members will have ready access to DOE experts, special computerized tools and access to "unfiltered" information. **The non-tribal communities and tribes, it was stated, would not have access to DOE experts, special tools, or to "unfiltered" information.** The messaging and story-telling to attain siting that was most effective would be studied and applied by DOE.

Public comments can be submitted on the Draft HALEU EIS until April 22. [22] Tell the Department of Energy to stop wasting taxpayer money, stop pretending nuclear energy is the solution to climate change, and stop encouraging HALEU production, which will lead to more radiological contamination of people and the environment from each process involved with HALEU production and its use.

Department of Energy's Road to Nowhere Repository Research over the Last Decade

Following the suspension of the Yucca Mountain repository project in 2010, the Department of Energy has conducted several studies of several deep geologic disposal options. The DOE's geologic disposal research includes a variety of potential geologic media, including argillite, crystalline and salt. [23] No decisions have been made and no repository has been sited. The study of volcanic tuff as a repository type hasn't completely ended, but is less openly discussed. The most recent Nuclear Waste Technical Review Board (NWTRB) report issued in 2024 highlights the Department of Energy's research over the last decade regarding spent nuclear fuel disposal. [24] [25]

Understanding the waste form characteristics, the thermal heat load and criticality risk continues to be studied and studies are needed. But, the Department of Energy seems to place

[22] Department of Energy, *Draft Environmental Impact Statement for Department of Energy Activities in Support of Commercial Production of High-Assay Low-Enriched Uranium (HALEU)*, DOE/EIS-0559, March 2024. https://www.energy.gov/ne/haleu-environmental-impact-statement Public comment is open until April 22, 2024 and comments may be sent to HALEU-EIS@nuclear.energy.gov

[23] U.S. Nuclear Waste Technical Review Board, *Evaluation of the U.S. Department of Energy Research and Development Activities on the Disposition of Commercial Spent Nuclear Fuel in Dual-Purpose Canisters*, February 2024. https://www.nwtrb.gov/our-work/reports/evaluation-of-the-u.s.-department-of-energy-research-and-development-activities-on-the-disposition-of-commercial-spent-nuclear-fuel-in-dual-purpose-canisters-(february-2024)

[24] U.S. Nuclear Waste Technical Review Board, *Evaluation of the U.S. Department of Energy Research and Development Activities on the Disposition of Commercial Spent Nuclear Fuel in Dual-Purpose Canisters*, February 2024. https://www.nwtrb.gov/our-work/reports/evaluation-of-the-u.s.-department-of-energy-research-and-development-activities-on-the-disposition-of-commercial-spent-nuclear-fuel-in-dual-purpose-canisters-(february-2024)

[25] D. Sassani et al., *SFWST Disposal Research R&D 5 Year Plan – FY2021 Update*, SAND2021-12491R, Albuquerque, New Mexico, August 2021.

more emphasis on promoting the appearance that a repository is feasible and little emphasis on actually siting and operating one.

The Department of Energy also often pivots to the concept of reprocessing, despite the costs, added waste streams for reprocessing, and enormous quantities of plutonium obtained by reprocessing commercial nuclear spent fuel. There are already many metric tons of surplus plutonium that the U.S. needs to dispose of. [26] After the cancellation, due to escalating costs, of the Department of Energy's proposed mixed oxide (MOX) fuel facility, there is no use for the plutonium obtained from reprocessing of commercial spent nuclear fuel.

When Yucca Mountain was proposed, both commercial spent nuclear fuel and also military or research spent nuclear fuel were to be disposed of in the same repository. And for years, highly enriched in uranium-235 fuels were reprocessed, such as fuel from the Naval submarine program and DOE research reactors. The reprocessing was highly polluting to air and groundwater and the recovered uranium-235 was too contaminated to be used in ordinary fuel fabrication facilities. But disposal of highly enriched spent nuclear fuel is a problem not being addressed now, as the Department of Energy repository research is now only addressing commercial spent nuclear fuel, not DOE's military or research spent nuclear fuel.

It appears that DOE has no disposal program for spent nuclear fuel at its national laboratories, including the Idaho National Laboratory that stores a variety of spent nuclear fuels and naval spent nuclear fuel. No research is being reported by the NWTRB.

But despite no actual operating repository anywhere on the horizon, the DOE would like to avoid the cost of repackaging the commercial spent nuclear fuel in dry storage. The DOE is successfully avoiding admitting the true costs of long-term management and disposal of spent nuclear fuel in several ways, including by claiming it can avoid spent nuclear fuel repackaging. Commercial spent nuclear fuel repackaging may be needed at existing dry storage sites, at consolidated storage facilities and/or at a repository sites. No repackaging facilities have been designed and no one wants to admit who is going to pay for them.

It should be noted that the electric utilities successfully sued the Department of Energy for not taking ownership of the spent nuclear fuel beginning in 1998. Taxpayers are paying utilities for the dry storage systems and continued storage of commercial spent nuclear fuel at stranded fuel sites via the taxpayer funded "Judgement Fund." The DOE is sensitive to the fact that the cost of continued storage of spent nuclear fuel grows larger, the longer that it is stored because there is no disposal facility. The DOE is seeking to make consolidated interim storage seem like a solution to the spent nuclear fuel problem. But it only shifts the problem and likely shifts it to poor communities in the western states.

[26] U.S. Department of Energy and NNSA, *Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement Summary*, DOE/EIS-0283-S2, April 2015.

It should also be noted that the collection of fees from electricity rate payers for disposal of spent nuclear fuel ceased in 2014 because a court found that the Department of Energy had no spent nuclear fuel repository program.

In 2013, the DOE was still claiming it would begin shipping spent nuclear fuel to consolidated storage by 2025 and would begin emplacing waste in a repository by 2048. [27] Now, the DOE is not discussing how many decades away a repository could become available, but it is generally acknowledged that it won't happen by 2048, which is about 60 years after the earliest dry storage systems were loaded with spent nuclear fuel.

A wide variety of dry storage systems were licensed, beginning in 1986. The first systems were bolted-closure casks. Later systems and the system prevalently in use are thin-walled welded-closed canisters. None of these canisters was intended for disposal.

By 2008, when the Department of Energy submitted its Yucca Mountain license application, most commercial spent nuclear fuel was still in pool storage and about 1,111 canisters had been loaded with spent nuclear fuel. As of December 2020, there were about 42,000 metric tons of heavy metal of commercial spent nuclear fuel in dry storage, in about 3,000 dual purpose (storage and transportation) canisters. By 2075, it is expected, **that without any new reactors**, there will be about 140,000 metric tons heavy metal in dry storage in about 10,000 canisters, see Figure 1 below. The capacity of the Yucca Mountain license application was 70,000 metric tons.

The commercial spent nuclear fuel is stored at 77 Independent Spent Fuel Storage Installation (ISFSI) sites in 35 states in the U.S. [28] [29] Furthermore, the spent fuel is packaged in combinations of fuel, higher decay heat and higher fissile loading, than was ever planned for disposal Yucca Mountain. Some of the spent fuel packaged for dry storage may not be transportable without repackaging as the NRC licensed some dry storage systems without requiring that the casks or canister to be able to be licensed for transportation.

In 2013, the Department of Energy estimated that spent nuclear fuel at commercial nuclear power plants could be removed by 2070. [30] But because of higher and higher burnup fuel being licensed by the NRC, the spent fuel is more radioactive and thermally hotter. Now DOE

[27] Evaristo J. (Tito) Bonano, "Preliminary Technical Evaluation of Dual-Purpose Canister Direct Disposal Alternatives," Sandia National Laboratory, For the Department of Energy, SAND2013-9261C, Presentation at the NWTRB Technical Meeting, Washington, DC, November 18-19, 2013.

[28] G. Freeze et al., *Integration of the Back End of the Nuclear Fuel Cycle*, SAND2021-10444, Sandia National Laboratories, Albuquerque, New Mexico, 2021.

[29] Timothy C. Gunter, Department of Energy Office of Spent Fuel and Waste Science and Technology (SFWST) and Geoff Freeze, Sandia National Laboratories, Update on DOE's Dual-Purpose Canister (DPC) Direct Disposal Activities, SAND2022-2040 PE, U.S. Nuclear Waste Technical Review Board Winter 2022 Board Meeting, March 1-2, 2022,

[30] Department of Energy, *Cooling Times for Storage and Transportation of Spent Nuclear Fuel*, Sandia National Laboratory, February 2013. https://www.osti.gov/servlets/purl/1145261

estimates that the hottest fuel would not be cool enough to meet transportation requirements until approximately 2100. [31]

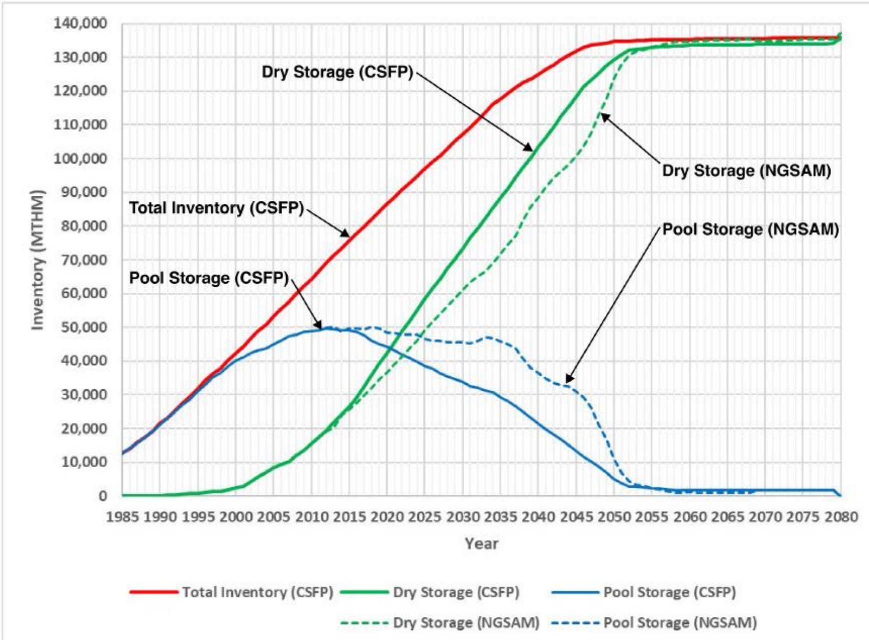

Figure 1. Projected inventory of U.S. commercial spent nuclear fuel in storage. (Source: Nuclear Waste Technical Review Board, February 2024 report.)

In March 2023, the Department of Energy proposed to increase nuclear energy electricity production in the U.S. by a factor of three. [32] **The Department of Energy has not acknowledged the overwhelming difficulties this will add to an already enormously expensive and untenable problem of spent nuclear fuel storage and disposal.**

The Department of Energy's research found that higher burnup fuels licensed by the U.S. Nuclear Regulatory Commission contained enough fissile material to have a nuclear criticality in a single storage canister. The NRC had obscured the criticality potential **by simply assuming** that water does not enter a canister during the licensing period of the dry storage canister.

Prior to around the year 2000, commercial spent nuclear fuel was of lower enrichment and lower burnup (or less time in a reactor), then in the two decades since the year 2000. Previously,

[31] U.S. Nuclear Waste Technical Review Board, *Preparing for Nuclear Waste transportation Technical Issues That Need to Be Addressed in Preparing for a Nationwide Effort to Transport Spent Nuclear Fuel and High-Level Radioactive Waste*, September 2019. https://www.nwtrb.gov See page 77 regarding high burnup spent nuclear fuel that is not repackaged would require many more years of cooling in pools and in dry storage and could not be transported before 2100.

[32] Department of Energy webpage, Pathways to Commercial Liftoff: Advanced Nuclear, March 2023. https://www.energy.gov/lpo/articles/sector-spotlight-advanced-nuclear DOE discusses deploying about 300 gigawatts (GW) by 2050, with current U.S. nuclear capacity of about 100 GW. See also the related COP28 announcement at https://www.energy.gov/articles/cop28-countries-launch-declaration-triple-nuclear-energy-capacity-2050-recognizing-key

the fuel in a single storage canister could not have a nuclear criticality even if water were to enter the canister. But for the higher burnup fuels, even taking credit for fission products that absorb neutrons, it was determined by DOE that a significant number of canisters contained spent nuclear fuel that would have a nuclear criticality if water enters the canister. [33] [34]

In the Yucca Mountain repository design initially proposed in 2002, [35] it was assumed by DOE that a smaller amount of spent nuclear fuel would be loaded into a corrosion-resistant TAD canister, and the fuel being used in the 1990s and before was not much of a criticality risk. But, with the increased use of higher and higher burnup fuels, there are many existing spent nuclear fuel dry storage canisters that would have a nuclear criticality if water entered the canister.

In a geologic repository, the existing thin-walled stainless steel canisters would be breached by corrosion quickly, far sooner than the more corrosion resistant TAD canisters that were never used. [36] The utilities considered the TAD relatively expensive and opted for the cheapest dry storage systems licensed by the NRC. I suppose the utilities were and still are expecting the U.S. taxpayer to sort out the mess sometime in the future.

So, for a number of reasons, the DOE seeks the shortcut of not repackaging the existing canisters of commercial spent nuclear fuel. Obvious problems for direct disposal of existing spent nuclear fuel dry storage canisters are that the thin-walled welded-closed canisters were never designed for repository disposal and these canisters face serious corrosion issues within a shorter time frame than was stated for the TAD.

The commercial spent nuclear fuel canisters pose a number of challenges for repository disposal. The spent nuclear fuel dry storage canisters have been loaded with an increased number of spent fuel assemblies and canisters have gotten larger and heavier. There is a higher thermal load per canister, as well, due to the higher amount of decay heat. This requires more cooling time before being placed in a repository. The canisters contain more fissile material and have neutron absorbers that may degrade. Nuclear criticality in the repository becomes more likely, with the exception of disposal in sufficiently salty brine. The chlorine atoms absorb neutrons and

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[33] E. Hardin et al., *Summary of Investigations on Technical Feasibility of Direct Disposal of Dual-Purpose Canisters*, Prepared for the U.S. Department of Energy, FCRD-UFD-2015-000129, Rev. 1; SAND2015-8712R, May 2015.

[34] E. Hardin, "Dual-Purpose Canister Direct Disposal Technical Feasibility Evaluation: Introduction and Summary," Presentation at the Used Fuel Disposition Annual Working Group Meeting, Law Vegas, Nevada, June 11, 2015.

[35] Department of Energy, *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, Office of Civilian Radioactive Waste Management, DOE/EIS-0250, February 2002. https://www.energy.gov/nepa/articles/eis-0250-final-environmental-impact-statement

[36] Department of Energy, Office of Nuclear Energy, Standardized Transportation, Aging, and Disposal (STAD) Canister Design, Presentation to the Nuclear Waste Technical Review Board, June 24, 2015. https://www.nwtrb.gov/meetings/past-meetings/summer-2015-board-meeting---june-24-2015 Both the earlier "TAD" and the later "STAD" are described in this presentation. None have actually been used. There are 189 bare fuel casks (10.4 percent of dry storage in 2015), 12 welded metal canisters in Holtec Hi-Star 100 transport overpacks (1.0 percent of dry storage in 2015), and 1,865 welded closed canisters (88.6 percent of dry storage in 2015. Of the 1865 canisters, 37 percent were Transnuclear, 41 percent were Holtec, and 20 percent were NAC.

was calculated to prevent criticality in a salt medium, depending on chloride concentration, for those commercial spent nuclear fuel canisters that were evaluated. (See SAND2015-8712R)

The spent nuclear fuel in the canisters is increasingly the high burnup fuel being used at commercial nuclear reactors. The higher burnup fuels contain more fissile material, making a nuclear criticality possible when water enters the canister. In a repository, it is expected that the canisters will corrode and water may infiltrate the repository. With higher fissile material inventory in a canister, nuclear criticality is possible in an increasing portion of the canisters.

Criticality events pose not only an increase in the fission products in the repository, the event may challenge the repository structure. Predicting whether or not the criticality is slow and sustained or rapid and energetic is subject to many variables. **"For transient criticality events, a sudden power pulse might damage fuel, neighboring waste packages, or the engineering barrier system in the vicinity of the critical waste package."** [37]

In my opinion, further attempts to refine the consequence to the repository from post-closure criticality events are misguided and will never achieve a sound safety concept for these concentrated fissile loadings. **Furthermore, the existing thin-walled welded-closed stainless steel canister licensed by the U.S. Nuclear Regulatory Commission continue to pose serious risks before being placed in a repository, as well as after being placed in a repository.**

Department of Energy and Nuclear Regulatory Commission continue to ignore that NRC cannot legally authorize away-from-reactor spent nuclear fuel storage

The U.S. Nuclear Regulatory Commission (NRC) has had another setback, as the Fifth Circuit will not grant another chance to prove its unlawful licensing is acceptable. The 5th Circuit Court of Appeals denied a petition to rehear the court's 2023 decision to vacate Interim Storage Partner's (ISP's) license to build and operate a consolidated interim storage facility for commercial spent nuclear fuel in Andrews Country, Texas. The court majority maintained that the NRC acted beyond its legal authority in issuing a license for the consolidated storage of spent nuclear fuel. The requested *en banc* review was denied, and the case is expected to go to the Supreme Court. [38]

The U.S. Nuclear Regulatory Commission granted licenses to two large consolidated interim storage spent nuclear fuel facilities, one proposed for New Mexico and the other proposed for Texas. [39] [40] A court challenge was brought against the Interim Storage Partners facility proposed

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[37] L. L. Price et al., *Repository-Scale Performance Assessment Incorporating Postclosure Criticality*, Sandia National Laboratory, M2SF-21SN010305061, For the Department of Energy, September 2021.

[38] Radwaste Solutions, *Nuclear Newswire*, "Full court refuses to review Texas interim storage case," March 19, 2024. https://www.ans.org/news/article-5882/full-court-refuses-to-review-texas-interim-storage-case/

[39] U.S. Nuclear Regulatory Commission, *Federal Register*, Vol. 86, No. 178, "Interim Storage Partners, LLC; WCS Consolidated Interim Storage Facility; Issuance of Materials License and Record of Decision," September 17,

for Andrews County, Texas. In addition, with the support of their governors, both Texas and New Mexico have passed legislation aiming to block these spent nuclear fuel consolidated storage facilities from going into operation in their states. [41]

Last August, a court of appeals ruled that the NRC license for the Texas consolidated interim storage facility be vacated because the NRC did not have the authority to authorize the private away-from-reactor facility. [42]

"The Nuclear Waste Policy Act creates a comprehensive statutory scheme for addressing spent nuclear fuel accumulation," the court said. "The scheme prioritizes construction of the permanent repository and limits temporary storage to private at-the-reactor storage or at federal sites. It plainly contemplates that, until there's a permanent repository, spent nuclear fuel is to be stored onsite at-the-reactor or in a federal facility.

"In sum, the Atomic Energy Act doesn't authorize the Commission to license a private, away-from-reactor storage facility for spent nuclear fuel. And the Nuclear Waste Policy Act doesn't permit it. Accordingly, we hold that the Commission doesn't have authority to issue the license challenged here."

Because of the Nuclear Waste Policy Act enacted by Congress, [43] the NRC did not have the authority to grant these licenses. The Nuclear Waste Policy Act provided regulations for the authorization of away-from-reactor consolidated storage of spent nuclear fuel, which the NRC ignored. The NRC ignored NWPA regulations that require limits on the amount of spent nuclear fuel allowed in consolidated storage and that the consolidated storage be conducted only after meeting conditions regarding the availability of a permanent spent nuclear fuel disposition facility.

Spent nuclear fuel continues to accumulate at roughly 2000 metric tons heavy metal each year. After the fuel is used in a nuclear reactor, the "used" or "spent" fuel is then removed from the reactor and cooled at least 5 years in a storage pool and then may be placed in a dry storage

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2021. This is the consolidated storage facility proposed for Andrews County, Texas. (The consolidated storage facility could store up to 40,000 metric tons heavy metal.)

[40] U.S. Nuclear Regulatory Commission, *Federal Register*, Vol. 88, No. 92, "Holtec International; HI-STORE Consolidated Interim Storage Facility," May 12, 2023. (The consolidated storage facility could store up to 100,000 metric tons heavy metal.)

[41] Adrian Hedden, *Carlsbad Current-Argus*, "Feds lose appeal of vacated license for nuclear waste storage site in Permian Basin, March 21, 2024. https://www.aol.com/feds-lose-appeal-vacated-license-105858592.html

[42] United States Court of Appeals for the Fifth Circuit, State of Texas; Greg Abbott, Governor of the State of Texas; Texas Commission on Environmental Quality; Fasken Land and Minerals, Limited; Permian Basin Land and Royalty Owners, versus Nuclear Regulatory Commission; United States of America, No. 21-60743. Filed August 25, 2023. The court found that the Atomic Energy Act did not delegate authority to the U.S. Nuclear Regulatory Commission to license a private, away-from-reactor storage facility for spent nuclear fuel. And the Nuclear Waste Policy Act doesn't permit the NRC to authorize an away-from-reactor spent fuel storage facility. The court found that the NRC does not have authority to issue the license to the Texas consolidated spent fuel facility. The court vacated the NRC's license of the proposed Texas consolidated interim storage facility.

[43] U.S. Congress, *Nuclear Waste Policy Act (NWPA) of 198*2, 97th Congress, Public Law 97-425, January 7, 1983. And U.S. Congress, *Nuclear Waste Amendments - Nuclear Waste Policy Amendments Act of 1987 (NWPAA), 100th Congress,* Public Law 100-203.

system. [44] Spent nuclear fuel at commercial power plants around the country was packaged into dry storage systems licensed by the NRC, as spent fuel pools were filling up to capacity. There is a wide variety of dry storage systems, but most now use thin-walled welded-closed stainless steel canisters for the spent nuclear fuel. [45]

There is a strong desire to remove spent fuel from communities around the country, some at reactor sites that still operate reactors and others that are called stranded fuel sites where the reactors have been decommissioned. While the NRC asserts all of these spent fuel dry storage facilities are safe, some of the dry storage such as on the Pacific Ocean coastline are particularly vulnerable. Not all of the spent nuclear fuel stored at stranded fuel sites is licensed for transportation. The spent nuclear fuel is often stored where the reactor and the storage pool often no longer exist, and there is no facility for examining the condition of the casks, canisters or the spent nuclear fuel.

Moving the spent fuel to New Mexico or Texas is appealing to communities now stuck with spent nuclear fuel. The design and the safety of the existing spent fuel dry storage facilities is generally the same as proposed for New Mexico and Texas. So, the problem is merely shifted from one place to another, but with enormous cost and risk of transportation of spent nuclear fuel provides a radiation dose to citizens all along the transportation routes, which adds up as hundreds or thousands of canisters are transported.

Regarding the proposed consolidated spent nuclear fuel storage facilities in Texas and in New Mexico, there has been no explanation of the financial arrangement of who pays for transportation of the SNF or who pays for the continued storage at the consolidated spent nuclear fuel storage facility or what those fees are.

The design does not include any capability for repackaging the spent fuel, if a canister is damaged or as dry storage canisters age and experience corrosion. The design does not include any capability of providing meaningful inspection of the canisters for corrosion, such as chloride-induced stress corrosion cracking. The spent nuclear fuel canisters were licensed with the mistaken belief that the Department of Energy would begin accepting spent nuclear fuel for disposal in 1998.

[44] Department of Energy, Prepared by Office of Nuclear Energy, *Spent Nuclear Fuel and Reprocessing Waste Inventory: Spent Fuel and Waste Disposition*, PNNL-33938, FCRD-NFST-2013-000263, November 2022. https://www.osti.gov/biblio/1974547 (Inventory ending calendar year 2021.)

[45] U.S. Nuclear Waste Technical Review Board, *Evaluation of the U.S. Department of Energy Research and Development Activities on the Disposition of Commercial Spent Nuclear Fuel in Dual-Purpose Canisters*, February 2024. https://www.nwtrb.gov/our-work/reports/evaluation-of-the-u.s.-department-of-energy-research-and-development-activities-on-the-disposition-of-commercial-spent-nuclear-fuel-in-dual-purpose-canisters-(february-2024)

Department of Energy is falling farther behind in research of spent nuclear fuel safety during inevitable long-term storage

The Department of Energy initiated a research program to investigate the feasibility of long-term dry storage and subsequent transportation of commercial spent fuel in 2009, states a paper in 2019. [46] Now, in 2024, there are still no answers and very little progress on key issues regarding safety of dry storage of spent nuclear fuel. [47]

The Department of Energy acknowledged the gaps in the technical basis for continued storage of spent nuclear fuel, first in 2012. [48] Then in 2019, an additional gap was identified that was the lack of technical basis for understanding what the radiological consequences of a spent nuclear fuel canister breach would be. [49] Each new fuel type requires additional research regarding the storage and disposal of the fuel. The Department of Energy acknowledges that it is already behind in researching the technical basis for fuel already in storage. [50]

Research priorities continue to change as unexpected findings emerge. A patchwork of research is conducted and so far, no conclusions can be drawn from the research that is needed to support the presumption that long-term storage of spent fuel and subsequent transportation is safe.

Research priorities continue to change as unexpected findings emerge. A patchwork of research is conducted and so far, no conclusions can be drawn from the research that is needed to support the presumption that long-term storage of spent fuel and subsequent transportation is safe.

Transportation spent nuclear fuel is needed in order to transport the fuel to a final repository, a reprocessing facility or to an interim storage facility. The transportation involves vibrations that could affect the spent fuel integrity. Normal conditions of transportation as well as accident conditions are of interest. The mechanical behavior and time to fatigue failure of the spent fuel

[46] Ned Larson (Department of Energy), Sylvia Saltzstein (Sandia National Laboratories) and Brady Hanson (Pacific Northwest National Laboratory), "Making the Case: Demonstrating the Integrity of Spent Nuclear Fuel During Long-term Storage and Subsequent Transportation: SAND2019-8749C," PATRAM 2019 Conference.

[47] U.S. Nuclear Waste Technical Review Board Public Meeting, August 30, 2023, Idaho Falls, Idaho. See various presentations including the Sibling Pin Test Campaign Phase I Summary and Draft Phase II Test Plan Overview by Scott Sanborn and John Bignell, Sandia National Laboratories; Advanced Reactor Fuel Gap and FEP Analyses, by Brady Hanson (PNNL-SA-189354); and others.

[48] B. Hanson et al., *Gap Analysis to Support Extended Storage of Used Nuclear Fuel*, FCRD-USED-2011-000136, For the Department of Energy, January 2012.

[49] M. Teague et al., *Gap Analysis to Guide DOE R&D in Supporting Extended Storage and Transportation of Spent Nuclear Fuel: An FY2019 Assessment*, For the Department of Energy, SAND2019-15479R, 2019.

[50] Ned Larson, Department of Energy, Office of Nuclear Energy, "Back-end Management of Advanced Reactors (BEMAR)," U.S. Nuclear Waste Technical Review Board Public Meeting, Idaho Falls, Idaho, August 30, 2023.

subjected to cyclic vibrations depends on many factors such as fuel burnup, oxide thickness, bonding efficiency and stress history. [51]

The research of how the spent fuel cladding holds up during extended dry storage or transportation is not sufficient to determine how long the spent fuel can be safely stored or how the increasingly fragile spent fuel cladding will hold up during transportation. Normal conditions of transportation are being studied but accident conditions also need to be studied.

Spent fuel degradation, especially to the thin zirconium cladding, is affected by many factors such as the vintage and composition of the cladding material, the fuel burnup in the reactor, the fuel drying temperatures, the amount of moisture remaining in the fuel upon being placed in dry storage and others.

Higher burnup results in higher radionuclide inventory. Proposed advanced reactors seek far higher reactor burnups, for which there are no data to support the safety of the storage of the fuel or transportation of the fuel after storage. Average burnups for pressurized water reactors had increased to 45 giga-watt-days per metric ton uranium (GWd/MTU) by 1999 and have continued to increase. The Natrium fast breeder reactor is to use high-assay low-enriched uranium (HALEU) fuel is seeking burnups exceeding 150 GWd/MTU and the Xe-100 high-temperature gas-cooled reactor using TRISO fuel is seeking burnups exceeding 168.5 GWd/MTU. [52]

Higher enrichments and higher burnups cause an increased amount of fission products which increases the fuel temperature during storage. The higher temperatures mean faster degradation rates. It also increases the buildup of higher actinides such as plutonium-239 and americium-241.

The research that has been conducted on spent fuels that were of lower enrichment in uranium-235 and of lower burnup (time in a reactor), roughly 35 GWd/MTU, has limited applicability to the higher burnup spent fuel. This applies to the study of spent fuel at the Idaho National Laboratory of low burnup fuels. [53]

The DOE has not completed adequate research for the higher burnup fuels now in use in commercial nuclear power plants. The problem of assuring the safety of spent fuel during extended storage or transportation has not been solved for the existing fleet of nuclear reactors in the U.S. **And in fact, the large number of proposed variations in advanced reactor fuels is greatly increasing the difficulty of attempting to study the degradation and the safety of the new spent fuels during storage and transportation.** [54]

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[51] Piotr Konarski et al., *Journal of Nuclear Materials*, Volume 555, "Spent nuclear fuel in dry storage conditions – current trends in fuel performance modeling," November 2021. (153138). This paper looks at studies in the U.S. and other countries. https://www.sciencedirect.com/science/article/pii/S0022311521003615#sec0006

[52] See Brady Hanson's presentation at the NWTRB website for the August 2023 meeting at https://www.nwtrb.gov/meetings/past-meetings/summer-2023-board-meeting---august-30-2023

[53] M. A. McKinnon and A. L. Doherty, *Spent Nuclear Fuel Integrity During Dry Storage – Performance Tests and Demonstrations*, Pacific Northwest National Laboratory, PNNL-11576, June 1997. (29022298) This report summarizes the results of fuel integrity surveillance in bolted closed casks stored at the Idaho National Laboratory between 1984 and 1991. The spent fuel was only 2.5 weight percent enriched in uranium-235.

[54] Williams, W. et al., U.S. NRC, *Metal Fuel Qualification – Fuel Assessment Using NRC NUREG-2246, "Fuel Qualification for Advanced Reactors*," NUREG/CR-7305 2023 at https://www.nrc.gov/docs/ML2321/ML23214A065.pdf)

Department of Energy doesn't know or won't say how long spent nuclear fuel will remain safe — as disposal remains elusive and many decades away, at best

Neither the DOE nor the U.S. Nuclear Regulatory Commission who licensed the dry storage systems want to admit how few years it may take for spent nuclear fuel dry storage canisters to experience a partial but debilitating degree of degradation or of complete through-wall canister breach.

While the DOE was well aware of chlorides in the atmosphere and acknowledged that fact in 2002, the DOE ignored the chloride-induced stress corrosion cracking mechanism in the stainless steel of spent nuclear fuel dry storage canisters. [55] The spent nuclear fuel that was packaged for dry storage, was placed in a variety of dry storage systems, but prevalently, was placed in thin-walled welded-closed stainless steel canisters, usually 0.5 inch thick. The canisters are placed in concrete vaults but they have continuous natural circulation of atmospheric air to cool the canister and are exposed to atmospheric chlorides during storage.

The dry storage systems used by the commercial nuclear power industry were licensed by the U.S. Nuclear Regulatory Commission, initially for twenty years. Canister aging mechanisms were ignored as the licensing was granted beginning in the late 1980s and only in 2012 did the NRC formally acknowledge that the stainless-steel canisters were susceptible to stress corrosion cracking. [56] [57]

The theoretical time for chloride-induced stress corrosion cracking to proceed is dependent upon several factors unique to each individual spent nuclear fuel canister. There are variables include canister temperature, atmospheric humidity, atmospheric levels of chlorides from sea salt or magnesium chloride or other source, and canister metal wall thickness and metal stresses. [58] The canister temperature depends on how long the spent fuel aged prior to packaging, the length of time in dry storage as the decay heat falls, and on the fuel burnup which affects the decay heat initially and its trend over time. The need to predict how long it will take for chloride-induced

[55] Department of Energy, *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, Office of Civilian Radioactive Waste Management, DOE/EIS-0250, February 2002. https://www.energy.gov/nepa/articles/eis-0250-final-environmental-impact-statement See Appendix K for the "Long-Term Radiological Impact Analysis for the No-Action Alternative."

[56] U.S. Nuclear Regulatory Commission, *Potential Chloride-Induced Stress Corrosion Cracking of Austenitic Stainless Steel and Maintenance of Dry Cask Storage System Canisters*, Information Notice 2012-20, 2012. https://www.nrc.gov/docs/ML1231/ML12319A440.pdf

[57] U. S. Nuclear Regulatory Commission, *Identification and Prioritization of the Technical Information Needs Affecting Potential Regulation of Extended Storage and Transportation of Spent Nuclear Fuel – Draft Report for Comment*, May 2012. ML120580143. This report contains tables ranking the level of knowledge and safety risk of spent nuclear fuel in storage and the dry storage systems. Stainless steel atmospheric stress corrosion cracking is acknowledged to have "low" level of knowledge and high research priority.

[58] G. Oberson et al., "U.S. NRC-Sponsored Research on Stress Corrosion Cracking Susceptibility of Dry Storage Canister Materials in Marine Environments – 13344." WM2013 Conference. February 24-28, 2013. Phoenix, Arizona.

stress corrosion cracking to initiate and then how long it will take for the cracking to compromise canister integrity has been recognized now for over a decade.

The U.S. Nuclear Regulatory Commission who licensed the dry storage systems, did so, without stating important corrosion mechanisms, without having any way to conduct meaningful corrosion or material degradation inspections, and without any way of repairing or repackaging a canister that was degraded or failed.

In 2002, the Department of Energy issued its wildly incorrect prediction that dry storage systems in use at commercial nuclear power plants would last for over 1100 years before breaching. [59] That analysis as well as the NRC's licensing of dry storage spent nuclear fuel canisters had ignored **chloride-induced stress corrosion cracking, which can be initiated within weeks [60] and then can progress the metal degradation from partial-cracking to through-wall within about 20 to 40 years. [61]**

Concerning the safety of dry storage of spent nuclear fuel is the concept of repackaging the dry storage canisters (and in some cases, dry storage casks). The U.S. Nuclear Regulatory Commission assumed in its 2014 "continued storage" Environmental Impact Statement that Dry Transfer Stations would appear when and where needed. [62] But it has never been stated who would pay for these systems and so far, no system has been designed.

Following over a decade since the problem of stress corrosion cracking was formally identified, the status of stress corrosion research can be summed up in a Sandia National Laboratories report from 2021 and related 2022 presentation: [63] [64] they are still studying the

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[59] Department of Energy, *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, Office of Civilian Radioactive Waste Management, DOE/EIS-0250, February 2002. https://www.energy.gov/nepa/articles/eis-0250-final-environmental-impact-statement See Appendix K for the "Long-Term Radiological Impact Analysis for the No-Action Alternative."

[60] U.S. Nuclear Regulatory Commission, *Atmospheric Stress Corrosion Cracking Susceptibility of Welded and Unwelded 304, 304L, and 316L Austenitic Stainless Steels Commonly Used for Dry Cask Storage Containers Exposed to Marine Environments*, NUREG/CR-7030, October 2010. This report estimated that the onset of stress corrosion cracking, under ideal conditions, would be expected to take between 32 and 128 weeks. But this estimate does not take into account the operating history of the dry storage cask or canister and the local environment at each location.

[61] Electric Power Research Institute (EPRI), *Flaw Growth and Flaw Tolerance Assessment for Dry Cask Storage Canisters*, 3002002785, October 2014. https://www.epri.com/research/products/000000003002002785 Figures 3-9 and 3-10, Crack depth vs. Time for two dry storage locations gave the prediction of 20 to 40 years for 100 percent crack depth.

[62] U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel*, NUREG-2157, September 2014. https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr2157/index.html

[63] C. Bryan et al., *FY21 Status Report: SNF Interim Storage Canister Corrosion and Surface Environment Investigations*, M2SF-21SN010207056/SAND21-12903 R. Albuquerque, New Mexico: Sandia National Laboratories, September 2021. https://www.osti.gov/biblio/1825847

[64] C. Bryan et al., "Stress Corrosion Cracking Research at Sandia National Labs," Electric Power Research Institute (EPRI) Extended Stroage Collaboration Program (ESCP) Winter 2022 Meeting, Charlotte, South Caroline, November 7-10, 2022. (Presentation found at NWTRB website for 2022 meetings.)

problem and have yet to provide an estimated time for damage to spent nuclear fuel dry storage canisters.

Stress corrosion cracking through stainless steel can include multiple cracks progressing through the metal, leaving a rotted metal canister and breaching the canister. The welds on the canister are particularly susceptible, and there are welds around each end and in multiple long welds along the length of the canister. Canisters are filled with helium before closure. A breach will let the helium out and air (oxygen) in. Oxygen entry to the canister may accelerate spent nuclear fuel degradation. The more compromised the fuel cladding, the more that oxygen ingress may degrade the fuel.

According to the NWTRB 2010 report, "a breach of the main canister may allow the release of radioactive material. Fuel previously oxidized to the U_3O_8 form 'is a fine powder that spalls from the fuel surface. The release of fines and/or fuel relocation from the split cladding must be evaluated if U_3O_8 formation is suspected. The extent of oxidation of irradiated UO_2 is a time and temperature-dependent phenomenon.'" [65]

Zirconium, plutonium and uranium are known to be pyrophoric. For example, uranium in the form of fine powder may be pyrophoric. [66]

A survey of the previous studies and research needs conducted by EPRI in 2017 [67] states that "The potential consequences associated with unmitigated CISCC [chloride induced stress corrosion cracking] of canisters have not been specifically analyzed." The EPRI review stated that: "Additional analysis may be required to determine bounding values of residual water content, burnup, heat load at start of storage, and storage duration prior to air ingress for which the potential for fuel oxidation and flammable hydrogen concentration can be eliminated as a concern, thereby avoiding the need to consider them as part of a consequence evaluation."

The Department of Energy merely acknowledges even in 2022 that the consequences of canister breach remain uncertain and are still being studied. [68]

The NWTRB's 2024 report acknowledges that the NRC's regulations concerning dry storage of spent nuclear fuel do not currently address storage for extended periods. [69]

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[65] U.S. Nuclear Waste Technical Review Board (NWTRB), *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel*, Arlington, Virginia, December 2010. This is a useful report generally, but its criticality discussion is inadequate, particularly for high burnup fuels used in light-water reactors since about 1999.

[66] T. C. Totemeier, Argonne National Laboratory, *A review of the corrosion and pyrophoricity behavior of uranium and plutonium*, ANL-ED-95-2, June 1, 1995. https://www.osti.gov/biblio/97298

[67] S. Chu, EPRI Project Manager, The Electric Power Research Institute (EPRI), *Dry Cask Storage Welded Stainless Steel Canister Breach Consequence Analysis Scoping Study*, Technical Update, 3002008192, November 2017.)

[68] C. Bryan et al., "Stress Corrosion Cracking Research at Sandia National Labs," Electric Power Research Institute (EPRI) Extended Stroage Collaboration Program (ESCP) Winter 2022 Meeting, Charlotte, South Caroline, November 7-10, 2022. (Presentation found at NWTRB website for 2022 meetings.)

[69] U.S. Nuclear Waste Technical Review Board, *Evaluation of the U.S. Department of Energy Research and Development Activities on the Disposition of Commercial Spent Nuclear Fuel in Dual-Purpose Canisters*, February 2024. https://www.nwtrb.gov/our-work/reports/evaluation-of-the-u.s.-department-of-energy-research-

Neither the Department of Energy nor the Nuclear Regulatory Commission have been willing to provide an estimate of the period of time it will take for partial- or through-wall canister metal corrosion such as from chloride-induced stress corrosion cracking which is known to be applicable to spent nuclear fuel dry storage canisters. Previous studies have indicated that stress corrosion cracking may cause through-wall cracking of the roughly 0.5-inch-thick stainless-steel canisters of spent nuclear fuel within as little as two or three decades after being loaded. [70] [71] No technical valid analysis is being provided that supports that the canisters are safe for 80 years, let alone after 80 years.

The U.S. Nuclear Regulatory Commission's stance on safety can be understood when you understand that it takes its role to shield the commercial utilities from needing to spend its own money is its main priority.

The commercial nuclear industry's position, according to the Nuclear Energy Institute [72] is captured as follows:

> "… we should recognize that the repository should be designed for the waste form, the canisters, not the other way around. Any repackaging, in needed, should not be performed at the nuclear power plant sites. Going back to what I said earlier. We're not repackaging facilities. We generate electricity. We safely store our waste. But we're not in the business of repackaging…"

The commercial nuclear utilities are eager to sell off the stranded fuel sites, passing the problem to companies that are likely to go bankrupt. The costs of stranded spent nuclear fuel, will inevitability be paid by the U.S. taxpayer. But the stalemate continues because utilities don't want to pay for repackaging and the DOE does not want to admit how much the repackaging is going to cost.

Without adequate questioning, the 2024 NWTRB report [73] repeats nuclear industry propaganda that spent nuclear fuel dry storage is safe because the dry storage systems were licensed according the U.S. Nuclear Regulatory Commission safety standards. Those standards

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and-development-activities-on-the-disposition-of-commercial-spent-nuclear-fuel-in-dual-purpose-canisters-(february-2024)

[70] U.S. Nuclear Regulatory Commission, *Atmospheric Stress Corrosion Cracking Susceptibility of Welded and Unwelded 304, 304L, and 316L Austenitic Stainless Steels Commonly Used for Dry Cask Storage Containers Exposed to Marine Environments*, NUREG/CR-7030, October 2010. This report estimated that the onset of stress corrosion cracking, under ideal conditions, would be expected to take between 32 and 128 weeks. But this estimate does not take into account the operating history of the dry storage cask or canister and the local environment at each location.

[71] Electric Power Research Institute (EPRI), *Flaw Growth and Flaw Tolerance Assessment for Dry Cask Storage Canisters*, 3002002785, October 2014. https://www.epri.com/research/products/000000003002002785 Figures 3-9 and 3-10, Crack depth vs. Time for two dry storage locations gave the prediction of 20 to 40 years for 100 percent crack depth.

[72] U.S. Nuclear Waste Technical Review Board (NWTRB), *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel*, Arlington, Virginia, December 2010. See page 17.

[73] U.S. Nuclear Waste Technical Review Board (NWTRB), *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel*, Arlington, Virginia, December 2010.

ignored aging mechanisms and well-known corrosion processes because initially the licensing was only for 20 years. **The stress corrosion cracking research continues and yet fails year after year to provide basic information: how long before the spent nuclear fuel dry storage canisters are fatally weakened or breached by stress corrosion cracking.**

Still no design of a Dry Transfer Station to repackage spent nuclear fuel

In 2010, the U.S. Nuclear Waste Technical Review Board (NWTRB) recommended several research programs related to the extended storage and transportation of spent nuclear fuel, including the design and demonstration of dry-transfer systems for removing fuel from casks and canisters following extended dry storage of light-water reactor commercial spent nuclear fuel. [74]

Congress created the NWTRB in the Nuclear Waste Policy Amendments Act of 1987 (NWPAA) (Public Law 100-203) to evaluate the technical and scientific validity of activities undertaken by the Secretary of Energy to implement the Nuclear Waste Policy Act. But the recommendations from the NWTRB are typically tardy and also are typically not heeded by the Department of Energy. The NWTRB does not track the status of progress on its recommendations.

The most recent NWTRB report was issued in 2024 and it discusses the need for repackaging of spent nuclear fuel in dry storage as no repository is available and it discusses the Department of Energy's research over the last decade regarding spent nuclear fuel disposal. [75] The DOE would like to avoid the cost of repackaging the spent nuclear fuel in dry storage. The repackaging may be needed at existing dry storage sites, at consolidated storage facilities and/or at a repository site.

The DOE has been researching the feasibility of disposing of existing spent nuclear fuel canisters that were not designed for disposal. The DOE's geologic disposal research includes a variety of potential geologic media, including argillite, crystalline and salt. [76] No decisions have been made and no repository has been sited. The DOE is not discussing how many decades away a repository could become available, but it is generally acknowledged that it won't happen by 2048, which is about 60 years after the earliest dry storage systems were loaded with spent nuclear fuel.

[74] U.S. Nuclear Waste Technical Review Board (NWTRB), *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel*, Arlington, Virginia, December 2010.

[75] D. Sassani et al., *SFWST Disposal Research R&D 5 Year Plan – FY2021 Update*, SAND2021-12491R, Albuquerque, New Mexico, August 2021.

[76] U.S. Nuclear Waste Technical Review Board, *Evaluation of the U.S. Department of Energy Research and Development Activities on the Disposition of Commercial Spent Nuclear Fuel in Dual-Purpose Canisters*, February 2024. https://www.nwtrb.gov/our-work/reports/evaluation-of-the-u.s.-department-of-energy-research-and-development-activities-on-the-disposition-of-commercial-spent-nuclear-fuel-in-dual-purpose-canisters-(february-2024)

In 2014, the U.S. Nuclear Regulatory Commission assumed in its generic EIS that Dry Transfer Stations would be used to repackage the spent nuclear fuel in dry storage, if needed and as needed. [77] We continue to wait for the Department of Energy to cite one or several spent nuclear fuel repositories and design and build them. It is acknowledged that this will not happen by 2048 and would take decades.

There are several reasons why a spent nuclear dry storage canister could need to be repackaged: degradation of the canister by mechanisms such as stress corrosion cracking, or damage to a canister by mishandling during movement at the dry storage site. The repackaging could also be required to provide the ability to meet transportation requirements, as not all dry storage systems were licensed for transportation.

But, while in theory the canister can be replaced with a new canister, and perhaps even a canister designed for disposal, the spent nuclear fuel inside becomes more fragile over time. The high-burnup fuel used by utilities, continues the trend of higher and higher enrichment and higher fuel burnup.

The spent fuel pools are nuclear reactor sites are demolished after the reactor operations cease because of the costs of maintaining spent nuclear fuel pools. In addition, even if spent nuclear fuel were cool enough to return to the pool after being in dry storage, the additional stresses to the spent fuel from re-exposure to water and repeated drying process for the repackaging into dry storage would introduce more unknowns about the future degradation processes for addition years of dry storage of the spent fuel. Basically, even if a spent fuel pool remained available at the site, it might not be feasible to use it to repackage a canister. Handling damaged spent fuel may be difficult or impossible in either a Dry Transfer Station or in a fuel pool.

In 2014, the NRC declared in its "Continued Storage EIS" [78] that repackaging facilities would become available as needed at spent nuclear fuel storage sites and repackaging every 100 years was assumed. But there is no facility for repackaging the spent nuclear fuel at any site and no Dry Transfer Station has been designed as of 2024.

Repackaging of spent nuclear fuel already placed in dry storage systems may be needed for continued storage at these stranded fuel sites if a permanent solution isn't found. Repackaging may be needed for those casks or canisters that are degraded or were not designed to meet transportation requirements. And repackaging may be needed to place the spent nuclear fuel into a container deemed acceptable for disposal, should the Department of Energy ever site one or more disposal repositories and decide what the disposal packaging needs are.

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[77] U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel*, NUREG-2157, September 2014. https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr2157/index.html

[78] U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel*, NUREG-2157, September 2014. https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr2157/index.html

Apparently, the NRC and the electric utilities hope that the Department of Energy will design, build and conduct the work of building Dry Transfer Stations, and repackaging the spent nuclear fuel. Over a decade after acknowledging the need for Dry Transfer Stations, there remains no design for a Dry Transfer Station. [79] This would save the electric utilities who own the commercial nuclear power plants the money and effort. There is no statement as to who is to design and pay for a Dry Transfer Station, or when.

Department of Energy Secretary sets horrible example and ignores ALARA by placing hands on Dry Storage Vault

A recent video by the Secretary of Energy shows Kathryn Huff standing next to a spent nuclear fuel dry storage facility and actually placing her hands on the concrete vault. See https://www.youtube.com/watch?v=ew_ZaFuBoSs Huff sets an incredibly poor example in her attempt to make the storage of spent nuclear fuel in dry storage seem safe.

Perhaps she knows that this particular vault has been adequately surveyed for gamma and also for neutron dose. Perhaps she does not plan to frequently visit such dry storage installations or to live near one, so she isn't worried about this one-time radiation exposure.

But does she know that she may be encouraging people, from citizens touring a facility to radiation workers to emergency responders, to wrongly assume that their radiation doses near spent nuclear fuel dry storage systems will be negligible?

She may expect that her estimated whole-body dose from posing for that video propaganda piece was low. But does she know her breast dose? Does she know her gonad dose? Does she know what a man's gonad dose would be from standing next to spent nuclear fuel in dry storage? It would depend on the specific energy levels of the gamma and the neutron radiation from the spent nuclear fuel.

Estimating the radiation dose that people receive from being near the spent fuel in dry storage is complex. The external radiation dose from being near spent fuel in a cask for transportation or in dry storage is of interest, both to the public and to workers. And the internal radiation dose from the neutron capture reaction in air and soil creates an additional radiation dose that is not monitored.

Radiation protection dose limits were developed primarily by observing cancer occurrence from external radiation exposure. Radiation protection limits are not calibrated for reproductive health. A man's gonads are unprotected, and are not protected by depth in the body. Radiation protection limits for whole body dose are not protective of reproductive health. The epidemiology for radiation workers has indicated that annual doses significantly below radiation worker limits (5000 millirem per year) allows excess cancers in radiation workers, despite the claim that the radiation protection limits for workers are protective.

[79] S. Bader, Updating the Dry Transfer System – 18110, WM2018 Conference, Phoenix, Arizona, March 18-22, 2018.

For external radiation, the basics of radiation shielding are time, distance and shielding. Limit your stay time and keep your distance from radioactive materials. Design the shielding to limit the radiation exposure.

The concept of ALARA was to keep radiation doses "as low as reasonably achievable." The idea was to minimize a workers radiation dose rather than simply not exceeding annual radiation dose limits. The Secretary of Energy for the Department of Energy appears to not understand ALARA.

Unshielded, the thin-walled canisters used prevalently for dry storage of spent fuel in the U.S. are enormous and can exceed 100,000 rad/hr. [80] For external dose, you can assume 1 rad is equivalent to 1 rem, even though the details of depth of the dose into the body, versus the dose at the surface of the body, which depend on the gamma ray energy, complicate this. A lethal dose often being defined as 400 rem, an unshielded spent fuel canister presents a large hazard, a lethal dose in about 14 seconds. With shielding, the doses are far lower, but still pose a chronic dose health hazard.

Huff was standing closer than 1 meter from the dry storage vault. **For a single pressurized water reactor (PWR) storage cask, initial enrichment of 5 percent of uranium-235, average burnup of 70 GWd/MTU, and a 1-year cooling time, at 1 meter, the total dose rate is 509 millirem/hr.** At 100 meters, the total dose rate is 0.343 mrem/hr. And at 1,600 meters, the total dose rate is 8.0E-7 mrem/hr. Over 80 percent of the dose is due to primary gamma for each of these distances.

After a 40-year cooling time, at 1 meter, the total dose rate is 4.73 mrem/hr. At 100 meters, the total dose rate is 3.13E-3 mrem/hr. And at 1,600 meters, the total dose rate is 1.6E-8 mrem/hr. However, for the 40-year cooling time, at 1,600-meter, secondary gamma contributes over 90 percent to the total dose. Also, at 1000 meters, primary dose is equivalent to neutron dose and neutron dose won't be measured without a neutron detector. [81] The low energy beta radionuclides of carbon-14 and tritium, also will not be detected by typical radiation monitoring metering or TLD badges.

For a hypothetical concrete cask loaded with pressurized water reactor fuel, the external radiation dose rate increases with increasing fuel burnup. The dose rate decreases with increasing distance from the cask and with increasing air density. The dose rate also decreases with years of cooling time. Again, Department of Energy Secretary Huff sets a horrible example by standing close to the vault and touching the vault. She does not explain that the radiation levels near a vault may vary depending on the time elapsed since the nuclear fuel was

[80] S. Chu, EPRI Project Manager, The Electric Power Research Institute (EPRI), *Dry Cask Storage Welded Stainless Steel Canister Breach Consequence Analysis Scoping Study*, Technical Update, 3002008192, November 2017. (Note that gamma dose rates from unshielded spent fuel canisters assumed for 60 GWd/MTU of 5 percent initial enrichment, gamma dose rates of 1.18E4 rad/h and 1.69E5 rad/hr.)

[81] Georgeta Radulesuc and Peter Stefanovic (Oak Ridge National Laboratory), *A Study on the Characteristics of the Radiation Source Terms of Spent Fuel and Various Non-Fuel Hardware for Shielding Applications*, ORNL/SPR-2021/2373, May 2022. (ML22144A062)

in a reactor and has cooled. No one who values their health, especially their reproductive health should behave this way.

The primary gamma radiation that passes through the cask or canister system creates a range of gamma energies. The radionuclides confined inside the cask or canister that contribute to primary gamma outside the container are cerium-144, ruthenium-106, cesium-134, europium-154, strontium-90 and cesium-137. [82]

But in addition to the gamma radiation, neutrons are escaping the casks or canister systems. Neutrons go right through metal. The neutrons hitting a human body do great harm. But not only that, these neutrons collide with air or soil and create what is called "secondary gamma." High burnup fuels emit more neutrons and cause higher neutron dose and higher secondary gamma dose. They would also create more carbon-14 and also activation products in air and soil.

The amount of radiation dose from neutrons is less than for primary gamma, but it contributes proportionately more to the dose rate with increasing distance from the cask. The contribution to radiation dose from secondary gamma is significantly increased with higher fuel burnup. The secondary gamma radiation also stays higher over time and does not decay away as rapidly as the primary gamma radiation.

Neutrons are emitted from the curium-244, curium-242, curium-246, and plutonium-238. Curium-244 is the dominating neutron source throughout a 40-year period.

For a 70 GWd/MTU average assembly burnup value and a 40-year cooling time, secondary gamma radiation dominated total dose rate at distances beyond 700 meters. A 10 percent decrease in air density produced a total dose rate increase at 1,600 meters from the cask of about 110 percent for fuel with a 5-year cooling time. [83]

Air density and soil composition affect radiation dose rates from the spent fuel in dry storage, particularly the far-field dose rates. Small air density variations can have a large effect on radiation dose rates at long distances from a cask. The dose rate increases with decreasing air density.

Depending on soil type, the groundshine dose is affected by the various scattering, neutron moderation, and absorption characteristics of the elements in the soil. The concentration of hydrogen in the soil as the hydrogen reduces the neutron energy and increases the probability of

[82] Georgeta Radulescu (Oak Ridge National Laboratory), U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, *Updated Recommendations Related to Spent Fuel Transport and Dry Storage Shielding Analyses*, NUREG/CR-7302, ORNL/TM-2023/2629, May 2023. (ML23135A870)

[83] Georgeta Radulesuc and Peter Stefanovic (Oak Ridge National Laboratory), *A Study on the Characteristics of the Radiation Source Terms of Spent Fuel and Various Non-Fuel Hardware for Shielding Applications*, ORNL/SPR-2021/2373, May 2022. (ML22144A062)

radiative capture reactions. This decreases the neutron groundshine but generates new secondary gamma sources. [84]

To recap, gamma radiation from the dry cask or canister systems occurs as gamma rays escape the cask. This occurs without external contamination of the cask or canister and without the loss of containment of the cask or canister. In addition to the gamma rays streaming from the cask or canister, neutrons are escaping from the cask or canister. While steel helps to shield gamma rays, neutrons are not stopped by steel. Neutron shielding typically includes material with hydrogen. Some neutron shielding materials may be vulnerable in a fire or other degradation. The escaping neutrons are not detected by gamma radiation detectors. The neutrons, however, to do create secondary gamma rays by interactions with the elements in soil. The neutrons also activate and make radioactive metal and concrete in the cask system. [85]

Metals can become activated by neutron absorption. For example, cobalt-59 present in metal can absorb a neutron and become cobalt-60 that is radioactive. The cobalt gamma dose from fuel upper and lower fittings gas plenum of the fuel assemblies is significant, especially at about 5 years of cooling, but tapers off after that.

When I was given training as a radiation worker, it was emphasized that beta radiation is easily shielded. Stontium-90 contained in the spent fuel is a beta emitter. Beta particles are shielded by the metal cask or canister. **However, the beta emission inside the cask can create x-ray photons outside the cask through the production of Bremsstrrahlung radiation. And this adds to the primary gamma from the cask.**

Not usually mentioned regarding dry spent fuel storage is that the neutrons activate air and dust that can be inhaled. [86] Nor is the potential surface contamination from contamination in the spent fuel pool mentioned. Based on the allowable surface contamination from radionuclides in spent fuel pool water that could contaminate the metal canister lowered into the pool to load the spent fuel, those radionuclides can pose an inhalation dose as well.

Inhaled radionuclides become incorporated into the body. While the radioactive decay rate and biological clearance time is taken into account, the actual harm to specific organs and overall health harm are thought by independent experts to be perhaps 100 times higher than indicated by stated radiation whole-body doses in rem. This means that what would be considered negligible, such as a 10 mrem per year dose may in reality be more like a 1 rem dose annually.

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[84] Georgeta Radulescu (Oak Ridge National Laboratory), U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, *Updated Recommendations Related to Spent Fuel Transport and Dry Storage Shielding Analyses*, NUREG/CR-7302, ORNL/TM-2023/2629, May 2023. (ML23135A870)

[85] Waste Control Specialists, *WCS Consolidated Interim Storage Facility Safety Analysis Report*, Revision 2, ML18206A527, undated. [See neutron monitoring, secondary gamma, neutrons in air, soil or concrete, "skyshine."]

[86] Department of Energy, *Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, Volume II Appendices A through J, DOE/EIS-0250F-S1, ML081750216, June 2008. [See activated air and dust in the repository and canister surface contamination dose description.]

When visiting nearby a dry storage facility for spent nuclear fuel, the radiation monitoring may be inadequate. Neutron monitoring is needed. Alpha particles may be present from canister surface contamination. Low energy beta particles may not be monitored, such as carbon-14 and tritium. Gamma activation of soil and air may be inhaled. And gamma radiation monitoring may be calibrated at these facilities to understate the true gamma dose. The gamma dose can vary depending on top or bottom of the system.

Department of Energy Secretary Huff is seeking to con communities into accepting consolidated storage of spent nuclear fuel, all without a geologic repository program. She is seeking consolidated storage to create the appearance of a solution for the nation's spent nuclear fuel problem. Consolidated storage is being sought so that much more spent nuclear fuel can be generated.

Huff is giving disinformation in her video and avoiding essential information important to citizens to know, such as — how many years do we have before we have spent nuclear fuel canister breaches and what are the possible consequences of such a breach, especially for high burnup fuel?

Articles by Tami Thatcher for April 2024.

On April 1, 2024, an error was corrected where the wrong year was given and is 2070. Two paragraphs were added for TRISO fuel disposal issues and other minor editing.

Thatcher has a Bachelor of Science degree in Mechanical Engineering and worked as an Advisory Engineer for a Department of Energy contractor, specializing in nuclear facility probabilistic risk assessment and safety analysis. For over a decade, she has studies and written about nuclear energy accidents and risks, Department of Energy nuclear facility accidents and risks, environmental contamination around the Idaho National Laboratory, radiation protection issues for workers and the public, INL legacy cleanup issues, and spent nuclear fuel and high-level waste storage and disposal issues.