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Buried Deep in the Department of Energy's Environmental Impact Statement, DOE Admits Proposed Versatile Test Reactor Accidents Can Be Catastrophic to Southeast Idaho

The Department of Energy has issued for public comment its Environmental Impact Statement (EIS) for the proposed Versatile Test Reactor (VTR). [1] [2]

The DOE wants us to believe that this time will be different - that the costs of the sodium-cooled fast neutron reactor project and its uranium-plutonium metal fuel won't spiral billions of dollars out of control as did the now cancelled mixed-oxide fuel facility at Savannah River. [3] [4]

The DOE wants us to believe its many assumptions and assertions about the accident risks posed by the project. Buried in the EIS document it does admit that if the VTR has a bad day, "the consequences can be in the hundreds or thousands of rem to the public…" [5] But trust us, they say, that is "beyond extremely unlikely."

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[1] U.S. Department of Energy's Versatile Test Reactor Draft Environmental Impact Statement (VTR EIS) (DOE/EIS-0542) at https://www.energy.gov/ne/downloads/public-draft-versatile-test-reactor-environmental-impact-statement-doeeis-0542 (Announced December 21, 2020). A copy of the Draft VTR EIS can be downloaded at https://www.energy.gov/nepa or https://www.energy.gov/ne/nuclear-reactor-technologies/versatile-test-reactor. Extended deadline, VTR EIS comments now due: March 2, 2021. Send by email to VTR.EIS@Nuclear.Energy.gov

[2] See Versatile Test Reactor (VTR) draft Environmental Impact Statement comments on our home page at http://www.environmental-defense-institute.org (see http://www.environmental-defense-institute.org/publications/EDI.Com.VTR.6.pdf and http://www.environmental-defense-institute.org/publications/CommentVTRdEIS.pdf and http://www.environmental-defense-institute.org/publications/CommentVTRdEIS2.pdf)

[3] Douglas Birch and R. Jeffrey Smith, *Center for Public Integrity*, "Nuclear Waste: A $1 Billion Energy Department Project Overshoots Its Budget by 600 Percent," June 25, 2013. https://publicintegrity.org/national-security/nuclear-waste-a-1-billion-energy-department-project-overshoots-its-budget-by-600-percent/

[4] U.S. Government Accountability Office, Surplus Plutonium Disposition, GAO-20-166, October 2019. https://www.gao.gov/assets/710/702239.pdf

[5] Excerpt from VTR EIS, Appendix D, page D-74, Section D.4.9 Versatile Test Reactor Beyond-Design-Basis Reactor Accidents, "By design, the VTR is able to withstand a wide range of accidents. Most events that could affect safe operation of the VTR are mitigated by the VTR design. This section addresses potential beyond-design-basis accidents that have the potential for high consequences even though the probability is very low (1×10^{-6} to 1×10^{-8} per year). These accidents represent events in which the consequences can be in the hundreds or thousands of rem to the public while probabilities are less than one in a million per year. Consideration of these very low-probability but potentially high-consequence accidents provides valuable insight for the public and decision-makers in understanding the overall risks of operation, siting decisions, and the need for emergency preparedness."

The DOE wants to bet the farm - your farm (or business or home or life or your child's life) that a severe reactor accident won't happen.

And even without a reactor accident, an accident involving making VTR's plutonium fuel or performing the required processing to store the fuel involves significant risk to communities within 50 miles of the facilities.

The project DOE is promoting aims for privatized profits at tax payer expense. It claims to help solve energy poverty by helping to generate electricity in the most expensive and accident-prone way known and by adding to the spent nuclear fuel storage and disposal problems we already have. [6] [7] [8] The Department of Energy has not estimated what the nation's spent nuclear fuel storage, repackaging and disposal costs will ultimately be.

The fees collected from operating commercial nuclear reactors probably won't even pay for the cost of repackaging the waste for disposal, let alone obtaining the two disposal repositories now needed. [9] [10] [11]

Other radioactive wastes from the VTR project will either be buried over the Snake River Plain aquifer as it the DOE's current practice or shipped elsewhere. The presumption that the Waste Isolation Pilot Plant (WIPP) in New Mexico can accept any and all waste that the DOE

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[6] Blue Ribbon Commission of America's Nuclear Future. 2012. (It uses 2010 estimates for spent fuel quantities) www.brc.gov

[7] U.S. Nuclear Waste Technical Review Board (NWTRB), Management and Disposal of U.S. Department of Energy Spent Nuclear Fuel. Arlington, December 2017. See p. 15.

[8] Nuclear Regulatory Commission, 10 CFR 51, Waste Confidence-Continued Storage of Spent Nuclear Fuel, Federal Register, Vol. 78, No. 178, September 13, 2013.

[9] Government Accountability Office, Spent Nuclear Fuel: Accumulating Quantities at Commercial Reactors Present Storage and Other Challenges, GAO-12-797. September 14, 2012. https://www.gao.gov/products/GAO-12-797 The amount of spent nuclear fuel is increasing by about 2,000 metric tons per year and likely more than doubling to about 140,000 metric tons before it can be moved off-site. "At the end of 2012, over 69,000 metric tons is expected to accumulate at 75 sites in 33 states…"

[10] Sandia National Laboratories, Spent Fuel and Waste Science and Technology, *Direct Disposal of Spent Nuclear Fuel in Dual Purpose Canisters: R&D Path Forward*, PowerPoint presentation, SAND2018-5437 PE, May 2018. https://www.osti.gov/servlets/purl/1515737 Their study estimated the cost of repackaging spent nuclear fuel canisters at $32.7 billion, see page 9. The criticality concerns for not repackaging were said to need to argue low risk rather than low probability of criticalities in the repository, meaning their argument would have to show criticalities were low consequence.

[11] U.S. Government Accountability Office, *Commercial Nuclear Waste: Effects of a Termination of the Yucca Mountain Repository Program and Lessons Learned*," GAO-11-229, May 10, 2011. https://www.gao.gov/assets/320/317634.html "Spent nuclear fuel is considered one of the most hazardous substances on earth. Without protective shielding, its intense radioactivity can kill a person exposed directly to it within minutes or cause cancer in those who receive smaller doses. Although some elements of spent nuclear fuel cool and decay quickly, becoming less radiologically dangerous, others remain dangerous to human health and the environment for tens of thousands of years. The nation's inventory of over 65,000 metric tons of commercial spent nuclear fuel--enough to fill a football field nearly 15 feet deep--consists mostly of spent nuclear fuel removed from commercial power reactors. The volume of commercial spent nuclear fuel is expected to more than double by 2055—assuming currently operating reactors receive license extensions and no new reactors are built--and is currently accumulating at 75 sites in 33 states…"

can't dispose of anywhere else continues a long pattern of DOE expecting to undermine the laws that were made to protect New Mexico from an ever-expanding mission.

The VTR project could use surplus plutonium stocks but these proved costly and complicated to purify at the DOE's canceled MOX plant. The VTR EIS says DOE may choose to import the plutonium from France or the UK. Importing the plutonium, however, would simply add to the nation's current plutonium disposal problems.

The DOE has actually stated it hopes the VTR project will "lead to reduced nonproliferation concerns." [12] [13]Translated this means DOE's stated goal is to *increase the proliferation concerns* – which is indeed, what the proposed program will actually do. It will make it easier for nuclear weapons material like plutonium to get into the wrong hands.

The DOE had to cease collecting fees from commercial nuclear power plants in 2014 because a court found that the DOE had no spent nuclear fuel disposal program and hasn't since 2010. [14] [15] [16] The VTR EIS relies on numerous inadequate waste management EISs, hoping we won't notice the multiple disconnects with reality. There is no spent nuclear fuel disposal facility on the horizon. [17] [18] [19]

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[12] The Department of Energy's Federal Register notice that is in Appendix A of the VTR EIS actually quotes DOE as having an objective of the VTR to lead to ***reduced nonproliferation concerns***. Most of us would like to reduce the weapons proliferation concerns, however.

[13] Also see Federal Register stating DOE's intent. Specifically, "DOE will continue to explore advanced concepts in nuclear energy that may lead to new types of reactors with further safety improvements and reduced environmental and nonproliferation concerns." https://www.federalregister.gov/documents/2019/08/05/2019-16578/notice-of-intent-to-prepare-an-environmental-impact-statement-for-a-versatile-test-reactor

[14] Steven Dolley, Elaine Hiruo, and Annie Siebert, *S&P Global Platts*, "Federal court orders suspension of US DOE nuclear waste fund fee," November 19, 2013. https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/111913-federal-court-orders-suspension-of-us-doe-nuclear-waste-fund-fee

[15] World Nuclear News, Zero day for US nuclear waste fee, May 16, 2014. https://www.world-nuclear-news.org/Articles/Zero-day-for-US-nuclear-waste-fee Collection of the fee ended on what is being called "zero day," May 16, 2014.

[16] Brandi Buchman, *Courthouse News Service*, "Entergy Says Feds Are 50 Years Behind on Nuclear Waste," July 2, 2017. https://www.courthousenews.com/entergy-says-feds-50-years-behind-nuclear-waste/

[17] See everycrsreport.com from September 16, 2019 on Civilian Nuclear Waste Disposal. By law, the Yucca Mountain repository was capped at 70,000 metric tons. DOE estimated that there was 81,600 metric tons in 2018. And it discusses the projected need to dispose of 130,000 metric tons, citing a 2007 projection. https://www.everycrsreport.com/files/20190916_RL33461_9c53abb93c522f94939ff34d94bba8f2b8c190ef.html#Content

[18] FCRD-UFD-2014-000069, August 2014, reports the Department of Energy already assuming to projected need to dispose of approximately 139,000 metric tons, projected to be produced through shutdown of the last reactor in 2055. (Two repositories were to hold 140,000 metric tons of spent nuclear fuel.) https://www.energy.gov/sites/prod/files/2014/10/f19/7FCRDUFD2014000069R1%20DPC%20DirectDispFeasibility.pdf

[19] Sierra Club, *Guidance on Implementing Sierra Club Policy on the Management of High-Level Nuclear Waste*, Adopted by the Board of Directors September 12, 2020. https://www.sierraclub.org/sites/www.sierraclub.org/files/uploads-wysiwig/sierraclub_guidance_high-level_nuclear_waste_management_2020_08_05.pdf?v=20200805 "Even more problematic, after cancelling the Yucca project, our federal government has not launched a scientific and technical effort to identify the necessary elements for a permanent repository and all the key safeguards. Instead the federal government is now jointly

The routine emissions from the VTR will be negligible, the VTR EIS assures us. And the routine radiological releases from the INL have been increasing over the last two decades, including releases of americium-241.

In Idaho and elsewhere, thyroid cancer incidence has been rapidly climbing. But curiously, all of the counties surrounding the INL have experienced more than a decade of roughly double the thyroid cancer incidence than the rest of Idaho and the rest of the country. [20] [21] [22] [23]

Americium-241 has been determined to pose a significant risk for thyroid cancer incidence which the VTR EIS ignores because of its focus on cancer fatalities, not incidence. [24]

When I started studying radiological releases from the INL, I never imagined what Idaho citizens would be facing now and in the future. With my years as a nuclear safety analyst at the INL and my years studying accidents, environmental surveillance, worker illness compensation and CERCLA cleanup, and the way the Department of Energy manages its nuclear facilities, I am terrified of the VTR program proposed for the INL. Citizens of southeast Idaho should be, too.

I have compiled a table of the VTR accidents, including the "beyond extremely unlikely" ones not discussed in the main body of the VTR EIS documents, see Table 1. The accidents are ordered by dose to the hypothetical maximally exposed individual located 3.1 miles from the facility during the accident. Many of these accidents would affect the public within 50 miles of the accident, but those figures are more difficult to conceptualize as they depend on population dose.

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participating in research being conducted by other countries, using Underground Research Laboratories for the studies."

[20] National Cancer Institute, Surveillance, Epidemiology, and End Results Program, Cancer Query System. https://seer.cancer.gov/canques/incidence.html

[21] Hyeyeun Lim et al., JAMA, "Trends in Thyroid Cancer Incidence and Mortality in the United States, 1974-2013," April 4, 2017. https://pubmed.ncbi.nlm.nih.gov/28362912/ or https://jamanetwork.com/journals/jama/fullarticle/2613728

[22] C. J. Johnson, B. M. Morawski, R. K., Rycroft, Cancer Data Registry of Idaho (CDRI), Boise Idaho, Annual Report of the Cancer Data Registry of Idaho, *Cancer in Idaho – 2017*, December 2019. https://www.idcancer.org/ContentFiles/AnnualReports/Cancer%20in%20Idaho%202017.pdf.

[23] Environmental Defense Institute February/March 2020 and July 2020 newsletter articles. "Rate of cancer in Idaho continues to increase, according to Cancer Data Registry of Idaho." As the SEER 9 region thyroid incidence peaked at 15.7 per 100,000, and the State of Idaho thyroid incidence average was 14.2 per 100,000, Bonneville County reached thyroid cancer rates of 30.9 per 100,000. [23] But other counties near the Idaho National Laboratory also have elevated thyroid cancer incidence rates: Madison (29.3 per 100,000), Fremont (27.9 per 100,000), Jefferson (28.9 per 100,000), and Bingham (28.6 per 100,000). But let's not forget Butte county. Butte county's thyroid cancer rate of 45.9 per 100,000 puts it in a class by itself. Much of Butte county is within 20 miles of the INL and nothing says radiation exposure like Butte's leukemia rate at 3 times the state rate and myeloma at 5 times the state average rate.

[24] T.R. Hay and J.P. Rishel, Pacific Northwest National Laboratory, Department of Energy, *Revision of the APGEMS Dose Conversion Factor File Using Revised Factor from Federal Guidance Report 12 and 13*, PNNL-22827, September 2013. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22827.pdf

Table 1. Versatile Test Reactor project accident highlights (includes those deemed "beyond extremely unlikely").

Accident scenario	**Material-at-risk of being released**	**Radiological material released**	**Dose at 330 ft (rem)**	**Dose at 3.1 miles (rem) [50-mile population LCF]**
VTR core disruption reactor accident – the only reactor accident and the only "beyond-design-basis accident noted in the VTR EIS.	66 fuel assemblies in-core and 44 fuel assemblies decayed 220 days, total of 1.57E9 curies, See Table D-42 for individual fuel assemblies	Use release fractions of Table D-32 for 1,100 C, which range from 1.0 to 0.001 For 1,300 C, the release is stated in the VTR EIS to be several times higher	520,000 rem This uses the release factors for 1100 C. The release fractions for the 1300 C accident would have been several times higher.	790 rem [220]
D.3.1.8 Aircraft Crash into VTR Fuel Fabrication Facility	5000 grams Pu, See Table D-2	1020 grams, Pu-239 equivalent	830 rem	1.1 rem [0.1]
D.3.1.9 Beyond-Design-Basis Earthquake Involving All VTR Fuel Fabrication and Preparation MAR	5000 grams Pu See Table D-2	1020 grams, Pu-239 equivalent	830 rem	1.1 rem [0.1]
D.3.3.5.2.2 Eutectic Fire Involving VTR 6 Fuel Assemblies in the VTR Experiment Hall	3 Fuel Assembles (half of the assemblies)	220-day cooled assemblies. See Table D-42 and see the uniquely chosen release fractions in Table D-10	160 rem	0.24 rem [0.02]
D.3.3.5.2.4 VTR Seismic Event Resulting in Collapse of the Experiment Hall	18 Spent fuel assemblies in experiment hall	220-day cooled assemblies. See Table D-42 and see the uniquely chosen release fractions in Table D-10	58 rem	0.071 rem [8E-9]

Accident scenario	Material-at-risk of being released	Radiological material released	Dose at 330 ft (rem)	Dose at 3.1 miles (rem) [50-mile population LCF]
D.3.1.4 Spill and Oxidation of Molten Pu-U with Seismically Induced Confinement Failure (During Fuel Production)	5,090 grams KIS-grade PuO_2	11.1 grams Pu-239 equivalent	9 rem	0.012 rem [1E-3]
D.3.6.1 Seismic event Causes Failure of Spent Fuel Storage Cask	6 spent fuel assemblies	3 spent fuel assemblies, 4-year cooled, See Table D-43 and see Table D-13 for unique and very low release fractions of 4.0E-5 for all but the noble gases	3.1 rem	3.9E-3 rem [4E-10]
D.3.1.6 Beyond-Design-Basis Fire Involving TRU Waste Drum (From Fuel Production)	398 grams KIS-grade Pu	1.96 grams Pu-239 equivalent	1.6 rem	2.2E-3 rem [2E-9]
D.3.4.1 Criticality Involving Melted Spent Fuel (Failed Confinement) (During Spent Fuel Handling and Treatment)	1.0E19 fissions	Noble gases and Iodine, see Table D-44	1.0 rem	3.9E-3 rem [8E-5]
D.3.1.5 Plutonium Oxide-to-Metal Conversion Explosion of 3013 Container of PuO_2 (Fuel Production)	5,090 grams KIS grade PuO_2	97.3 grams Pu-239 equivalent	0.27 rem	0.11 rem [1E-2]

Table sources: See various tables throughout Appendix D of the VTR EIS. The 50-mile population LCF [latent cancer fatality] is the number of expected latent cancer fatalities for the entire population within 50-miles, in order to compare the accident severity presented in the table. But the actual value should not be construed as realistic. The Department of Energy's rate of cancer fatalities per rem low-balls the actual figure, omits cancer incidence, and increased birth defects as well as other health impacts. The VTR EIS does include a long-term figure but appears to do so incorrectly by neglecting the wide spread impact of contaminated food and future generations of people living in the long-lived radioactive contamination. Note that for some accidents, the release is modeled to stay closer to the INL. The explosion of a 3013 can of plutonium oxide, D.3.1.5, however, has a substantial offsite dose, higher than several other accidents that had higher doses at 3.1 miles.

Department of Energy sticking to the misleading characterization that the nation's spent fuel could fit on a football field

The Department of Energy has a fast facts article with several technically untrue statements. The DOE article states that the nation's current inventory of 83,000 metric tons of spent nuclear fuel could fit on a single football field at a depth of less than 10 yards. [25] This would be 30 ft deep. Apparently, they borrowed this from another propaganda piece from 2017. [26]

Other reports have long characterized the volume of the nation's spent nuclear fuel in depth on a football field. [27] [28] But whether characterized as 15 ft deep for 69,000 metric tons or 30 ft for 83,000 metric tons, the characterization is very misleading.

Although the proposed Yucca Mountain repository license submittal was for 70,000 metric tons of storage, as limited by the Nuclear Waste Policy Act, it has been projected that for past and expected nuclear reactor operation in the U.S., by 2055 there will be roughly 10,000 canisters (or 140,000 metric tons heavy metal) of spent nuclear fuel needing disposal, and a significant portion of them would be capable of going critical if water ingress occurs. [29]

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

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[25] Department of Energy, Office of Nuclear Energy, *5 Fast Facts about Spent Nuclear Fuel*, March 30, 2020. https://www.energy.gov/ne/articles/5-fast-facts-about-spent-nuclear-fuel "In fact, the U.S. has produced roughly 83,000 metrics tons of used fuel since the 1950s—and all of it could fit on a single football field at a depth of less than 10 yards."

[26] Argonne National Laboratory, Nuclear Engineering Division, Nuclear Energy FAQS, November 2017 at https://www.ne.anl.gov/pdfs/NuclearEnergyFAQ.pdf "All of the spent nuclear fuel generated in every U.S. nuclear plant in the past 50 years would fill a single football field to a depth of less than 10 yards."

[27] Government Accountability Office, Spent Nuclear Fuel: Accumulating Quantities at Commercial Reactors Present Storage and Other Challenges, GAO-12-797. September 14, 2012. https://www.gao.gov/products/GAO-12-797 The amount of spent nuclear fuel is increasing by about 2,000 metric tons per year and likely more than doubling to about 140,000 metric tons before it can be moved off-site. "At the end of 2012, over 69,000 metric tons is expected to accumulate at 75 sites in 33 states, enough to fill a football field about 17 meters deep." Apparently they converted to metric units by changing feet to meters (?)

[28] U.S. Government Accountability Office, *Commercial Nuclear Waste: Effects of a Termination of the Yucca Mountain Repository Program and Lessons Learned*," GAO-11-229, May 10, 2011. https://www.gao.gov/assets/320/317634.html "Spent nuclear fuel is considered one of the most hazardous substances on earth. Without protective shielding, its intense radioactivity can kill a person exposed directly to it within minutes or cause cancer in those who receive smaller doses. Although some elements of spent nuclear fuel cool and decay quickly, becoming less radiologically dangerous, others remain dangerous to human health and the environment for tens of thousands of years. The nation's inventory of over 65,000 metric tons of commercial spent nuclear fuel--enough to fill a football field nearly 15 feet deep--consists mostly of spent nuclear fuel removed from commercial power reactors. The volume of commercial spent nuclear fuel is expected to more than double by 2055—assuming currently operating reactors receive license extensions and no new reactors are built--and is currently accumulating at 75 sites in 33 states…"

[29] Alsaed Abdelhalim, Enviro Nuclear Services, LLC, Spent Fuel and Waste Disposition, *Review of Criticality Evaluations for Direct Disposal of DPCs and Recommendations*, SFWD-SFWST-2018-000***, SAND2018-4415R, April 20, 2018. https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2018/184415r.pdf

thermal heat load. [30] Even so, the repository could heat up and invalidate the geological stability of the repository.

There is also the need limit the potential for multiple criticalities, should one package go critical. The ability of the spent fuel to go critical depends on the enrichment in fissile material, the buildup of fissile material during reactor operation, the presence of fission products (reduces the ability to go critical but changes over time), and whether the neutron absorbers in the container remain intact. Some of the higher enriched fuel now used by the commercial nuclear industry, even with neutron absorbers intact, will go critical if the canister is partially or fully flooded with unborated water.

The Department of Energy could argue that the probability of going critical was low, and this was easier to argue before the commercial utilities began using higher enrichments, often referred to as "high burn-up fuel" because the fuel can be operated longer in a nuclear reactor.

The Department of Energy had to admit, however, that criticality could occur after containers corroded and there was no assurance that neutron absorbers would be intact or that geometries separating fissile material would be maintained.

The Department of Energy's originally envisioned inventory for Yucca Mountain had included 2 percent enriched commercial spent nuclear fuel and the residual vitrified waste from reprocessing at West Valley. It was expanded substantially when the Navy ceased reprocessing the high enriched naval and DOE research fuels by 1992 and it meant that now these fuels would require disposal. And it was another substantial change when the DOE identified the surplus weapons plutonium, potentially for disposal at Yucca Mountain.

And the disposal of surplus plutonium at the proposed Yucca Mountain Repository created additional criticality concerns.

Two scientists from Los Alamos National Laboratory would explain how the plutonium-239 posed a particularly high criticality risk at Yucca Mountain. [31] [32] The Department of Energy has continued to argue that while criticality is possible at Yucca Mountain, it is sufficiently unlikely and of unimportant consequence if it does occur. [33] But the risk of criticality posed by the disposal of surplus weapons plutonium (and spent nuclear fuel) at Yucca Mountain is substantial and not to be casually dismissed, no matter how emphatically the DOE tries to arm-wave the risk away. **And in addition, the criticality risks remain after 10,000 years, yet there is no**

[30] 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

[31] C. D. Bowman and F. Venneri, Los Alamos National Laboratory, *Underground Autocatalytic Criticality from Plutonium and Other Fissile Material*, LA-UR 94-4022, 1994.

[32] C. D. Bowman, Los Alamos National Laboratory, *Underground Supercriticality from Plutonium and Other Fissile Material*, LA-UR-94-4022A, 1994.

[33] Rob P. Rechard et al., Sandia National Laboratory, *Consideration of Criticality when Directly Disposing Highly Enriched Spent Nuclear Fuel in Unsaturated Tuff: Bounding Estimates*, May 1996.

regulatory requirement to assess or limit the criticality risk after 10,000 years, either at Yucca Mountain or WIPP.

The regulations provide some inappropriate leeway regarding criticality and groundwater protection after 10,000 years giving the Department of Energy room to wiggle regarding criticalities (and their fallout) that occur after 10,000 years even though the criticality risks don't peak until after 25,000 years. Groundwater protection after 10,000 years is limited to only those events deemed more likely than an annual probability of 1.0E-4/yr. But there are thousands of years to be exposed to a potential criticality event.

Over time, the criticality risk doesn't go away. For pressurized water reactor (PWR) fuel arranged as it would be in a canister known as a 32-PWR, having initial 4 percent enrichment (and operated in a reactor to 40 GW-d/MT burnup), k-effective versus time was determined. The higher the k-effective value, the higher the reactivity. A k-effective value at or above 1.0 (or above about 0.98 for margin) when flooded with water can go critical.

While the criticality risk of the fuel is high in the first 100 hours after shutdown and remains at its highest during the first year, the reactivity, or k-effective, declines during the first 100 years. However, after about 100 years, the k-effective climbs steadily, peaking at about 25,000 years after its use in a reactor before starting to decline again. [34]

The heat load of the spent nuclear fuel placed in the repository poses a risk to the structure of the repository and the DOE never actually decided whether to use a "hot" repository or a "cool" repository design. The amount of waste and how it is spaced in the repository obviously affect the ability to cool thermally hot spent nuclear fuel.

In reality, which is not where DOE spin-doctors live, there needs to be space to allow thermal heat removal to limit the heat buildup and limit the temperatures in the repository. Next, there is the need to design a container to keep a single container from going critical and this can limit the fuel assemblies that can go in a container. Then the fuel must be spaced to prevent multiple containers from going critical if one goes critical, which is not as remote a possibility as you might guess, as years pass. And finally, there is the requirement to limit the trickle-out to groundwater and this involved spreading out the spent nuclear fuel so that the trickle-out of radionuclides would be diluted as water infiltrates the repository and radionuclides leach out from corroded containers remained below the drinking water standards imposed on the repository.

[34] Energy Workshops, *2018 SFWST Annual Working Group Meeting, Las Vegas, Nevada May 22 to May 24*, 2018. https://energyworkshops.sandia.gov/nuclear/2018-sfwst-rd-team-meeting/ See presentation #05 on direct disposal of spent nuclear fuel, page 4 the figure of K-effective versus time, and see page 10 for regulations that dismiss fallout effects on groundwater for criticality events after 10,000 years if less than 1.0E-4 annual probability at https://energyworkshops.sandia.gov/wp-content/uploads/2018/05/05-Direct-Disposal-of-Spent-Nuclear-Fuel-in-Dual-Purpose-Canisters-RD-Path-Forward-SAND2018-5437-PE.pdf

As you can see, imagining the volume of spent nuclear fuel clustered together, stacked in a football field, is nothing like the reality of the difficulty actually faced in hoping to contain the leach out of radionuclides over time as containers corrode and water infiltrates the waste.

The Department of Energy, makes another misleading statement, that spent fuel is a solid. [35] Keep it dry and in an inert gas rather than expose it to air, and usually the spent fuel is a solid. Still, radioactive gases that have built up in the fuel are gases and heat up the fuel, those gases are released. Depending on the condition of the cladding, hydrides that have built up when the fuel was stored in water, the uranium or zirconium hydrides can offgas hydrogen, if the fuel is exposed to air. Hydrogen offgassing can make cutting into spent nuclear fuel canisters a tricky business — which no one has tackled yet.

Oxidation can occur if the spent nuclear fuel is exposed to air. Normally, spent nuclear fuel canisters are sealed after put helium, an inert gas, into the canister. Much about spent fuel degradation with exposure to oxygen and the pyrophoric behavior of uranium and zirconium has been learned by the Department of Energy, the hard way. [36] [37]

For some idea of how uranium behaves, consider that uranium in a 30-gallon inner drum inside a barrel, disposed of at the Idaho National Laboratory from the Rocky Flats weapons plant, upon excavation, ignited and material was forceable expelled, hitting the cab of the excavator. Oxygen introduced to the inner drum caused **rapid oxidation that released hydrogen from uranium hydride** and resulted in a fire and some self-propelled movement of material. [38]

We haven't really touched on the state of affairs with regard to proving that a repository can actually safely contain the waste over millennia. The Department of Energy sees that problem as simply one of "public perception."

One wonders if the safety folks at DOE are believing the DOE's own propaganda. If so, the risk of nuclear disaster is far higher than anyone has supposed.

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[35] Department of Energy, Office of Nuclear Energy, *5 Fast Facts about Spent Nuclear Fuel*, March 30, 2020. https://www.energy.gov/ne/articles/5-fast-facts-about-spent-nuclear-fuel "In fact, the U.S. has produced roughly 83,000 metrics tons of used fuel since the 1950s—and all of it could fit on a single football field at a depth of less than 10 yards."

[36] Primer on Spontaneous Heating and Pyrophoricity, DOE-HDBK-1081-2014, 2014 https://www.standards.doe.gov/standards-documents/1000/1081-BHdbk-2014/@@images/file

[37] Brett Carlsen et al., *Damaged Spent Nuclear Fuel at U.S. DOE Facilities, Experience and Lessons Learned*, INL/EXT-05-00760, November 2005. At https://inldigitallibrary.inl.gov/sites/sti/sti/3396549.pdf See Appendix A for an experience in 1980 when transporting spent fuel. A previously unknown phenomena occurred which was oxygen scavenging from the air by exposure of fuel at the points of cladding failure, which enlarged the existing cladding breaks. From this experience, it was learned that the transported fuel required use of an inert gas such as helium in spent fuel shipments. Further experience is described when the high temperature fuel was submerged back into the pool, resulting in overpressure, in steam and spalling of fuel material from the fuel rods, fuel debris and contamination of the pool.

[38] Kevin Daniels et al., Idaho Cleanup Project, CH2M-WG Idaho, LLC, "Independent Investigation Report of the November 2005 Drum Fire at the Idaho National Laboratory Site," RPT-190, March 2006. https://ar.icp.doe.gov/images/pdf/200605/2006051600209TUA.pdf

Department of Energy Already Needs Two Spent Fuel Repositories and Would Need a New One Every Year, If Nuclear Energy Were to Make a Difference for Climate

The Department of Energy needs two spent nuclear fuel repositories and doesn't even have one. Although the proposed Yucca Mountain repository license submittal was for 70,000 metric tons of storage, as limited by the Nuclear Waste Policy Act, it has been projected that for past and expected nuclear reactor operation in the U.S., by 2055 there will be roughly 10,000 canisters (or 140,000 metric tons heavy metal) of spent nuclear fuel needing disposal, and a significant portion of them would be capable of going critical if water ingress occurs. [39]

The Nuclear Waste Policy Act remains the law; it limits the quantity of spent nuclear fuel from commercial nuclear power plants to 63,000 metric tons heavy metal (MTHM), 2,333 MTHM for DOE SNF and 4,667 MTHM for HLW. The quantity of commercial SNF, DOE SNF, and DOE-managed HWL are each greater than DOE's allotment for the first repository. [40] But DOE hasn't obtained its first repository, which by law, would be at Yucca Mountain.

The Department of Energy promised to begin disposal of spent nuclear fuel by 1998. Then came other promised dates that have come and gone. The U.S. Nuclear Regulatory Commission believed those empty promises from the Department of Energy, expecting to disposal by 1998, then 2008, and then by the first quarter of this century. [41] The Department of Energy's rapidly evolving waste emplacement concepts continued to evolve as every assumption about how the repository would contain the waste didn't hold up. No utility has packaged its spent nuclear fuel into DOE's recommended "transport, aging and disposal" TAD canister. The Yucca Mountain repository concept also relies on never designed titanium drip shields that no one honestly believes are feasible to install decades after the waste is emplaced.

Department of Energy has no spent nuclear fuel repository program and hasn't since 2010. The Department of Energy **has no credible cost estimate for the costs of disposal of now-existing spent nuclear fue**l plus the fuel from already operating reactors. Few people know that there is already more than double the amount of spent nuclear fuel (and high-level waste) than Yucca Mountain was set to legally hold. And few people know that if nuclear energy were to make a dent in climate, we would need a new Yucca Mountain every year.

The Department of Energy was struggling for years to keep the radionuclide trickle-out doses below EPA standards. But something would happen to drastically lower the Department of Energy's trickle out problem and radiation doses between 2007 and 2008 when the DOE

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[39] Alsaed Abdelhalim, Enviro Nuclear Services, LLC, Spent Fuel and Waste Disposition, *Review of Criticality Evaluations for Direct Disposal of DPCs and Recommendations*, SFWD-SFWST-2018-000***, SAND2018-4415R, April 20, 2018. https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2018/184415r.pdf

[40] U.S. Nuclear Waste Technical Review Board (NWTRB), Management and Disposal of U.S. Department of Energy Spent Nuclear Fuel. Arlington, December 2017. See p. 15.

[41] Nuclear Regulatory Commission, 10 CFR 51, Waste Confidence-Continued Storage of Spent Nuclear Fuel, Federal Register, Vol. 78, No. 178, September 13, 2013.

submitted its license application for Yucca Mountain to the NRC. I had trouble understanding how the predicted doses dropped from a couple hundred millirem to less than 1 mrem/yr for post-10,000-year time frame. Both the earlier and later submittals had assumed perfect titanium drip shield performance, despite the implausibility of ever installing them in the repository.

The problem of the estimated high radionuclide trickle-out from Yucca Mountain ended when Sandia took over the modeling of radionuclide trickle out and elected to squash the assumed water infiltration rates through the proposed Yucca Mountain repository. **A review of Sandia's modeling for Yucca Mountain that yielded estimates of low radiation doses from water contamination from the trickle out of radionuclides found that the Sandia models were technically indefensible**. [42]

That independent review of DOE's calculations had been contracted by the DOE but withheld from the State of Nevada. The review's conclusion was that the Department of Energy's modeling, by Sandia, of water infiltration to the disposed of waste **did not provide a credible representation of water infiltration at Yucca Mountain**.

In other words, because the periodic spikes in water infiltration had raised the estimated radiation dose, the water infiltration spikes were simply removed from the modeling in order to drive the estimated radiation exposures down. The contamination trickle-out problem that had previously estimated 95th percentile radiation doses above 1000 mrem/yr (yes, one thousand mrem/yr) and would struggle to meet the 100 mrem/yr median requirement by EPA regulations now had contrived the modeling to slash the estimated radiation dose to a person living 15 km (or 11 miles) downgradient to less than 1 mrem/yr. [43]

The Department of Energy is also focusing on trying to say that multiple criticalities in a waste repository won't add that much harm to a disposal repository's already estimated harm. They want to argue that the criticality doesn't harm the repository and doesn't lead to significantly higher radiological releases than it already expects. There is plenty of reason to be concerned about the DOE's drive to find the answers it wants.

The Department of Energy stated it had collected $28.2 billion from commercial nuclear utilities for the "Nuclear Waste Fund." The U.S. Court of Appeals agreed to end DOE's collection of fees because DOE did not have waste disposal program for spent nuclear fuel and also because the DOE's latest fee assessment covered an enormous range of possible costs, from

[42] Senate Hearing 109-523, Yucca Mountain Repository Project, May 16, 2006. https://www.govinfo.gov/content/pkg/CHRG-109shrg29473/html/CHRG-109shrg29473.htm

[43] Letter from Council for the State of Nevada to Secretary of the U.S. Nuclear Regulatory Commission, State of Nevada's Supplement to its June 4, 2008 Petition Asking the NRC to Reject DOE's Yucca Mountain License Application as Unauthorized and Substantially Incomplete, July 21, 2008. The letter cites the review of DOE's infiltration model performed at DOE's request by ORISE (Oak Ridge Institute for Science and Education). ORISE provided the results of this independent review to DOE on April 30, 2008. http://www.state.nv.us/nucwaste/news2008/pdf/nv080721nrc.pdf

somewhere between $25 billion and $2 trillion dollars, so there was no way to determine the adequacy of the fees paid. [44]

The court found that the DOE's 2011 plan to somehow find a spent nuclear fuel disposal facility by 2048 was "pie in the sky." [45]

Under the 1982 Nuclear Waste Policy Act, DOE was to have a disposal facility by 1998. And nuclear utility customers would pay one-tenth of a cent for every kilowatt hour of nuclear-generated electricity in to the Nuclear Waste Fund. The collection of the fee ended on what is being called "zero day," May 16, 2014. [46]

In FY-2020, various funding appropriations for interim storage of spent nuclear fuel have been put forth. Two consolidated interim storage sites, one New Mexico and near it in southwest Texas, are pursuing licenses from the Nuclear Regulatory Commission. [47] [48] [49] Because current regulations limit the Department of Energy's role involving interim storage when no license for a disposal facility has been obtained, some of the bills put forth in Congress are trying to change that.

In the last decade, there's been a lot of focus in the Department of Energy's spent fuel disposal research on disposal in a salt medium. [50] [51] And the proposed placement of two consolidated interim storage facilities is located within 30 miles of the salt mine disposal at the Waste Isolation Pilot Plant (WIPP) in New Mexico.

The U.S. has decided by the 1970s that it needed a deep geologic repository in order to contain the radionuclides in spent fuel and high-level waste over the thousands of years, actually over a million years, that the radionuclides remain radiotoxic. After 50 years of trying, the Department of Energy is no closer to obtaining a solution for safely containing the nation's spent nuclear fuel and high-level waste.

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[44] Steven Dolley, Elaine Hiruo, and Annie Siebert, *S&P Global Platts*, "Federal court orders suspension of US DOE nuclear waste fund fee," November 19, 2013. https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/111913-federal-court-orders-suspension-of-us-doe-nuclear-waste-fund-fee

[45] Ibid.

[46] World Nuclear News, Zero day for US nuclear waste fee, May 16, 2014. https://www.world-nuclear-news.org/Articles/Zero-day-for-US-nuclear-waste-fee

[47] Tami Thatcher comment submittal for Environmental Defense Institute for the NRC's draft Environmental Impact Statement for the Holtec Consolidated Interim Storage Facility Project, Docket NRC-2018-0052, September 2020 at http://www.environmental-defense-institute.org/publications/CommentNRCdEISHoltecT.pdf

[48] David B. McCoy, Citizen Action New Mexico, comment submittal for the NRC's draft Environmental Impact Statement for the Holtec Consolidated Interim Storage Facility Project, Docket NRC-2018-0052, September 2020 at http://www.environmental-defense-institute.org/publications/CommentNRCdEISHoltecM.pdf

[49] Environmental Defense Institute comments by Tami Thatcher on the Interim Storage Partners proposed Consolidated Interim Storage at the Waste Control Specialists site in Andrews County, Texas at http://environmental-defense-institute.org/publications/CommentNRC2018Texas.pdf

[50] Henrik Lijenfeldt et al., Spent Fuel and Waste Science and Technology, *Summary of Investigations on Technical Feasibility of Direct Disposal of Dual Purpose Canisters*, SFWD-SFWST-2017-000045, September 2017. https://info.ornl.gov/sites/publications/Files/Pub102524.pdf

[51] Energy Workshops, *2018 SFWST Annual Working Group Meeting, Las Vegas, Nevada May 22 to May 24*, 2018. https://energyworkshops.sandia.gov/nuclear/2018-sfwst-rd-team-meeting/ See presentation number 68 and others.

The Department of Energy wants people to think that "interim" or actually "indefinite" storage of spent nuclear fuel is satisfactory. The Department of Energy wants to ramp up and make more spent nuclear fuel so DOE doesn't want people to understand the truth of what burden, in terms of cost and in terms of the release of radionuclides to the environment, what devastation to humanity and all life, that this involves.

Another Elephant in the Room: The Costs and Risks of Continuing Spent Fuel Storage

The issues of cost and risk for "continuing storage" of spent nuclear fuel, above ground, are something the Department of Energy is also not being truthful about.

The failure of the Department of Energy to secure a solution for the disposal of spent nuclear fuel has resulted in some commercial nuclear utilities having to result to rather torturous litigation in order to get the DOE to pay some of the utilities' expenses for continued storage of the spent nuclear fuel. The 1982 Nuclear Waste Policy Act allowed the Department of Energy to enter into contracts with commercial nuclear utilities, with the Department of Energy promising to take ownership of the spent nuclear fuel.

In 2014, it was estimated by contractors for the Department of Energy that by 2035, half of the commercial spent fuel inventory in the US would be stored in approximately 5,000 dual-purpose-canisters. And if no nuclear power reactors were built, but existing reactors continued to run as projected, the spent nuclear fuel inventory was projected to be approximately 139,000 metric tons heavy metal (MTHM) by 2055, or 10,000 canisters in 2055. [52]

But as the utilities sought to be paid for continuing costs of caring for spent nuclear fuel after the 1998 date the DOE was to have a repository for the spent fuel, many would have to fight in court. The Department of Energy fought strenuously to avoid compensating the utilities, saying that the problem was "due to an unavoidable delay." Years of litigation ultimately found that the Department of Energy did need to pay for some of the costs of continuing spent fuel storage and settlements with utilities. [53] But the settlements for partial breach of contract only cover the time up to the date of the court filing. So additional settlements must continue to be requested as time moves on but the spent fuel doesn't.

Commercial power utilities with stranded fuel, that shutdown their nuclear reactors, also wanted to shut down the spent fuel pools. Other utilities simply ran out of space in their spent fuel pools. The only answer was to put the spent fuel into dry storage casks or canisters.

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[52] E. Hardin et al., Spent Fuel and Waste Disposition, Prepared for U.S. Department of Energy, Office of Used Nuclear Fuel Disposition, *Investigations of Dual-Purpose Canister Direct Disposal Feasibility (FY14)*, FCRD-UFD-2014-000069 Rev. 1, October 2014. https://www.energy.gov/sites/prod/files/2014/10/f19/7FCRDUFD2014000069R1%20DPC%20DirectDispFeasibility.pdf

[53] EveryCRSReport.com, Contract Liability Arising from the Nuclear Waste Policy Act (NWPA) of 1982, R40996, February 1, 2012. https://www.everycrsreport.com/reports/R40996.html

There are various dry storage systems licensed by the U.S. Nuclear Regulatory Commission. And most of the fuel is in thin-walled stainless steel canisters rather than bolted-lid containers. For many of the canisters, thin means so thin-walled that the Department of Energy is loath to mention just how thin: about 0.5 to 0.5625 inches of wall-thickness of the canister containing about 10 metric tons of spent nuclear fuel. [54]

The dry storage systems used by the utilities were never designed for disposal of the spent nuclear fuel at Yucca Mountain or any other disposal facility. Some of the containers can't be transported, [55] but those that can, are referred to a dual-storage-canisters, meaning they can be stored in place and also transported.

Various presentations and reports for the Department of Energy display a disclaimer stating "This is a technical presentation that does not take into account the contractual limitations under the Standard Contract. Under the provisions of the Standard Contract, DOE does not consider spent fuel in canisters to be an acceptable waste form, absent a mutually agreed to contract modification." [56]

According to a decommissioning document submitted to the NRC regarding one utility's canistered spent fuel, "the government's [DOE's] stated positions with respect to such acceptance [of spent fuel in canisters], including assertions in legal proceedings, have been inconsistent." And as recently as 2008, the Department of Energy continued to give empty promises to the U.S. nuclear power electrical generating utilities of promised dates for opening Yucca Mountain by 2020. [57]

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[54] E. Hardin et al., Fuel Cycle Research and Development, Prepared for U.S. Department of Energy Used Fuel Disposition Campaign, *Assumptions for Evaluating Feasibility of Direct Geologic Disposal of Existing Dual-Purpose Canisters*, FCRD-UFD-2012-000352, Rev. 1, November 2013. (SAND2013-9780P), https://www.osti.gov/servlets/purl/1673713 See Appendix A.

[55] E. Hardin et al., Fuel Cycle Research and Development, Prepared for U.S. Department of Energy Used Fuel Disposition Campaign, *Assumptions for Evaluating Feasibility of Direct Geologic Disposal of Existing Dual-Purpose Canisters*, FCRD-UFD-2012-000352, Rev. 1, November 2013. (SAND2013-9780P), https://www.osti.gov/servlets/purl/1673713 p. 24: Storage-only canister systems include the MSB (24-PWR, Energy Solutions) and the NUHOMS-24PS, -24PH, -24PHB< -24PHBL, -52B and -07P (Transnuclear). These canisters currently exist at the Idaho National Laboratory, and at the Calvert Cliffs, Surry, Oconee, Arkansas Nuclear One, Palisades, Davis-Besse, Point Beach, Susquehanna, and H.B. Robinson nuclear power plants. These are sealed canisters, not to be confused with non-canistered cask systems (storage-only or storage-transportation) which have bolted closures.

[56] E.L. Hardin and D.J. Clayton, Sandia National Laboratories, R.L. Howard, J.M Scaglione, E. Pierce and K. Banerjee, Oak Ridge National Laboratory, M.D. Voegele, Complex Systems Group, LLC, H.R. Greenberg, J. Wen and T.A. Buscheck, Lawrence Livermore National Laboratory, J.T. Carter and T. Severynse, Savannah River National Laboratory, W. M. Nutt, Argonne National Laboratory, Prepared for: U.S. Department of Energy, Office of Used Nuclear Fuel Disposition, *Preliminary Report on Dual-Purpose Canister Disposal Alternatives (FY13)*, FCRD-UFD-2013-000171, Revision 1, December 2013. https://www.energy.gov/sites/prod/files/2013/12/f5/PrelimRptDPCDisposalAlternativesR1.pdf

[57] Dominion Energy Kewaunne, Inc., Kewaunee Power Station Post-Shutdown Decommissioning Activities Report, February 26, 2013. https://www.nrc.gov/docs/ML1306/ML13063A248.pdf

In 2009, the Department of Energy Secretary Steven Chu stated that Yucca Mountain was no longer an option. [58] In 2010, President Obama created the Blue-Ribbon Commission on America's Nuclear Future and the commission issued its report in 2012. [59] The BRC's strategy included "**prompt efforts** to develop one or more geologic disposal facilities" and "p**rompt efforts** to develop one or more consolidated interim storage facilities." [60]

Originally the Department of Energy had envisioned and had partially designed a "transport, aging, and disposal" container called the "TAD." It was to be highly corrosion resistant. The license application by the DOE for Yucca Mountain assumes that spent nuclear fuel is placed into TADs and that the TADs don't corrode for 10,000 years. (Other containers, like the multi-purpose canister, were assumed for Department of Energy high-level waste and spent fuel.) Inside Yucca Mountain, the commercial spent fuel was to be protected by the TAD, the neutron absorber in the TAD, additional metal waste package coverings, and the titanium drip shield protects the container of spent nuclear fuel. And in all this fanciful imagining, the likelihood of criticality is deemed to be "low." [61] And the trickle out of radionuclides from the dissolving containers and the fuel they hold is deemed to be so slow that water downgradient from the Yucca Mountain disposal site doesn't cause more than a 1 mrem/yr radiation dose.

Just a few problems with unloading the welded, thin-walled canisters and putting that spent nuclear fuel in a TAD. First of all, no design for a TAD was ever completed or licensed. Second of all, despite NRC regulations requiring the canisters they licensed to allow the spent fuel to be retrievable, it isn't.

The NRC licensed the dry storage canisters in use at many commercial nuclear power plants in the U.S. The NRC codified the requirement in its regulations, including 10 CFR 72.122(1), which states

> *Storage systems must be designed to allow ready retrieval of spent fuel, high level radioactive waste, and reactor-related GTCC [greater-than-class C] waste for further processing or disposal.* [62]

The canisters used in the US were approved by the NRC but were never actually designed for ready retrieval of spent fuel. So little attention was paid to corrosion issues that degradation including the neutron absorber material in the canisters as well as spent fuel pool racks has

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[58] U.S. Department of Energy, "Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste," January 26, 2013.

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

[60] Dominion Energy Kewaunne, Inc., Kewaunee Power Station Post-Shutdown Decommissioning Activities Report, February 26, 2013. https://www.nrc.gov/docs/ML1306/ML13063A248.pdf

[61] Scientific Analysis/Calculation Administration Change Notice, ANL-DO0-NU-000001, Screening Analysis of Criticality Features, Events, and Processes for License Application, Yucca Mountain Project, 2008. https://www.nrc.gov/docs/ML0907/ML090720250.pdf

[62] B. B. Bevard et al., Oak Ridge National Laboratory, *BWR Spent Nuclear Fuel Integrity Research and Development Survey for UKABWR Spent Fuel Interim Storage*, ORNL/TM-2015/696, October 2015. https://info.ornl.gov/sites/publications/files/Pub60236.pdf (discusses U.S. NRC regulations and the issue of spent fuel retrievability from canisters in the U.S.)

occurred and in just a few years. The majority of currently loaded spent nuclear fuel canisters in the US used boron carbide with aluminum, known as Boral. Despite optimism by repository researchers for this type of neutron absorber to last for thousands of years, [63] degradation has already been occurring. [64]

The U.S. Nuclear Waste Technical Review Board (NWTRB) recommended the "design and demonstration of dry-transfer fuel systems for removing fuel from casks and canisters following extended dry storage." [65]

It would seem that the NRC may have started to recognize the difficultly involved with grinding open a welded canister, perhaps with a degraded neutron absorber so the criticality was more likely, and somehow deftly preventing the fuel from being exposed to oxygen, while using the shielding of the water in the spent fuel pool, with fuel of the temperature above boiling, and all with virtually no way to inspect the status of the fuel or the neutron absorber in the canister, while assuring that the fuel remained subcritical and was not further damaged during the transfer of fuel.

A study updated in 2019 by the Department of Energy confirms that the NRC had no documented evaluation of the consequences of spent nuclear fuel canister failure. The NRC has prepared the draft Environmental Impact Statement for the proposed Holtec consolidated interim storage facility in New Mexico without having any documented basis for the consequences of an expected event, leakage of a spent nuclear fuel canister. [66]

Instead of using thin-walled welded canisters that cannot be adequately inspected or repaired, the Swiss required the use of bolted thick-walled casks. They store them in a building, away from ocean salt spray air, for example. They have a hot cell for repackaging a cask if needed. Read more at SanOnofreSafety.org. [67]

The NRC's response has typically been to admit there's a problem while not actually admitting there's a problem. With regard to the inability to retrieve spent nuclear fuel from NRC-licensed canisters, the NRC solution seemed to be to remove the regulation or provide guidance

[63] E. Hardin et al., Spent Fuel and Waste Disposition, Prepared for U.S. Department of Energy, Office of Used Nuclear Fuel Disposition, *Investigations of Dual-Purpose Canister Direct Disposal Feasibility (FY14)*, FCRD-UFD-2014-000069 Rev. 1, October 2014. See page 4-1. https://www.energy.gov/sites/prod/files/2014/10/f19/7FCRDUFD2014000069R1%20DPC%20DirectDispFeasibility.pdf

[64] U.S. Nuclear Regulatory Commission, Generic Issue 196. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML042670379

[65] U.S. Nuclear Waste Technical Review Board, *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel*. Arlington, Virginia, 2010. pp. 14 and 125, (at www.nwtrb.gov) as cited in https://info.ornl.gov/sites/publications/files/Pub60236.pdf

[66] U.S. Department of Energy, Spent Fuel and Waste Science and Technology, Gap Analysis to Guide DOE R&D in Supporting Extended Storage and Transportation of Spent Nuclear Fuel: An FY2019 Assessment, SAND2019-15479R, December 23, 2019. https://www.osti.gov/servlets/purl/1592862

[67] SanOnofreSafety.org webpage "Swiss Solution – Swiss nuclear waste storage systems exceed US safety standards" at https://sanonofresafety.org/swiss/

that gives gibberish saying there's no need to inspect canister internals, unless, of course, there's a safety issue. [68]And forget about opening a welded canister, it would lead to elevated worker radiation exposures. The full extent of the inability to open a spent fuel canister of higher enriched fuel with a potentially degraded neutron absorber in the canister internals isn't really fessed up to.

But the Department of Energy has now for some years investigated the direct disposal of these canisters, rather than remove the fuel from the canisters and repackage them into the more corrosion resistant TAD as stated in Yucca Mountain's license application to the NRC. [69]

The Department of Energy's research during that last decade has been examining the behavior of different geologic mediums including clay-rich (argillaceous) media including shales, hard rock (crystalline or granite), or salt but not much research any more for volcanic "tuff" as found at Yucca Mountain.

The elephant in the room regarding the safety and disposal of the growing number of welded-closed spent nuclear fuel canisters prevalently used by U.S. commercial nuclear power utilities is rarely discussed.

While cutting open these spent nuclear fuel dry storage canisters may be possible, in twenty years of talking about it, the method to use for cutting open the canisters has not been decided. No design has progressed beyond a vague conceptual stage. Nor have the risks been presented.

The U.S. Department of Energy's proposed Yucca Mountain spent fuel and high-level waste repository discussed dry transfer and wet transfer systems for years, and wildly vacillated about the size of spent fuel pools and capability of dry transfer systems, especially in regard to how to repackage commercial spent nuclear fuel received in non-disposal canisters. [70] [71]

In one study performed for the Department of Energy in 2000, two options for cutting open the non-disposable spent nuclear fuel canisters were discussed. [72] But neither option included any specific method for the proposed remote cutting operation and the radiological accident risks were not evaluated. The study did acknowledge that determining the specific methods for cutting

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[68] Federal Register, Fuel Retrievability in Spent Fuel Storage Applications, A Notice by the Nuclear Regulatory Commission on June 8, 2016. https://www.federalregister.gov/documents/2016/06/08/2016-13569/fuel-retrievability-in-spent-fuel-storage-applications

[69] Energy Workshops, *2018 SFWST Annual Working Group Meeting, Las Vegas, Nevada May 22 to May 24*, 2018. https://energyworkshops.sandia.gov/nuclear/2018-sfwst-rd-team-meeting/ See presentation #05 on direct disposal of spent nuclear fuel, https://energyworkshops.sandia.gov/wp-content/uploads/2018/05/05-Direct-Disposal-of-Spent-Nuclear-Fuel-in-Dual-Purpose-Canisters-RD-Path-Forward-SAND2018-5437-PE.pdf

[70] P. W. McDaniel et al., Prepared for U.S. Department of Energy by Bechtel SAIC, *Yucca Mountain Project Surface Facilities Design*, November 2002. https://www.osti.gov/servlets/purl/808023

[71] Senate Hearing 109-523, Yucca Mountain Repository Project, May 16, 2006. https://www.govinfo.gov/content/pkg/CHRG-109shrg29473/html/CHRG-109shrg29473.htm

[72] Prepared for U.S. Department of Energy by TRW Environmental Safety Systems Inc., Civilian Radioactive Waste Management System Management & Operating Contractor, *White Paper: Waste Handling Building Conceptual Study*, TDR-WHS-SE-000002 Rev 00, October 2000. https://www.osti.gov/servlets/purl/893534-wmX91n/

open the canisters would be a significant task. The range of safety issues associated with cutting open canisters containing high burnup fuel now used by utilities was not developed.

In a study for the Department of Energy published in 2015, eight proposed methods for cutting open non-disposable canisters were evaluated, [73] indicating that no method has actually been fully designed or used.

And what about the dry transfer system designed for the Idaho National Laboratory that remains to be built? The environmental impact statement (EIS) for the proposed Idaho Spent Nuclear Fuel Facility addressed the need to repackage only very specific Department of Energy spent nuclear fuel: high-temperature gas-cooled Peach Bottom reactor fuel, light-water breeder reactor Shippingport fuel, and research TRIGA fuel. [74] The easy-breezy EIS assumes away fuel drop events and essentially all accidents. [75] These fuels are less susceptible to oxidation than typical uranium oxide fuels used by the commercial nuclear power generating industry in the U.S. There are no operations involving large welded closed commercial spent nuclear fuel canisters at the proposed Idaho Spent Fuel Facility designed by Foster Wheeler Environmental Corporation.

In 2010, the U.S. Nuclear Waste Technical Review Board (NWTRB) recommended the "design and demonstration of dry-transfer fuel systems for removing fuel from casks and canisters following extended dry storage." [76] But this still hasn't happened.

In addition to the costs associated with spent nuclear fuel disposal because the industry's welded canisters were not considered suitable for disposal, the U.S. Nuclear Regulatory Commission has not grappled with the safety ramifications of not being able to retrieve spent fuel from these canisters, should one be damaged. [77]

In a dangerous and exceedingly dishonest way, the NRC has stipulated that aging degradation will not be included in its risk assessment of the canisters, despite known high likelihood, ineffective inspection programs and essentially no means for addressing aging degradation of the dry storage canisters predominantly used by the commercial nuclear industry.

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[73] Sven Bader et al., *A study of transfer of UNF [used nuclear fuel] from non-disposable canisters – 15388, WM Symposia, Inc.*, July 2015. **https://www.osti.gov/biblio/22824303**

[74] Training, Research, and Isotope reactor fuel by General Atomics (TRIGA) fuel was used in various reactors built by General Atomics and is high enriched fuel. Many of the 1600 TRIGA fuel elements are stored at the Idaho National Laboratory in 2004 when the EIS was written but additional shipping to the INL was also needed.

[75] U.S. Nuclear Regulatory Commission, *Environmental Impact Statement for the Proposed Idaho Spent Fuel Facility at the Idaho National Engineering and Environmental Laboratory in Butte County, Idaho*, NUREG-1773, 2004. https://www.nrc.gov/docs/ML0404/ML040490135.pdf design by Foster Wheeler Environmental Corporation.

[76] U.S. Nuclear Waste Technical Review Board, *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel*. Arlington, Virginia, 2010. pp. 14 and 125, (at www.nwtrb.gov) as cited in https://info.ornl.gov/sites/publications/files/Pub60236.pdf

[77] Read the Environmental Defense Institute December 2020 newsletter, including "Devil in the details of the Standard Contract with the Department of Energy under the NWPA" and "The 'Nuclear Waste Fund' fee is no longer being collected from commercial nuclear power utilities – because the Department of Energy has no spent fuel disposal program," at http://www.environmental-defense-institute.org/publications/News.20.Dec.pdf

The stainless steel that the canisters are made of has long been known to be vulnerable to aging failures such as chloride-induced stress corrosion cracking. The NRC has even recognized that such events are to be expected and yet continues to officially deemed the events "incredible." What are the potential radiological consequences of spent fuel canister breaches? I'll discuss that in the next article.

To underscore the extent of the U.S. Nuclear Regulatory Commission's lack of concern for the cost or even feasibility of its assumptions regarding consolidated interim storage, it is interesting to review the license the NRC granted for the proposed facility in Utah, the Private Fuel Storage facility.

The U.S. Nuclear Regulatory Commission granted a license for interim storage of spent nuclear fuel in Utah, in 2005, to Private Fuel Storage (PFS), on the Goshute Indian Reservation. The facility was fought by the State of Utah and not built. The concerns by the State of Utah included the problem that the Department of Energy in October 2005 had announced a strategy to accept disposal canisters rather than the dual purpose (storage and transportation) canisters to be used at PFS. [78] The proposed interim storage facility at Utah would not have capability to repackage the canisters to a type approved of by the Department of Energy.

The NRC Licensing Board said that the issue was of no concern for the NRC. **If the canisters required repackaging, then the canisters shipped to PFS in Utah would have to be shipped back to the utilities, at the utilities expense, to repackage the canisters.** To the NRC, the issue did not affect the PFS licensing approval or the environmental impact statement for PFS. [79]

The NRC decided that it was not the NRC's problem if there was no place to ship the canisters to and no financial resources to ship or repackage the canisters. And the NRC didn't care if it actually was not possible to safely retrieve the spent fuel from the non-disposable canisters and place the spent fuel into different canisters.

The license was granted to PFS by the NRC only by the NRC refusing to care about the costs, risks and lack of capability to actually repackage the canisters. The NRC just said the problem didn't exist because the canisters at PFS would be shipped back to the utilities. Those utilities could include stranded fuel sites with no capability to repackage the canisters. This is how short-sighted, immoral and outrageous the U.S. NRC is. And the same thing is happening as the NRC prepares to approve consolidated interim storage in New Mexico and Texas.

Ironically, the entire stated reason for the consolidated interim storage proposed at New Mexico and Texas is to repurpose the land where the spent nuclear fuel is currently stored — and

[78] Yucca Mountain Repository Project, Senate Hearing 109-523, May 16, 2006, https://www.govinfo.gov/content/pkg/CHRG-109shrg29473/html/CHRG-109shrg29473.htm

[79] In The Matter Of Private Fuel Storage L.L.C., Docket No. 72-22, November 14, 2005, Applicant's Response to State of Utah's Motion to Reopen the Record and to Amend Utah Contention Utah UU, Docketed USNRC. ML053260506.

this is where the canisters would be sent back to for repackaging or if the license at the interim storage facility was not extended.

The NRC refuses to admit that a canister leak of significant size is credible. There is no way that an environmental impact statement could yield an acceptable result if the NRC was truthful. And the full extent of the damage to the fuel in the canister as the fuel oxidizes over time will "unzip" the cladding and allow fuel pellets to relocate inside the canister. This also makes the criticality risk higher, should a moderator (such as water) enter the canister.

Unlike the radiological consequence evaluation from the 2008 YM Supplement, most NRC radiological release evaluations, assume that the canister leak is very small, releasing only a fraction of the releasable material from the canister and the inhalation continues for 30 days. The duration of 30 days is stipulated by the NRC on the basis that actions will be taken within 30 days to terminate the release. [80] But there is no technically valid basis for concluding that any action can be taken to terminate the release because there is no technology to repair a canister containing spent fuel and no means for removing the spent fuel from the canister. There is no means developed to place a leaking canister into a sealed confinement such as a cask. Nor is there capability to provide adequate heat transfer for the long term with a container-in-a-container approach.

As oxygen enters the canister, any cladding damage will allow the uranium to oxidize. The uranium fuel matrix will swell, further damaging the cladding. It is not clear that NUREG-2224 fuel release fractions are adequate.

For Yucca Mountain evaluations, canister leakage from outdoor storage of aging dry canisters was not evaluated despite the long-term storage of a high number of canisters to allow additional cooling of the canister to limit the thermal loading of the repository.

For Yucca Mountain evaluations, the radiological releases from spent fuel were assumed to occur inside buildings with highly effective HEPA filters, that were assumed to be 0.9999 effective. With the dose evaluated to a receptor (the location of the maximally exposed individual) located miles from the facility, the estimated doses remained less than one rem, but only by ignoring realistic unfiltered radiological release scenarios.

The Department of Energy's estimated Yucca Mountain pre-closure radiological doses and the NRC's independent fuel storage installations are stated to have low radiological doses. **But the reality is that these agencies excel at whittling down the radiological doses on paper, while actually exposing the public to much higher, and sometimes lethal, potential accident radiological release doses with their proposed facilities.**

The annual costs of continued storage will be paid for by the U.S. tax payer, at Department of Energy sites like the Idaho National Laboratory for DOE research spent nuclear fuel and for commercial nuclear spent fuel as utilities sue the Department of Energy for those costs. And the

[80] U.S. Nuclear Regulatory Commission, Interim Staff Guidance – 5, Revision 1, Confinement Evaluation, See Attachment to ISG-5 Revision 1, page 11 https://www.nrc.gov/reading-rm/doc-collections/isg/isg-5R1.pdf

multi-billion-dollar costs of repackaging the spent nuclear fuel as the containers corrode is not something the U.S. Nuclear Regulatory Commission nor the Department of Energy want citizens to think about.

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