Testimony of Tami Thatcher on Oregon State Legislature, SB 215 and SB 216 regarding proposed legislation that "Repeals the law that requires there to be a place for radioactive waste to be disposed of before a nuclear power plant may be sites in this state. Repeals the law that requires a proposed nuclear power plant first receive approval from the electors of this state."

Submittal by Tami Thatcher, March 12, 2025 to the link at https://olis.oregonlegislature.gov/liz/2025R1/Measures/Overview/SB216

Testimony of Tami Thatcher, March 12, 2025

Tami 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, I have studied 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.

RESPONSE TO SPECIFIC ASSERTIONS MADE DURING MEETING HELD MARCH 10, 2025

The testimony for those opposed to the efforts to promote nuclear energy in Oregon were limited to a strict 2 minutes.

There were also statements given at the end of the meeting that no one witnessing could respond to. The statements or assertions given at the end of the meeting require as response.

It was mentioned that nuclear reactors operate with 93 percent capacity and can be expected to operate for 80 years. That sounds great. But these statements were misleading and perhaps not fully understood.

The 93 percent capacity of nuclear power plants is computed without accounting for planned outages. This is important because outages are typically 6 months or more for conventional large 1000 megawatt-electric (MWe) nuclear power plants. These plants have often run for almost 2 years and then take at least a 6-month or longer refueling outage. Many nuclear power plants can run an entire year — but it must be understood that many nuclear power plants have historically had very long outages, lasting many months. The outage durations for various new advanced reactors are not known.

There is an aspiration for nuclear power plants to run for 80 years, but this is unproven. Many plants have run for 40 years and have sought license extensions to operate 60 years or 80 years. But there are many more nuclear power plants that are permanently shutdown before operating even 40 years. There is no operating experience to support the assertion that it can be counted on that a reactor can operate for 80 years – it is merely an aspiration at this point.

The World Nuclear Industry Status Report 2024 tracks how much power is being generated by nuclear energy worldwide and much more about the nuclear industry and gives a more complete picture. [1]

Premature shutdowns have plagued many reactors, especially many of the non-Light-Water-Reactor designs. The small modular reactors (SMRs) may face operating problems that result in less than 40 years of operation due to higher material stresses that are associated with the smaller cores. While there is plenty of experience with sodium-cooled reactors and gas-cooled reactors, the operating histories of these types of reactors has shown premature permanent shutdown and uneconomic operation.

So, asserting that every type of nuclear reactor being promoted can achieve 93 percent capacity and an 80-year operating life is not based on experience and is especially not necessarily applicable to the many proposed advanced nuclear reactors, including small nuclear reactors.

An assertion was made equating the challenge of spent nuclear fuel disposal with the issue of disposal of batteries. This shows a real lack of understanding of the challenges of spent nuclear fuel disposal. A report from 1978 would be instructive, *Geologic Disposal of High-Level Radioactive Wastes – Earth Science Perspectives*. [2] The 1978 report made an estimate of how many cubic meters of water would be needed to dilute the spent nuclear fuel they expected in 2000 [and we are making more waste than this], to then drinking water standards. "A volume of 5.2×10^{16} m^3 of water, which is almost 4 percent of the oceanic volume (1.4×10^{18} m^3), would be needed to dilute the wastes on hand at the year 2000 to levels specified in the RCG [Radiation Concentration Guides]; this volume is almost double that of fresh water in global storage in lakes, rivers, ground water, and glaciers. Even after a million years, the volume of water needed to dilute these wastes to the levels specified in the RCG is significant in terms of water stored in individual major lakes and aquifers."

So, the problem of lacking engineered containers, so far unlikely to confine spent nuclear fuel reliably for even 100 years, and the problem of not finding geological solutions to contain the radioactive waste, is a significant one that threatens life in the United States and on Earth. Progress touted in other countries needs to be balanced with their actual lack of a repository, the actual costs not being known, and that they may often have far less waste and more benign forms, such as lower enrichments in those wastes, as in Sweden (See more at NWTRB.gov.)

Stating an opinion that the spent nuclear fuel waste problem, that the proposed new reactors may not involve much waste, could be true. The new SMRs, if built, may be shutdown soon, before ever generating years of spent nuclear fuel, for many reasons. The plants may be too uneconomical to operate, may be obsolete before being completed, may be deemed too dangerous to operate, etc. and thus, may not operate for very long. The money spent on pursing

[1] A Mycle Schneider Consulting Project, Paris, *The World Nuclear Industry Status Report 2024*, September 2024. WNISR Project website www.WorldNuclearReport.org

[2] J.D. Bredehoeft, A.W. England, D.B. Stewart, N. J. Trask, and I. J. Winograd, Geologic Disposal of High-Level Radioactive Wastes- Earth-Science Perspectives, U.S. Geological Survey Circular 779, 1978.

SMRs in Oregon, however, will take money away from more timely and effective solutions, effectively suppressing better solutions.

The spent nuclear fuel generated by small modular reactors, being weapons usable in enrichment (HALEU fuel), and designed to operate longer in a reactor, thus accumulating more fission products in the fuel, creates a highly radioactive waste that poses serious criticality risks and weapons proliferation risks. The SMR fuels will also require disproportionally more space in a repository. The nuclear waste from the variety of small modular reactors (water-, molten-salt-, and sodium-cooled SMR designs) has been evaluated and can be expected to "increase the volume of nuclear waste in need of management and disposal by factors of 2 to 30." Lindsay M. Krall, Allison M. Macfarlane, and Rodney C. Ewing, *PNAS*, "Nuclear waste from small modular reactors," Received June 26, 2021, Published May 31, 2022, https://doi.org/10.1073/pnas.2111833119.

The world has had a serious nuclear energy disaster roughly every decade, Three Mile Island in 1979, Chernobyl in 1986 and Fukushima in 2011. The U.S. Nuclear Regulatory Commission in the United States, is being pressured to license any and all design proposals, whether or not the designs are adequate, even on paper. And, the now-present risk of weaponized drones poses a serious terrorism or warfare risk that will undermine safety design features, making these new nuclear reactors, particularly the small modular reactors that lack building containments and their stored spent nuclear fuel, a target. The loss of land, property and homes and lives from nuclear reactor accidents and the lack of compensation, especially for SMR's less than 100 MWe each and from SNF storage, was not discussed during the meetings held.

SUMMARY (As Previously Submitted)

Oregon legislators need to understand the history and the truth of the overly optimistic claims made by the nuclear promotors. Government leaders are often easily misled to believe the claims of affordability and safety by nuclear promotors.

Oregon needs to prevent more spent nuclear fuel from being produced in Oregon and keep the existing laws in place. Oregon should also make laws to block the creation of DOE or a private company from putting a Consolidated Interim Storage facility in the state.

The Department of Energy is further behind now than in 1980 with regard to obtaining permanent disposal of spent nuclear fuel. The nuclear promotors will leave future generations with unsolved problems associated with long-term above ground storage and unavailable disposal facilities. Oregon Legislators should oppose SB 215 and SB 216.

The State of Oregon has responsible laws to prohibit creating more radioactive spent nuclear fuel until a permanent disposal solution was found. Now, nuclear promotors are aggressively seeking to have those sensible laws repealed. But no arrangement with the Department of Energy and no temporary license from the U.S. Nuclear Regulatory Commission will protect Oregon citizens.

Nuclear promotors are claiming that new nuclear energy will be affordable, reliable, and safe, despite plenty of current evidence to the contrary. The fact is that nuclear energy is unaffordable and that small modular reactors will cost more than conventional large reactors, on a per megawatt basis. The focus is largely on construction and operating costs. Other huge costs such as the repository costs or accident compensation costs are usually not included.

Nuclear promotors are claiming that spent nuclear fuel has been stored safely so far, and imply that no one should worry about it. There's far more to know about the lack of assurance of long-term storage as decades of storage go by and as new fuels may increase storage challenges. Safety concerns should also address the increasing vulnerability to weaponized drones.

Nuclear promotors are mentioning the U.S. Department of Energy's program for consent-based siting of temporary "consolidated interim storage." Yet, when the spent nuclear fuel at the reactor site or a consolidated interim storage facility has no place to be shipped to, it will remain where it is. The consolidated interim storage being sought, untethered from any repository, creates the illusion of a solution. Yet, there is dismal lack of progress on any permanent solution such as a repository.

Nuclear promotors aren't discussing that there is already twice as much spent nuclear fuel to dispose of now than the never-built Yucca Mountain repository was to have held. They aren't admitting that DOE has no plan for the additional spent nuclear fuel from proposed new reactors. They aren't admitting the highly uncertain cost of a repository siting and design effort. They aren't admitting the technical challenges of attempting to confine the radionuclides in spent nuclear fuel or high-level waste, which may amount to a very expensive failed experiment.

The federal U.S. Department of Energy is responsible for siting a permanent repository for the nation's spent nuclear fuel and waste resulting from spent fuel reprocessing. The Department of Energy has a track record of decades of broken promises, technical failures and expanding costs at the federal sites like Hanford where it has reprocessed spent fuel, largely for obtaining nuclear weapons materials. Nuclear promotors dangle "recycling" as the smart solution to spent nuclear fuel and repeatedly say that failures at DOE's Hanford site are unrelated to nuclear energy expansion.

Nuclear promotors who say spent nuclear fuel "isn't a waste, but a future resource," fail to mention reprocessing's high cost and who will pay. (The usual choices are ratepayers or taxpayers.) They fail to mention that reprocessing always releases gaseous fission products and is highly polluting to the air we breathe. The chemical aqueous methods create tank waste, like the waste leaking from Hanford tanks. They fail to mention that certain "recycling" or reprocessing methods like pyroprocessing would not address existing spent nuclear fuel. Even with reprocessing or "recycling," the nation needs one or several repositories.

The nuclear designers and builders won't be the ones paying for spent nuclear fuel storage, for an accident, or for one or several repositories. The nuclear promotors are pretty predictable in their avoidance of candid discussion of the costs and the risks that will fall upon citizens who expected more from their state and federal decisionmakers.

THE DEPARTMENT OF ENERGY HAS NO REPOSITORY PROGRAM

The status of the Department of Energy's spent nuclear fuel (and high-level waste) repository program is that the Department of Energy has no repository program and has not collected disposal fees from ratepayers since 2014 — because they have no repository program.

Nuclear promotors tend to confuse the consent-based siting process for consolidated so-called 'interim" storage, with repository siting. There is no repository siting effort. Opposition to the proposed Yucca Mountain repository was wide-spread in Nevada and deepened by the negative experiences with the Department of Energy.

The national already has more than double the amount of spent nuclear fuel than was allowed at the never-built Yucca Mountain repository. The DOE is not planning for the additional spent nuclear fuel from new nuclear reactors (or proposed restarts). The nation may need more than one repository and yet has no program for even siting a repository. The DOE is continuing to study spent nuclear fuel disposal. DOE states estimated costs based on speculative assumptions and bases the estimate on less SNF than DOE knows they will have to dispose of. The cost estimates for a repository are low-balled and likely to be crushingly high. The technical challenges of confining the radionuclides in the spent nuclear fuel (or high-level waste) cannot be overstated.

STATUS OF TECHNICAL BASIS FOR SAFETY OF LONG-TERM STORAGE AND TRANSPORTATION OF SPENT NUCLEAR FUEL: ANALYSIS GAPS ARE GROWING AND LONG-TERM SAFETY IS UNKNOWN

The nuclear promotors want to convince people that nuclear fuel is a "solid," that past safe storage means safe storage in the future, for any period of time and any new type of fuel.

The nuclear promotors don't want to talk about the gaps in understanding just how long the containers holding dry spent nuclear fuel will last before corroding through. They don't want to talk about who pays for the consequences of releasing the vast amount of radioactive material from dry storage of spent nuclear fuel, as well at from wet pool storage or from a reactor accident.

Experience with spent nuclear fuel during transportation efforts, early on, showed that if cladding was damaged, that spent nuclear fuel exposed to air would start to oxidize. This damaged SNF when unloaded in a pool, contaminated the pool when the fuel was resubmerged. The industry learned that they needed to keep an inert gas in the containers of dry spent fuel to prevent fuel oxidation. Later on, hotter fuels, they learned, could not be resubmerged in a pool as had earlier low burnup fuels, at least not without far longer cooling times.

Fuel type, cladding condition and operating history matter. And oxygen exposure to the fuel matters. That nice solid spent nuclear fuel can oxidize so much that it heats up. The full discussion of what may happen when SNF canisters are breached is something the industry does not want to talk about. How soon canisters may be breached from aging, is not something that the industry wants to talk about.

The Department of Energy is responsible for the analysis of the technical basis for long term dry storage of spent nuclear fuel, and DOE acknowledges that they are behind in this research, and that the large variety of new fuels and new reactors will only exacerbate the problem. DOE also acknowledges that research for disposal is needed for each new fuel type and its various operating conditions. No one is talking about the costs or risks of spent nuclear fuel storage after the short licensing period is over and communities are stuck with spent nuclear fuel that can't be safely stored or transported, there is no repository for and no expensive and highly polluting recycling process that the nuclear promoters keep dangling.

The status is that the U.S. Department of Energy is the sole agency with the role of citing nuclear waste disposal of spent nuclear fuel and the high level waste resulting from the reprocessing of spent nuclear fuel.

The NuScale "small modular reactors" design could mean up to twelve reactors in a single facility. The design of the NuScale fuel will require more space in a deep geologic repository, on an energy equivalent basis, than large light-water reactor spent fuel. And whereas existing light-water spent fuel would fit 4 assemblies in a canister, the number of assemblies from a NuScale reactor could be restricted to 1 or perhaps less per disposable canister.

The nuclear waste from the variety of small modular reactors (water-, molten-salt-, and sodium-cooled SMR designs) has been evaluated and can be expected to "increase the volume of nuclear waste in need of management and disposal by factors of 2 to 30." Lindsay M. Krall, Allison M. Macfarlane, and Rodney C. Ewing, *PNAS*, "Nuclear waste from small modular reactors," Received June 26, 2021, Published May 31, 2022, https://doi.org/10.1073/pnas.2111833119.

We already need two deep geologic repositories that size of the legally mandated original size of the proposed Yucca Mountain repository, just to accommodate existing spent fuel, high-level waste and the spent fuel expected from currently operating reactors.

In 2010, Yucca Mountain was defunded. In 2014, "Zero Day," the Department of Energy had to stop collecting fees from rate payers for spent nuclear fuel disposal because it has no program to obtain a deep geologic repository.

The above ground dry storage licensed by the U.S. Nuclear Regulatory Commission would use the same design at reactor sites as a consolidated "so-called interim" storage sites. The spent nuclear fuel canisters currently that would be used by NuScale are thin-walled stainless steel welded closed canisters. The dry storage of spent nuclear fuel is a single barrier system, with a thin layer of stainless steel of the canister that is long-known to be susceptible to through-wall cracking, such as chloride-induced stress corrosion cracking and other mechanisms. Dry storage is susceptible to radiological releases even though analyses of such events has been withheld by the NRC and nuclear promotors fail to acknowledge the consequences of canister failure. The NRC argues that dry storage is safe only by choosing to exclude aging degradation from its evaluations and by claiming that somehow, releases will stay within regulatory limits.

There is currently no technology to detect cracking in a loaded canister. There is currently no technology to repair a damaged canister containing spent fuel and no way to unload the fuel. The canisters may last over a hundred years or as little as 20 years.

While other countries chose bolted-closed thick walled casks that allow replacement of the cask, the U.S. NRC allowed the cheaper thin-walled welded closed canister. Canister replacement will be needed because there is no incentive to pay the enormous cost of obtaining a repository. There have been no facilities designed or built to repackage a canister that is damaged or to a disposable cask or canister.

If the one or several deep geologic repositories are constructed and licensed, the cost will be the burden we have placed on future generations. The fees that had been collected from ratepayers will not even cover the cost of repackaging the fuel into disposable casks. And there is little assurance that a repository will adequately limit the migration of radionuclides to future generations.

The cost of repackaging above ground dry storage spent nuclear fuel will also be the burden for the not-too-distant future and for future generations. The consequences of failure of a reactor, of a spent fuel pool, of dry storage of spent fuel or during transportation is not limited to Oregon.

The Department of Energy has made no progress on obtaining a deep geologic repository. Its efforts have been focused on consolidated "interim" storage in New Mexico and south Texas, all without any plan for locating, constructing or licensing a permanent repository. The consolidated "interim" storage facilities use the same design as the reactor site. But neither the consolidated nor reactor site storage allow for repackaging a damaged canister.

MAGNITUDE AND LONGEVITY OF THE HAZARD OF SPENT NUCLEAR FUEL (OR HIGH-LEVEL WASTE) IS UNPRECEDENTED

The radioactive material in spent nuclear fuel remains toxic and hazardous to humans and other living things for over hundreds of thousands of years. Yet, temporary storage of spent nuclear fuel in canisters will require repackaging within perhaps about 100 years and may fail within 20 years due to chloride-induced stress corrosion cracking. These canisters have no current technology for repackaging. The faulty canister designs were accepted when the belief was that disposal of the spent nuclear fuel would occur before spent fuel canister failure. But obtaining permanent disposal for spent nuclear fuel remains more elusive today than it was 20 years ago.

HISTORY OF NUCLEAR WASTE POLICY

The history of Department of Energy repository failure is relevant to understand. In 1983, the Nuclear Waste Policy Act of 1982 (NWPA) was enacted, making permanent disposal of commercial spent nuclear fuel a federal responsibility. From 1983 through 2010, $15 billion had already been spent on repository investigation of other sites and on the Yucca Mountain Repository research, design effort, and license application submittal. [3] After more than three decades and over $15 billion spent, Yucca Mountain is no closer to disposal of spent fuel than when it was designated to be the nation's repository for spent fuel in 1987. [4]

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[3] Government Accountability Office (GAO), Report to Congressional Addresses, "Commercial Nuclear Waste – Effects of the Yucca Mountain Repository Program and Lessons Learned," GAO-11-229, April 2011. See https://www.gao.gov.

[4] Brian Isom, The Center for Growth and Opportunity at Utah State University, "Waste storage or waste of money – It's time to move on from Yucca Mountain," February 20, 2020. https://www.thecgo.org/benchmark/waste-storage-or-waste-of-money/

DOE's 1998 Yucca Mountain cost estimate [5] includes keeping the repository open for at least 100 years and monitoring the repository performance for up to 300 years. **Essentially, the Yucca Mountain repository is an experiment.** And the costs taking action if the repository does not perform well have never been included in the 1998 or any subsequent estimate.

See a timeline for management of spent nuclear fuel in Table 1.

Table 1. Timeline of key events in U.S. plans for managing spent nuclear fuel and high-level waste.

Date	Event
By 1940 to present	U.S. nuclear weapons program includes uranium enrichment at Oak Ridge, plutonium production reactors at Hanford, multiple research reactors and defense-related wastes continue to be generated. (The Waste Isolation Pilot Plant (WIPP) in New Mexico accepts transuranic defense waste but not spent nuclear fuel or high-level waste.)
1954	Congress passes Atomic Energy Act of 1954, promoting the peaceful use of atomic energy
1955	U.S. begins using nuclear power to generate electricity
1957	National Academy of Sciences recommends geologic disposal as the permanent solution for spent nuclear fuel and high-level waste (HLW)
1970	U.S. begins search for potential repository sites
1970	Lyons, Kansas, site selected as the first national repository
1972	Lyons site withdrawn due to technical problems and public opposition
1983	Nuclear Waste Policy Act (NWPA) signed into law
1986	Department of Energy recommends three sites for further study: Yucca Mountain, Hanford in Washington and Deaf County in Texas
1987	Congress amends NWPA, directing DOE to study only Yucca Mountain
1988-2008	DOE studies Yucca Mountain and plans to dispose of both commercial spent nuclear fuel and DOE-owned defense SNF/HLW.
1994	Outside experts independently raise issues about criticality concerns for surplus plutonium disposal at Yucca Mountain. DOE did not provide technically defensible criticality studies for either surplus plutonium nor high-burnup fuel for the 2008 license submittal. Two scientists from Los Alamos National Laboratory would explain how the plutonium-239 posed a particularly high criticality risk at Yucca Mountain. [6] [7] 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. [8] In SNF, criticality risks remain after 10,000 years, yet there is

[5] Department of Energy, *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program*, DOE/RW-0510, December 1998.

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

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

[8] 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.

Date	Event
	no regulatory requirement to assess or limit the criticality risk after 10,000 years, either at Yucca Mountain or WIPP.
1998	The date DOE had contractually agreed to accept commercial spent nuclear fuel. This failure leads to lawsuits brought by commercial nuclear utilities who sought reimbursement for spent fuel management, specifically for dry spent fuel storage as spent fuel pools ran out of space.
19987	DOE ignores repository suitability criteria not met by Yucca Mountain. A presentation to the Nuclear Waste Technical Review Board acknowledges Yucca Mountain fails to meet suitability criteria. Water infiltration through YM is greater than expected and migration of contamination is as little as 50 years, far more rapid than the 1000 years for significant radionuclide travel. Other problems include high seismicity and volcanism. [9] [10]
1998	DOE's 1998 Yucca Mountain cost estimate [11] includes keeping the repository open for at least 100 years and monitoring the repository performance for up to 300 years. **Essentially, the Yucca Mountain repository is an experiment.** And the costs taking action if the repository does not perform well have never been included in the 1998 or any subsequent estimate.
1998	Waste Isolation Pilot Plant (WIPP), a Department of Energy disposal facility in New Mexico for transuranic waste related to nuclear weapons production is certified by the U.S. Environmental Protection Agency. WIPP first waste shipment in 1999. WIPP excludes spent nuclear fuel and high-level waste. WIPP is not designed to handle the heavy and large sized commercial spent nuclear fuel canisters.
1998-present	U.S. taxpayers, rather than electricity rate payers, are funding the dry storage of commercial spent nuclear fuel. Commercial nuclear power plants with a contract that DOE take SNF by 1998, win lawsuits and are paid money for the cost of spent nuclear fuel management such as dry spent fuel canisters and facilities, now 75 facilities in 33 states. The money is the taxpayer funded "Judgment Fund" and DOE continues to pay with taxpayer money for the dry storage of spent fuel at commercial power plants who were able to sue to DOE's partial breach of contract because DOE did not take spent fuel beginning in 1998.
2002	DOE and President G.W. Bush designate Yucca Mountain as suitable for repository development and licensing
2008	DOE submits YM license application to the Nuclear Regulatory Commission
2009	The Obama presidential administration determines Yucca Mountain is not a workable solution. Lawsuits over the technical problems associated with YM would take years to litigate.

[9] State of Nevada and related findings indicating that the proposed Yucca Mountain site is not suitable for development as a repository, webpage, https://www.yuccamountain.org/archive/nuctome2.htm

[10] Richard Burleson Stewart and Jane Bloom Stewart, Fuel Cycle to Nowhere – U.S. Law and Policy on Nuclear Waste, Vanderbilt University Press, 2011. ISBN 978-0-8265-1774-6

[11] Department of Energy, *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program*, DOE/RW-0510, December 1998.

Date	Event
2009	NIRS letter to President Obama includes the finding that sound science has not been the basis of the plans for the Yucca Mountain Repository.[12]
2010	Blue Ribbon Commission established
2010	Yucca Mountain research is defunded. Despite having a much-photographed tunnel entrance, the repository above ground support facilities and the repository were never constructed and the design is largely an incomplete conceptual design.
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." It still hasn't happened as of January 2024.
2011	GAO-11-229 and -230 identify currently existing amounts of waste slated for Yucca Mountain as 65,000 metric tons of commercial spent nuclear fuel and 13,000 metric tons of DOE SNF/HLW.
2011	GAO-11-810 states that from 1983 to 2010, $15 billion was spent on research and the license application for Yucca Mountain (but no facility constructed).
2012	Blue Ribbon Commission recommends DOE adopt a consent-based approach to siting nuclear waste facilities
2013	DOE releases *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* and this calls for a separate DOE-waste repository
2014	"Zero-Day" requires DOE to stop collecting Nuclear Waste Fund money from electricity ratepayers because DOE has no spent nuclear fuel repository program
2014	Nuclear Regulatory Commission (NRC) completes *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel*, NUREG-2157, replacing the previous "waste confidence" rule. Essentially, both the "continued storage" and the "waste confidence" positions mandate ignoring spent nuclear fuel management costs and technical challenges.
2015	NRC review finds DOE's YM application meets regulatory requirements but lacks land withdrawal and water rights.
2016	NRC creates a report for the DOE yielding a very low radiation trickle-out from the YM repository, *Supplement to the U.S. Department of Energy's 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*, NUREG-2184.

[12] Nuclear Information & Resource Service (NIRS), Letter to President Obama Concerning Yucca Mountain and the Re-evaluation of U.S. Radioactive Waste Policy and Management, May 2009. : http://www.nirs.org/radwaste/hlw/obamaltrsigners.pdf

Date	Event
2018	A criticality analysis shows previous DOE assumptions were flawed regarding criticality of high burnup fuel, above 3 percent enriched, and that criticalities are credible. [13]
2010-present	DOE continues to assert in multiple National Environmental Policy Act (NEPA) documents that its solution to spent nuclear fuel is Yucca Mountain, despite defunding and no program for the Yucca Mountain repository.
2010-present	DOE continues to hint that spent fuel reprocessing is the solution despite this being contrary to the Blue-Ribbon Commission report recommendations because of the increased volume of nuclear waste and high cost
2010-present	DOE continues to promote the growth in nuclear energy despite having no program for a commercial spent fuel repository or for a DOE-owned SNF/HLW repository
Before 2010-present	DOE is promoting numerous new "advanced" reactor designs, many of which require many more canisters of spent nuclear fuel in a repository, from 2 to 30 times more, on an electricity generated basis, all without consideration of the adverse impact on any repository program
2019	2019 Gap Analysis admits DOE does not have an adequate technical basis for assuming decades of SNF storage is safe and may cause degradation affecting transportation. No one knows who will pay for addressing replacement/repackaging from age-related degradation prior to obtaining a repository.
2019	DOE study by Sandia National Laboratory makes estimate of cost for disposal of commercial spent nuclear fuel, making multiple assumptions that are not compliant with existing laws or any technical study. For example, it assumes Yucca Mountain will be opened. It assumes that Yucca Mountain or an identical site can accept far more SNF than allowed by current law. It assumes basically no technical hurdles. And it assumes that past cost estimates are adequate and are simply converted to 2018 dollars. The cost of repackaging SNF for disposal is considered; however, the cost of any needed repackaging at 75 sites in 33 states to address corrosion and aging or other damage as decades of dry storage continue, is excluded.
2020	GAO-21-603 states that the Nuclear Waste Fund from fees collected from electricity generated by nuclear energy, and not previously spent, totals $43 billion, in 2020.
2021	GAO-21-603 identifies existing commercial spent nuclear fuel as 86,000 metric tons and has about 14,000 metric tons of DOE defense- and research-related SNF/HLW.
2023	DOE continues to admit that it does not have an adequate technical basis for existing SNF, for high-burnup SNF now used in commercial nuclear reactors, and the problem is greatly exacerbated by the growing number of varieties of new types of nuclear reactors.

[13] Allseed 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

Date	Event
2023	DOE is paying numerous universities, businesses and others, called "consortia," to look for communities to convince to host a consolidated interim storage facility
2024	DOE promotes tripling the amount of nuclear energy in the U.S. without any consideration of the lack a repository for SNF from existing plants and without any consideration of the technical and financial peril of more nuclear reactors, and the disproportionately higher amount of space required for many of the new fuels from small modular reactors.
2024	Commercial spent nuclear fuel continues to accumulate at roughly 2000 metric tons per year. Depending on premature shutdowns, by 2055, **without any new nuclear reactors**, over 140,000 metric tons of commercial spent nuclear fuel is expected. This exceeds the statutory limit of Yucca Mountain of 70,000 metric tons, and excludes the DOE-owned defense- and research-related SNF/HLW that will require a different repository.
2024	No alternative to Yucca Mountain has been identified. DOE has shifted to assuming that only commercial spent nuclear fuel would go to Yucca Mountain, if the Yucca Mountain repository existed. No repository for a DOE-owned defense- and research-related SNF/HLW repositories has been identified.
By 2090	Much of the spent nuclear fuel will be over or approaching 100 years in dry storage and may require repackaging due to corrosion or other age-related or incident-related issues, unrelated to disposal. Transportation requires an intact canister. DOE, according the GAO-21-603 has not included the cost of developing a method for canister repackaging and has not include the cost of canister repackaging. DOE has included estimates of repackaging costs as needed for disposal, which are likely gross underestimates.
2117	SAND2019-6999 study assumes 2117 repository opening date for a commercial-only spent nuclear fuel repository. Many assumptions are not in compliance with current regulations and have not been evaluated for ability to confine radionuclides. Cost estimate in 2018 dollars is $141 to $168 billion and assumed only 109,300 metric tons of commercial spent nuclear fuel even though over 140,000 metric tons of commercial SNF would be expected even with no new nuclear reactors. The $168 billion estimate is an underestimate that ignores the realities of the technical immaturity of many of the facilities needed. Also, with only $43 billion collected and remaining in the Nuclear Waste Fund, taxpayers are likely to be on the hook for enormous costs of attempting to obtain a permanent disposal path for commercial spent nuclear fuel.

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 about 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. [14]

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. [15] Even so, the repository could heat up and invalidate the geological stability of the repository. The decision as to whether or not to plan for a hot repository (with higher decay heat) or a cold repository approach (less decay heat) was never decided.

The 2021 GAO report did a disservice by highlighting lower cost estimates of less than the total amount of expected commercial spent nuclear fuel and costs limits by funding source. GAO-21-603 gave a spent nuclear fuel disposal cost estimates in the text for only the amount to be paid from the Nuclear Waste Fund. Then, in a footnote, the total cost estimate for Yucca Mountain was presented which was to be paid by the Nuclear Waste Fund, the Judgement Fund and from "other resources." The Judgement Fund is the money paid by the U.S. taxpayer to commercial nuclear power utilities for the cost of dry storage of spent nuclear fuel because the government failed to take ownership of the SNF by 1998, as per the "Standard Contract" that many utilities had. Costs remaining (not covered by the Nuclear Waste Fund and the Judgment Fund) will be paid by the U.S. taxpayer.

It should be noted that for new nuclear plants, the Judgment Fund isn't likely to apply and ratepayers will be paying more for spent nuclear fuel storage. **Ratepayers for new nuclear plants will be on the hook for more of the dry storage and continued storage costs that U.S. taxpayers now subsidize.** The stated nuclear plant costs typically exclude these ongoing perhaps decades or centuries of spent nuclear fuel storage costs, ignore the need for replacement of these facilities or repackaging of spent fuel (not repackaging for disposal) and exclude the cost of a spent nuclear fuel repository.

The Nuclear Waste Fund has not collected any funds since "Zero Day" in May 2014 because the Department of Energy has no spent nuclear fuel disposal program. The total amount in the Nuclear Waste Fund from the fee collected from ratepayers (and not already spent) is about $43 billion as of September 2020, but the low-balled cost of a repository for just the commercial spent nuclear fuel is already $168 billion.

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[14] 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

[15] 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 Nuclear Waste Policy Act of 1982 created a fee on electricity generated by nuclear power plants that would accumulate in the Nuclear Waste Fund for spent nuclear fuel disposal. That money had been collected into that fund and currently has $40 billion. [16]

No money has been collected for the Nuclear Waste Fund from nuclear utilities since the fee was set to zero on May 16, 2014, as a result of litigation in the U.S. Court of Appeals for the District of Columbia Circuit, because the Department of Energy had no spent fuel disposal program.

The Department of Energy had contractual obligations to begin disposing of spent nuclear fuel generated by electric utilities by 1998. Because DOE has not met its contractual obligations to begin disposing of the fuel, many utilities filed lawsuits. The utilities won and out of this came the Judgement Fund, financed by U.S. taxpayers. So far, about $8.6 billion has been paid to electric utilities for their costs of spent nuclear fuel management and storage and the total federal liability is expected to be $39.2 billion. [17]

It costs about half a billion per year for DOE payment to utilities for not taking the spent fuel in 1998 as promised.

When the 2021 GAO cost estimate for spent nuclear fuel disposal of only a portion of the commercial spent nuclear fuel is stated as $168 billion, it should be remembered that the U.S. already spent $15 billion on Yucca Mountain all without resulting in a license to construct that partially designed facility. It was never decided whether Yucca Mountain could withstand being a hot repository and many other crucial details. The plan included monitoring how the repository performed — yet did not include any estimate of the cost if the repository did not perform well. **There are several reasons why the 2021 GAO repository cost estimate is likely to far exceed $168 billion dollars.**

The Department of Energy has continued to characterize the nation's spent nuclear fuel inventory as able to fit on a single football field. Yet, whether characterized as 15 ft deep for 69,000 metric tons or 30 ft for 83,000 metric tons, the characterization is very misleading. Changing to an "Olympic swimming pool" is also deceptive of the space required in a repository.

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. [18]

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[16] Nicole Feldman, Freeman Spogli Institute for International Studies, *Stanford University, School of Sustainability*, "The steep costs of nuclear waste in the U.S.," July 3, 2018. https://sustainability.stanford.edu/news/steep-costs-nuclear-waste-us

[17] Government Accountability Office (GAO), Report to Congressional Addresses, "Commercial Spent Nuclear Fuel – Congressional Action Needed to Break Impasse and Develop a Permanent Disposal Solution," GAO-21-603, September 2021. https://www.gao.gov/nuclear-waste-disposal (page 19)

[18] 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

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

The spent nuclear fuel from operating the nuclear power plants around the U.S. has no place to go. **The Department of Energy is responsible for taking ownership of the radioactive spent nuclear fuel that remains hazardous and a risk to the environment for millennia. But the Department of Energy has no disposal facility and has no program for a disposal facility.** The DOE cannot even collect fees for paying for a fraction of the cost of disposing of spent nuclear fuel, because a court found that DOE had no spent fuel disposal program.

The DOE would like to give the impression that parking lot dumps, like the spent fuel storage facilities proposed for New Mexico and Andrews, Texas are a solution. But those facilities are not designed for the long-term. And when their U.S. Nuclear Regulatory Commission license expires and there is still no disposal facility, these states will be stuck with radioactive waste that cannot be repackaged and has no place to go.

SPENT FUEL STORED IN POOLS OR CANISTERS IS UNSAFE

People living with stranded spent nuclear fuel want to get it out of their state. They want the spent fuel canisters, that the NRC licensed as safe, to be moved somewhere else. Then, they won't have to worry about it. Let some other unfortunate people in another state have this ticking time bomb of radioactive airborne releases from a cracked canister of spent fuel.

Most people do not understand that spent nuclear fuel storage systems, even if somewhat below grade, have only one barrier to airborne release — the canister wall. Air is required to circulate around the canister and so no other isolation is present in these systems, like the Holtec system proposed for New Mexico and already on the coast at the San Onofre nuclear plant.

Spent storage pools subject a large amount of spent fuel to insufficient cooling and airborne release. Dry canister systems have been used because the spent fuel pools were filling up.

Storing the spent nuclear fuel in NRC-licensed casks was supposed to require that the fuel be able to be repackaged if there was a problem. But the NRC did not comply with its own regulations and granted licenses to the Holtec and other thin-walled canister systems. Other countries use safer technology that involves thick-walled casks and the systems to repackage the 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

[19] 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

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. [20]

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. The Swiss require a hot cell for repackaging a cask if needed. Read more at SanOnofreSafety.org [21] (and also the December 2020 EDI newsletter).

The NRC has also licensed far higher reactor burnup levels and this has meant far higher criticality risk in each canister. The fuel in a canister will go critical if water enters the canister, which, in the past, was not the case, for the lower enriched fuels.

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. [22] See the Environmental Defense Institute December 2020 newsletter article for more details, "The last 10 years of repository research shows that the criticality issues are a problem, especially for 'direct disposal' of spent nuclear fuel canisters."

The spent fuel canisters now prevalently in use in the U.S. are going to fail. And the NRC is keeping any study of the actual range of radiological consequences, under wraps. The airborne leakage of radioactive gases, the NRC can argue, can be maintained below regulatory limits. But this argument may rely on meeting the regulatory limits by evacuation of people living near the interim storage site.

With the unsafe canister designs, once the canisters start failing, and the problem is deemed just a South Texas and New Mexico problem, there will be little incentive for replacing the unsafe storage canister design and little incentive for seeking a permanent disposal solution.

The AP article cites how the San Onofre nuclear plant in California is seeking to move their spent fuel to New Mexico. The San Onofre spent nuclear fuel is stored in Holtec canisters and a storage system, essentially the same as proposed for New Mexico. The San Onofre spent fuel storage facility was licensed by the NRC. Yet, it is on the coastline of the Pacific Ocean and even more susceptible to long-known chloride-induced stress corrosion cracking. The through-wall

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[20] 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

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

[22] 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

cracking can occur within twenty years. The NRC licensed outrageously shortsighted and unsafe storage of spent nuclear fuel at San Onofre as well as the other nuclear power plants in the U.S.

The masters of subtlety, a U.S. Nuclear Regulatory Commission basically admits that currently there is no ability to detect cracks in dry spent nuclear fuel canisters.

The transcript of the NRC meeting held October 11, 2018 includes the response to questioning about canister inspection capability. The NRC engineer responds: "Separately, we do have a contract with PNNL, one of the DOE laboratories, to set up a mockup of a cask to collaborate with EPRI to actually see how the robotics, how these tools are resulting in the inspections to actually assess and see, can they detect the flaws, can they understand and characterize the flaws. So, I think it's progressing well, I think we have confidence in the industry and the direction they're going to be able to inspect these in the future." [23]

Translation, thanks to Donna Gilmore for SanOnofreSafety.org, is that the nuclear industry has again admitted that they currently have no ability to inspect canisters for cracks. They have no ability to "detect the flaws" or "understand and characterize the flaws." [24]

What this means is that spent nuclear fuel canisters at nuclear plants around the country may start leaking and/or exploding without warning and with no means of repackaging the spent fuel into a new canister.

The NRC hasn't actually included chloride-induced canister cracking in its risk assessments. And they know that through-wall cracking takes less than 20 years from exposure to salt water or other chloride-rich water. See our July 2018 EDI newsletter [25] and our comments regarding Holtec and Interim Storage Partners proposed interim storage facilities. [26] [27] See also the Environmental Defense Institute February 2019 newsletter article, "Despite the U.S. NRC Spin, There is No Ability to Detect Dry Spent Nuclear Fuel Canister Cracks."

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[23] SanOnofreSafety.org at https://sanonofresafety.org/ and see the U.S. Nuclear Regulatory Commission transcript for the October 11, 2018 meeting, Strategic Programmatic Overview of the decommissioning and Low-Level Waste and Spent Fuel Storage and Transportation Business Lines (ML18295A698) (pages 104 and 105) at https://www.nrc.gov/docs/ML1829/ML18295A698.pdf

[24] Donna Gilmore, SanOnofreSafety.org, Press Release, "Regulators consider whether to allow San Onofre nuclear waste to be stored in defective Holtec storage system," January 24, 2019. https://sanonofresafety.files.wordpress.com/2019/01/pressrelease2019.jan24nrc2pm.pdf

[25] Tami Thatcher, Environmental Defense Institute, July 2018 Newsletter article "Spent Nuclear Fuel Dry Storage Safety Issues Largely Ignored," http://www.environmental-defense-institute.org/publications/News.18.July.pdf

[26] Tami Thatcher, "Public Comment Regarding Application to the U.S. Nuclear Regulatory Commission on the "Holtec International HI-STORE Consolidated Interim Storage Facility Project," Docket NRC-2018-0052-0058, July 30, 2018. http://www.environmental-defense-institute.org/publications/NRCHoltec2018.pdf

[27] Tami Thatcher, "Public Comment Regarding Interim Storage Partners LLC's Consolidated Interim Storage Facility," Docket NRC-2016-0231, November 2018. http://www.environmental-defense-institute.org/publications/CommentNRC2018Texas.pdf

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." [28] **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. [29]

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. See the Environmental Defense Institute January 2021 newsletter article for more details, "The NRC Required Canistered Spent Nuclear Fuel To Be Retrievable – But It Isn't and Prevalent Canister Storage Poses Huge Safety Risks as Well as Higher Disposal Costs."

What are the canister leak consequences for a leak, even of modest size? The answer is, even using the NRC's fuel release fractions rather than the entire canister radionuclide inventory, the radiation dose within a few miles could be over several hundred rem. In other words, deadly. And if somehow, there is any radiological monitoring being conducted by someone (the NRC doesn't require it), you will be evacuating and not coming back to your home. See the Environmental Defense Institute January 2021 newsletter article for more details, "Spent Nuclear Fuel Canister Breaches – The Potential Radiological Releases are Too Scary for the NRC to Admit."

To gain an idea of the contents of a single spent fuel canister, see Table 2 below. The estimated inhalation dose may be based on out-of-date dose conversion factors.

Table 2. Selected commercial spent nuclear fuel inventory in a canister.

Nuclide [a]	**Inventory per Assembly (Ci)** [b]	**Number of Assemblies**	**Release Fraction** [c]	**Release (Ci)**	**Eff DCF** [d] **(mrem/uCi)**	**Inhalation Dose at 500 m for 30 days (rem)**
Hydrogen-3	5.0E2	36	0.15 (gases)	2700	6.40E-2	0.11
Iodine-129	3.6E-2	36	0.15 (gases)	0.1944	1.74E2	0.02
Krypton-85	5.8E3	36	0.15 (gases)	31320	0	0
Cobalt-60	3.3E1	36	1 (crud)	1188	2.19E2	166.51
Strontium-90	6.5E4	36	3E-5 (volatiles)	70	1.3E3	58.24

[28] 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

[29] 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

Nuclide [a]	**Inventory per Assembly (Ci) [b]**	**Number of Assemblies**	**Release Fraction [c]**	**Release (Ci)**	**Eff DCF [d] (mrem/uCi)**	**Inhalation Dose at 500 m for 30 days (rem)**
Ruthenium-106	1.3E4	36	3E-5 (volatiles)	14	4.77E2	4.27
Cesium-134	4.1E4	36	3E-5 (volatiles)	44	4.6E1	1.29
Cesium-137	1.1E5	36	3E-5 (volatiles)	119	3.19E1	2.43
Barium-137m	9.9E4	36	3E-3 (fines)	10692	?	?
Plutonium-241	8.0E4	36	3E-3 (fines)	8640	8.25E3	45,619
Yttrium-90	6.5E4	36	3E-3 (fines)	7020	8.44	37.9
Promethium-147	2.3E4	36	3E-3 (fines)	2484	39.2E1	623
Europium-154	6.2E3	36	3E-3 (fines)	669.6	2.86E2	122.5
Curium-244	1.4E4	36	3E-3 (fines)	1512	2.48E5	239,985
Plutonium-238	6.8E3	36	3E-3 (fines)	734	3.92E5	184,146
Antimony-125	1.9E3	36	3E-3 (fines)	205.2	1.22E1	1.6
Europium-155	1.8E3	36	3E-3 (fines)	194.4	4.14E1	5.15
Americium-241	8.8E2	36	3E-3 (fines)	95.04	4.44E5	27,007
Plutonium-240	4.0E2	36	3E-3 (fines)	43.2	4.29E5	11,861
Plutonium-239	1.8E2	36	3E-3 (fines)	19.44	4.29E5	5337
					Total (rem) At 500 m for 30 days, Inhalation dose	~400,000 rem

a. The list of radionuclides is incomplete and only includes some of the radionuclides typically contributing the most to radiation dose.

b. Inventory per assembly based on Yucca Mountain Supplement 2008, Appendix E at ML081750216. The number of pressurized water reactor assemblies involved was 36 PWR assemblies, at 5 percent enrichment, 80 gigawatt-days/metric ton uranium (GWd/MTU), and decay time of 5 years, per Appendix E of the 2008 YM Supplement.

c. Release fractions based on U.S. NRC, Dry Storage and Transportation of High Burnup Spent Nuclear Fuel, NUREG-2224, November 2020, ML20191A321, Table 3-1, for “accident-fire conditions.” There are many variations in the release fractions used in past radiological release evaluations. (The release fraction for gases (0.3), volatiles (2E-3), fuel fines (2E-3) had been assumed for oxidation release in DOE-RW-0573, Rev. 1, for high burnup fuel.)

d. The effective dose conversion factors (mrem/microcurie) are from 1999 and somewhat out of date, from a Private Fuel Storage analysis, ML010330302. Chi/Q for 500 meters is multiplied by breathing rate, 1.94E-3 (s/m^3) * 3.3E-4 (m^3/s) = 6.4E-7 must be multiplied by the curies inhaled and the effective dose conversion factor.

e. The YM Supplement does not reveal the atmospheric dilution factor used for the 11 mile dose (10,200 meters), nor were the documents cited as source documents actually revealing the atmospheric dilution factor, the Chi/Q for the public dose. (ML-90770783 did not include the public and ML090770554 available online was incomplete.) ML092360330 gives the distance to the public but not the atmospheric dilution factor, which the Department of Energy appears to go to great lengths to avoid revealing. The 2007 Bechtel SAIC report, 000-00C-MGR0-02800-000-00B is not found on NRC's Adams database. Also, according to the YM Supplement, the 95th percentile dose for a noninvolved worker for the canister scenario, Table E-11, is inexplicably lower than the 50th percentile dose. This appears to be an error. But for the 50th percentile dose, no exposure time or dilution factor given, the dose was 0.21 rem. Removing the HEPA filters would yield a 2100 rem dose to the noninvolved worker. The doses to the involved workers or workers deemed close to the canister accident are not given. In any case, a 500 rem dose is acknowledged to kill 50 percent of people in short order and based on the experience of SL-1 emergency responders said to have received 20 rem doses, the other 50 percent are not going to live more than a few years.

The dose from Table 2 is for a person standing in the radiological plume 500 meters from the canister for 30 days. Also, the respirable fraction is assumed to be 1.0, consistent with Department of Energy assumptions for high burnup fuel. [30]

An acute radiation dose exceeding 400 rem is considered lethal. The acutely high doses in Table 1 far exceed 400 rem and this perhaps explains why the NRC refuses to admit that a canister leak of significant size is credible. The U.S. NRC has also been eliminating requirements for canister monitoring and capability for emergency response.

The NRC makes statements that a canister leakage would not exceed regulatory requirements. This sophistry doesn't mention that keeping doses below, say, 25 rem, could require permanent evacuation of residents. There is no discussion of the fact that automobiles and homes are not insured for radiological events.

CONSOLIDATED SO-CALLED INTERIM STORAGE IS NOT A SOLUTION

Consolidated "interim" storage of spent nuclear fuel in some sparsely populated region of the country like New Mexico or southern Texas might appear as progress. The DOE is aggressively seeking communities that can be bribed into accepting the "interim" storage of spent nuclear fuel (and high-level waste) until, it is hoped, perhaps many decades from now, a permanent disposal option can be obtained.

Yet, the spent fuel shipped to so-called "interim" spent fuel storage disposal sites won't be safe to store there for what will be "permanent" storage and there is no permanent disposal facility in view.

Neither the reactor sites producing spent nuclear fuel nor the remote "interim" storage facilities have capability for repair or replacement of damaged or compromised fuel canisters. That means that those canisters may release radionuclides to the environment. The actual airborne release will depend on the fuel and other conditions, but are potentially so large that the

[30] Department of Energy, Yucca Mountain Repository SAR, Docket No. 63-001, DOE/RW-0573, Rev. 1, https://www.nrc.gov/docs/ML0907/ML090700894.pdf Ch 1.6, Page 1.8-18 [286]

NRC won't reveal how large the release may actually be. Also, damaged canisters would also be unsafe to ship to a repository if one became available.

The Department of Energy already needs two spent nuclear fuel (or "high level waste") repositories and it does not have one. If nuclear reactor operation were to make a dent in climate change, the U.S. would need a new spent fuel repository, the original size estimated for the Yucca Mountain Repository, every year.

CRITICALITY AND OTHER SNF STORAGE AND DISPOSAL CONCERNS

The space needed for a repository is also affected by the need to limit the potential for multiple criticalities, should one package go critical. The DOE has found that criticalities are to be expected. 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, without actually credible analysis, used to argue that the probability of criticality occurring in a repository was low. But that is no longer true because the commercial utilities began using higher enrichments in the fuel for their nuclear plant. This fuel is often referred to as "high burn-up fuel" because the fuel can be operated longer in a nuclear reactor.

The Department of Energy has had to admit 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 high-level waste from reprocessing at West Valley. [31] 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.

The disposal of surplus plutonium from weapons production included for disposal at the proposed Yucca Mountain Repository created additional criticality concerns.

[31] Spent nuclear fuel and high-level waste (HLW) resulting from spent nuclear fuel reprocessing are specific types of radioactive waste; however, some documents use the term ***high-level waste*** to mean both the spent nuclear fuel and the waste from spent nuclear fuel reprocessing.

Two scientists from Los Alamos National Laboratory would explain how the plutonium-239 posed a particularly high criticality risk at Yucca Mountain. [32] [33] The Department of Energy had continued to argue that while criticality is possible at Yucca Mountain, it is sufficiently unlikely and of unimportant consequence if it does occur. [34] 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 regulatory requirement to assess or limit the criticality risk after 10,000 years, either at Yucca Mountain or WIPP.**

The history of the proposed Yucca Mountain repository is revealing. The regulations for the proposed Yucca Mountain repository 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 (and the criticality risk), peaking at about 25,000 years after its use in a reactor before starting to decline again.** [35]

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.

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

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

[34] 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.

[35] 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

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 a remote possibility. And finally, there is the requirement to limit the trickle-out to groundwater. 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 so that the contamination from the repository remains below the drinking water standards imposed on the repository.

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. [36] 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 can be 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. [37] [38]

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**

[36] 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."

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

[38] 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.

hydrogen from uranium hydride and resulted in a fire and some self-propelled movement of material. [39]

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."

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. [40]

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. [41] 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. [42] 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.

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[39] 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

[40] 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

[41] 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.

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

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 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/year 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**. [43]

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. [44]

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.

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

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

[44] 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. [45]

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." [46]

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. [47]

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. [48] [49] [50] 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. [51] [52] 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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45 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

46 Ibid.

47 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

48 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

49 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

50 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

51 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

52 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.

In addition to the unsolved technical difficulties and the cost of disposing of the spent fuel and high-level waste are 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. [53]

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. [54] 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.

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

[53] 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

[54] 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

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. [55]

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, [56] 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." [57]

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. [58]

In 2009, the Department of Energy Secretary Steven Chu stated that Yucca Mountain was no longer an option. [59] In 2010, President Obama created the Blue-Ribbon Commission on America's Nuclear Future and the commission issued its report in 2012. [60] The BRC's strategy

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[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 See Appendix A.

[56] 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.

[57] 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

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

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

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

included "**prompt efforts** to develop one or more geologic disposal facilities" and "p**rompt efforts** to develop one or more consolidated interim storage facilities." [61]

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." [62] 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.* [63]

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 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

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

[62] 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

[63] 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.)

researchers for this type of neutron absorber to last for thousands of years, [64] degradation has already been occurring. [65]

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." [66]

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. [67]

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. [68]

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 that gives gibberish saying there's no need to inspect canister internals, unless, of course, there's a safety issue. [69]And forget about opening a welded canister, it would lead to elevated worker

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[64] 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

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

[66] 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

[67] 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

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

[69] 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

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. [70]

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. [71] [72]

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. [73] 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 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, [74] indicating that no method has actually been fully designed or used.

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[70] 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

[71] 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

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

[73] 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/

[74] 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**

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. [75] The easy-breezy EIS assumes away fuel drop events and essentially all accidents. [76] 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." [77] 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. [78]

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.

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

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[75] 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.

[76] 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.

[77] 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

[78] 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

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. [79] 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. [80]

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 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

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

[80] 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.

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. [81] 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.**

Past law makers recognized that these so-called "interim" storage locations would take the heat off of finding solutions for permanent waste disposal and they placed limits on the amount of waste that could be placed in interim storage.

The Department of Energy wants to remove these limits and store unlimited amounts of spent fuel at these above ground parking lot dumps called Consolidated Interim Storage.

No agreement with the Department of Energy and no temporary license from the U.S. Nuclear Regulatory Commission will protect Oregon from deteriorating storage of spent nuclear fuel or from deliberate sabotage of SNF storage that endangers citizens of Oregon.

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[81] 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