February 13 and February 20 Public Comment Submittal on Oregon State Legislature, HB 2215 and SB 676, that "Removes requirement that adequate repository for terminal disposition of high-level radioactive waste be licensed as precondition for issuance of site certificate for nuclear-fueled thermal power plant" and "Removes requirement that proposed site certificate for nuclear-fueled thermal power plant be submitted to electors of this state for approval or rejection"

Comment submittal by Tami Thatcher, February 20, 2023 to the link at https://olis.oregonlegislature.gov/liz/2023R1/Testimony/HCEE?meetingDate=2023-02-13-15-00

February 20, 2023 Written Comment Submittal

My name is Tami Thatcher. I have experience as an Advisory Engineer at a Department of Energy nuclear reactor facility in safety and risk assessment. For about the last ten years, I have studied and written about nuclear issues for the Environmental Defense Institute.

The NuScale "small modular reactors" would place twelve reactors in a 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 reactor," 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 with 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 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.

The criticality risks for spent fuel canisters now accepted by the NRC are now far higher than in the past, due to higher enrichments of the fuel. This also adds to dry storage and transportation risks as well as disposal difficulty.

Nuclear industry promotors are good at providing biased and incomplete information. Oregon legislators need to understand the history and the truth of the overly optimistic claims made by the nuclear promotors, by NuScale and others. Government leaders are often easily misled to believe the claims of affordability and safety by nuclear promotors and rarely take the effort to seek the truth.

Oregon needs to prevent more spent nuclear fuel from being produced in Oregon and keep the existing laws in place. 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.

Comments below repeat my February 13 written submittal

BACKGROUND

Although the citizens of Oregon and other states may not know it, the U.S. Department of Energy (DOE) currently has no program for permanent disposal of spent nuclear fuel.

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.

The State of Oregon created responsible laws to prohibit creating more radioactive spent nuclear fuel until a permanent disposal solution was found. Now, nuclear promotors want those sensible laws repealed.

State Legislators in Oregon are foolish to seek to repeal these laws that prevent generation of more spent nuclear fuel.

More states should enact laws like the existing Oregon laws prohibiting generation of more spent nuclear fuel in their state.

NO PERMANENT SPENT FUEL REPOSITORY IS AVAILABLE

Informed citizens would oppose removal of the sensible laws to prevent more generation of spent nuclear fuel in their state. The Department of Energy not only does not have any permanent repository on the horizon, DOE has no permanent disposal program for the spent nuclear fuel.

The Yucca Mountain charade is more than a political problem. Many technical problems were never solved.

Despite an entrance tunnel, the Yucca Mountain repository was never constructed, nor were any supporting facilities constructed. Commercial spent fuel was never put into disposable canisters that the DOE wanted used. Instead, the U.S. Nuclear Regulatory Commission allowed cheaper canisters to be used and no one actually knows how to remove the fuel from these canisters to put the fuel into disposable canisters. The NRC requirements for the canisters included the requirement that the spent fuel be removable. Alas, the canisters now commonly in use, like Holtec thin-walled canisters, have no technology developed to repackage the fuel into canisters that were considered disposable. There is also no technology developed to repair or replace a damaged thin-walled canister like the Holtec canister.

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.

The thin-walled metal canisters that the spent nuclear fuel is being stored in are stainless steel and are known to be susceptible to chloride-induced stress corrosion cracking within a couple decades. There is no way to repair a cracked canister and no way to repackage the fuel into a new canister. The U.S. NRC allowed unsafe canisters to be used for packaging spent nuclear fuel. Only now is the NRC beginning to admit that although the capability of repackaging the spent nuclear fuel was a requirement, that they actually don't have a way to repackage the fuel if defects in the canister are found or if fuel loading errors were made. **Leave the problems to future generations — that is the U.S. Nuclear Regulatory Commission's and the Department of Energy's approach.**

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.

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. [1]

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. [2] 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

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[1] 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

[2] 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

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 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. [3]

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 [4] (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

[3] 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

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

years after its use in a reactor before starting to decline again. [5] 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 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." [6]

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[5] 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

[6] 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

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." [7]

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 [8] and our comments regarding Holtec and Interim Storage Partners proposed interim storage facilities. [9] [10] 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."

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." [11] 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. [12]

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."

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[7] 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

[8] 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

[9] 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

[10] 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

[11] 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

[12] 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

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 1 below. The estimated inhalation dose may be based on out-of-date dose conversion factors.

Table 1. 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
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

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)
					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 1 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. [13]

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

[13] 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]

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 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 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.

THE ACTUAL COSTS OF OBTAINING A PERMANENT REPOSITORY HAVE NOT BEEN ESTIMATED

The truth about the difficulties in obtaining a permanent repository for spent nuclear fuel (also called high-level waste that is a term sometimes used to mean both spent nuclear fuel and the radioactive waste from reprocessing of spent nuclear fuel) need to be understood. The technical difficulties of confining the radioactive material have not been solved for the millennia that the radionuclides remain toxic and can migrate to air, water and soil.

The issue of spent fuel storage and disposal costs. The issues must include, in addition to the history of trying to obtain a repository, including the technical issues and the use of fraud and technically indefensible models, **the issue of cost must be addressed.** While cost may be difficult to pin down, a realistic perspective on the enormous unfunded costs of one or two repositories, the costs of repackaging fuel for disposal, the cost of transportation from reactor sites to interim storage, the costs of transportation (and repackaging) from the interim storage facility to a repository, the costs of transportation infrastructure upgrades, and the cost of a

severe accident during storage and during transportation or at the interim storage site need to be presented. The annual costs of continued storage will be paid for by the U.S. tax payer, at Department of Energy sites like the Idaho National Laboratory for DOE research spent nuclear fuel and for commercial nuclear spent fuel as utilities sue the Department of Energy for those costs. And the multi-billion-dollar costs of repackaging the spent nuclear fuel as the containers corrode is not something the U.S. Nuclear Regulatory Commission nor the Department of Energy want citizens to think about. Consent-based siting must present a realistic perspective of the costs beyond the costs of constructing a nuclear power plant and beyond the costs of constructing an interim storage facility.

Citizen must be told the truth about enormous financial costs of trying to obtain one or two repositories and/or of perpetual repackaging of spent nuclear fuel.

THE LONGEVITY OF THE RADIONUCLIDES IN SPENT NUCLEAR FUEL IS HARD TO FATHOM

The longevity of the radioactive waste is hard to fathom, and even nuclear professionals often do not realize how long the radioactive waste in spent nuclear fuel (and high-level waste) remain radioactive. While certain fission products like cesium-137 and strontium-90 each have a roughly 30-year radioactive half-life, and their presence is greatly diminished in 500 years, other radionuclides in spent nuclear fuel remain radioactive for thousands and over hundreds of thousands of years. The radioactive decay of some decay series actually make the waste more radioactive over time. The waste is still highly radiotoxic for a million years even though the decay heat generated at that time is far less than when the fuel was removed from a nuclear reactor.

The Department of Energy's Performance Assessment for disposal of radioactive waste not being exhumed from the Idaho National Laboratory's Radioactive Waste Complex after the CERCLA so-called "cleanup" has been conducted focused on the first 1000 years and didn't concern itself at all with performance after 10,000 years despite the peak radioactivity occurring after 10,000 years.

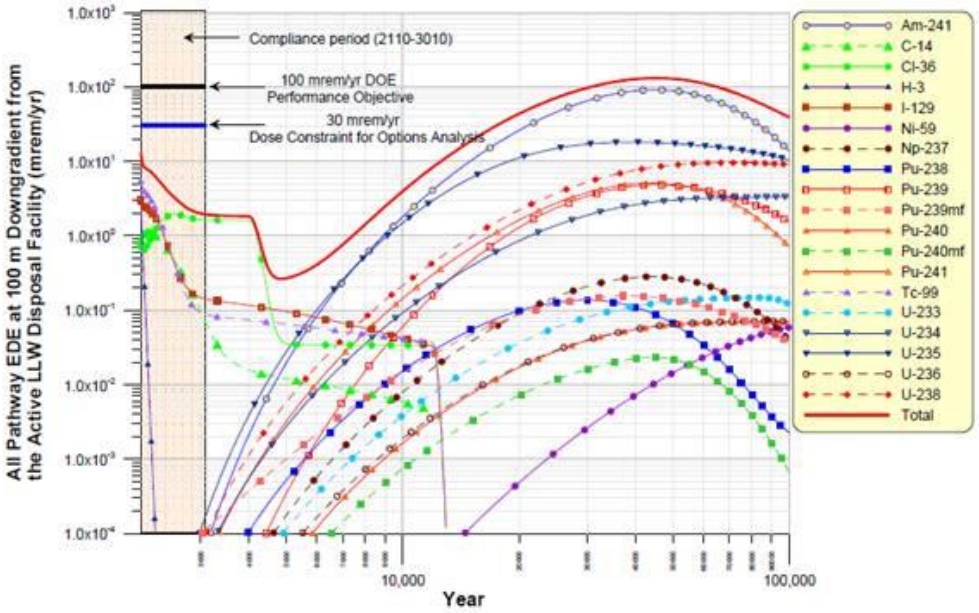

Figure 4-2. All-pathways effective dose equivalent 100 m downgradient from the Radioactive Waste Management Complex boundary from year 2110 to year 100,000 with cover infiltration rate equal to 1 cm/year.

The Department of Energy likes to emphasize the short-lived radionuclides that decay away within at least a few hundred years. But, the DOE does not like to discuss the long-lived but very harmful to health when inhaled or ingested, long-lived radionuclides, that are shown in the Figure above.

Downgradient of INL, the migrating buried waste will reach 100 mrem/yr unless the soil cap performance is perfect for millennia. But that is based on contrived modeling of soil "sorbing" factors that slow the migration of the waste into the aquifer and contrived mixing that maximizes dilution. [14] The DOE's report summarizing the "forever contamination" at RWMC was never disclosed to the public prior to EDI's freedom of information act request. [15] The figure above, from the DOE's report showing the rising radiation doses largely from migration of

[14] See that the publicly available administrative record for RWMC cleanup does not contain the assessment of radionuclide migration and radioactive doses after 10,000 years. The pre-10,000-year contaminant migration is artificially suppressed for the first 10,000 years and then rapidly escalates and stays elevated for hundreds of thousands of years. See the Administrative Record at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) documents for documents associated with this cleanup action, including "Record of Decision" documents and EPA mandated Five-year Reviews at http://ar.inel.gov or http://ar.icp.doe.gov

[15] U.S. Department of Energy, 2008. Composite Analysis for the RWMC Active Low-Level Waste Disposal Facility at the Idaho National Laboratory Site. DOE/NE-ID-11244. Idaho National Laboratory, Idaho Falls, ID and U.S. Department of Energy, 2007. Performance Assessment for the RWMC Active Low-Level Waste Disposal Facility at the Idaho National Laboratory Site. DOE/NE-ID-11243. Idaho National Laboratory, Idaho Falls, ID. Available at INL's DOE-ID Public Reading room electronic collection. See https://www.inl.gov/about-inl/general-information/doe-public-reading-room/

contaminants to the aquifer is shown in the figure below depicting the 100 mrem/yr case without credit for the soil cap slowing migration of contaminants to the aquifer.

The main point I'm trying to make is the time scale on the figure above, which gives the reader some important perspective on the longevity of radioactive waste that includes plutonium, americium, uranium, technetium-99 and iodine-129. While these radionuclides are easily shielded, once they are released to air or water, they are toxic when inhaled or ingested.

Neither the Department of Energy nor the Nuclear Regulatory Commission can be trusted. Even the National Academy of Sciences has often made sure that its oversight panels were overstocked with industry promotors to the degree that their information is biased and inadequate. The recent panel for removing a portion of the Hanford tank waste comes to mind and how ignorant they were of the actual DOE regulations and manuals and how these worked in practice. The recent National Academy of Sciences report,[16] despite its highly educated membership, incorrectly states that the term "low-activity waste" has been defined by the Department of Energy in the current version of DOE Manual 435.1 when actually there is no definition for low-activity waste.

The degree to which DOE's regulations can be exempted on whim or modified on whim did not appear to be understood by that NAS team or by the U.S. Government Accountability Office (GAO). The GAO has misinformed our Congress about various aspects of the radioactive tank waste at DOE facilities. [17] Something like a National Academy of Sciences panel is needed but not one whose composition is driven by the nuclear industry. The Blue Ribbon Panel of the past provided a useful compilation of the status of things, but really nothing more than a faith-based belief that a repository would be found and all that was needed was to gently conjure a willing community to host "interim" storage of nuclear waste.

The U.S. Environmental Protection Agency has a times been considered more reliable than the Department of Energy; however, the EPA has been infiltrated with the influence of the Department of Energy. This is clear as the EPA has allowed inadequate regulations for disposal of waste when under DOE pressure and when the EPA basically agrees to anything DOE wants during federal so-called "cleanup" projects under CERCLA. Monitoring of waste burial sites for CERCLA at INL has often been inadequate and biased to hide contamination findings by reduced monitoring and reduced reporting. Spotty monitoring of land and the aquifer means "no discernable trend could be found." The EPA is more of a lap poodle than a watch-dog.

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[16] National Academies of Sciences, Engineering, and Medicine 2020. *Final Review of the Study on Supplemental Treatment Approaches of Low-Activity Waste at the Hanford Nuclear Reservation: Review #4*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25710. Access to free PDF downloads is available currently.

[17] Government Accountability Office, Hanford Cleanup – DOE's Efforts to Close Tank Farms Would Benefit from Clearer Legal Authorities and Communication, GAO-21-73, January 2021 at www.gao.gov (See page 29.)

The DOE has also conducted numerous public comment opportunities on efforts at "consent-based" spent nuclear fuel storage, only to refuse to publish those public comments such as the consent-based interim spent nuclear fuel storage meetings conducted a few years ago. [18] [19]

Complete and truthful information about the difficulty and costs associated with obtaining one or two or more permanent repositories is needed and lacking. Complete and truthful information about the adverse health impacts from radiation in addition to cancer mortality is also lacking.

Nearly all universities are seeking funding from the nuclear industry, including the Department of Energy and the Department of Defense and therefore, most universities are not an unbiased resource for information on nuclear issues. To the contrary, anyone not willing to coverup nuclear industry problems is weeded out.

I have for years watched the Department of Energy minimize, ignore, lie, and coverup problems all while pretending to provide accurate information. I have also watched the U.S. Geological Survey do the same, in order to coverup Department of Energy contamination.

The nuclear industry does not just coverup its fraud, its high accident risk and its high costs, it covers over the actual human health harm from radiation exposure. While increased cancer risks are acknowledged, the full range of adverse impacts are usually not analyzed or disclosed but have been observed including birth defects, infertility, heart disease, and reduced immune system functioning.

The nuclear industry systematically refuses to conduct meaningful epidemiology in the U.S. The problem of obtaining truthful information about the nuclear-related issues is immense. Meaningful consent-based process is not possible without truthful and complete information. Voters are given propaganda that dismisses the past problems, the current problems and the immense problems that will burden future generations.

In Idaho, the Department of Energy has been aggressively spreading propaganda and disinformation at the Idaho National Laboratory, the associated Citizens Advisory Board and the Idaho Leadership in Nuclear Energy Commission.

The DOE-funded Idaho National Laboratory hosted propaganda meetings to spread lies about the Chernobyl accident. DOE knows how to conduct propaganda meetings, but DOE does not know how to tell the truth about the issues and problems. Not even at a Nuclear Waste Technical Review Board meeting does the DOE tell the truth. There needs to be some accountability for the lies DOE tells, but really, there is not. Until there is some accountability for the continuing lies, there is no reason to expect anything to change.

U.S. Government Accountability (GAO) reports are, unfortunately, typically biased to promote Department of Energy and the nuclear industry propaganda. And the U.S. Congress is not equipped to see the deceptive information and challenge it.

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[18] Before ending the consent-based siting effort, information found about the Department of Energy's consent-based siting at www.energy.gov/consentbasedsiting and its Integrated Waste Management and Consent-based Siting booklet at http://energy.gov/ne/downloads/integrated-waste-management-and-consent-based-siting-booklet

[19] Environmental Defense Institute's comment submittal on the Consent-based Approach for Siting Storage for the nation's Nuclear Waste, July 31, 2016. http://www.environmental-defense-institute.org/publications/EDIXConsentFinal.pdf

TRANSPORTATION COSTS AND RISKS

The issue of uncompensated or inadequately compensated accidents, including transportation accidents. The NRC's unrealistically low-balled transportation accident severity for a transportation accident is inadequate for the varieties of untested casks and the range of transportation risks, including sabotage. The NRC's assurances of safety during spent fuel storage are also bogus and rely on either evacuation or grossly inadequate radiological monitoring if something goes wrong.

As a country, in the U.S. we have not found the money to keep up with normal and expected repair of our crumbling roads, railways and bridges. Bridge and railway accidents have increased during the last twenty years, as has the severity of fires involved with railway transport of oil.

Yet the nuclear promotors want to greatly increase the transportation of nuclear waste and in larger and heavier containers. The Price Anderson Act does not compensate citizens for radiological releases from transportation accidents that may result in contaminated homes, property, businesses and shortened life spans and disease. The radiological contamination could be severe, despite assertions and active government-sponsored propaganda campaigns to the contrary.

The costs of contaminated land and ruined industries such as farming or potash mining near the consolidated storage facility must be addressed.

The issue of inadequate emergency response. Not only was the emergency response to the Department of Energy WIPP accidents inadequate in 2014, and the Department of Energy plutonium inhalation event at INL in 2011, it was inadequate at the Idaho National Laboratory's Radioactive Waste Management Complex in 2018 when, due to deliberate actions to ignore the known contents of waste drums, four waste drums forcefully expelled their powdery contents within a fabric enclosure. At this Department of Energy laboratory, the fire department responded to the event due to activation of a fire alarm and the fire department had no idea a radiological event had occurred. The radiation constant air monitors did not alarm and the facility had no available radiological support with knowledge of what might have happened in the facility and had no radiological support staff with self-contained breathing apparatus training – because it was assumed that no matter the unreasonable risks they were taking, there would not be an event.

Citizens need to understand how the lack of proper decontamination facilities means that a serious radiological release from a spent fuel canister is going to radiologically contaminate medical facilities in their community.

INADEQUATE RADIOLOGICAL MONITORING

The issue of inadequate routine or accident radiological monitoring. The history of unreliable and inadequate radiological monitoring programs having anything to do with the NRC or the Department of Energy should also be discussed. In the few locations with U.S. Environmental Protection Agency radiological monitoring, they rely on DOE's contractors to provide sample data and data blackouts are common when radiological emissions are elevated.

The Department of Energy's environmental monitoring programs are often wrong about the source of contamination as in southeast Idaho they attribute elevated levels of airborne americium-241 to past nuclear weapons testing when in fact it is due to ongoing INL radiological emissions. There is no independent oversight and no error reporting or review of the DOE's highly biased and inadequate environmental monitoring program, see idahoeser.com.

The DOE's environmental monitoring contractor routinely does not provide quarterly monitoring reports, incorrectly attributes INL radiological releases to historical weapons testing, fails to provide trending information, and fails to explain the large gaps in data availability. There is no independent or honest assessment and oversight of the lapses common to the DOE's environmental monitoring program.

Communities and citizens who care about their health, the health of their children and spouses, the health of future generations, need complete and accurate information about the costs, accidents risks, and adverse health effects of radiation exposure. Chronic radiation exposure in southeast Idaho from continuing radiological airborne releases have caused every county surrounding the INL to have roughly double the incidence of thyroid cancer compared to the rest of the state and the country. This has been the case for many years. The stated estimated annual doses from airborne releases are said to be a fraction of a millirem, effective whole body and are said to be less than background radiation levels. **Despite what the DOE says, the thyroid dose from the airborne emissions is above natural background.**

And the DOE and the State of Idaho have ignored the increased thyroid cancer incidence. This is just one example of DOE lying to the public about the human health risk. The DOE has lied to its radiation workers for decades and continues to lie to them about their radiation exposures and the health risks. Most people do not understand how similar the DOE's accepted radiation protection policies are based on "tobacco science."

The radiation health standards which are based on the one-time exposure of the World War II atomic bombings of Japan really do not reflect the full reality of living with chronic radiation exposure from contaminated air, soil, water and food. Even the Secretary of the International Commission on Radiological Protection admitted, before resigning, that the modeling **of internal dose (from inhalation or ingestion) underestimated the harm at least 100-fold.**

PLACING THE BURDEN ON FUTURE GENERATIONS IS IMMORAL

The Department of Energy (along with the U.S. Nuclear Regulatory Commission) appear to accept the approach that they are placing the financial burden and the health risks over millennia on future generations. Placing this burden on future generations and threatening the health of humans and all creatures for millennia is immoral and unacceptable. If the Department of Energy had any inclination to care about humans and all life on this planet, it would not be seeking to maximize the creation of more radioactive waste that it does not know how to isolate over millennia. The DOE also would not have delayed real solutions for climate change when those solutions were non-nuclear.

The DOE and NRC should not look upon less densely populated regions as regions that they can radioactively contaminate. My grandparents were part of the "low population zone" in Idaho that the DOE and NRC systematically dismiss at worthy of concern. The attitude that radiation

doses to less- densely populated areas are more acceptable is an injustice to people living in farming and ranching areas and other less populated areas.

I have seen State and local officials in Idaho who have virtually no comprehension of the problems with nuclear energy and radioactive waste be easily swayed by the DOE and people in the nuclear industry.

The ease with which the DOE misinforms these officials is frightening and I have witnessed it. The officials rarely question what DOE says, and when they do ask a question, they usually accept the insufficient explanations that are offered.

All too often, State and local officials (like the Mayor of Idaho Falls) place their trust in "officialdom" and do not question the incorrect and incomplete information they are carefully spoon fed by the Department of Energy. Then there are bribes to these officials from people hoping to profit from nuclear facilities. An informed public is vital to survival of the human species, as it is all too easy to bribe government officials at every level.

"Interim" storage is likely to cause serious contamination as the facilities fall into ruin over time, whether consolidated or left where the nuclear reactor operated.

Successful siting of federal consolidated interim storage facilities would not be needed if disposal facilities existed. Already, two repositories the size of the proposed Yucca Mountain repository are needed. Successful siting of an interim storage facility requires timely obtaining a permanent repository and being able to ship the waste from the interim storage site to the permanent repository. The spent fuel canisters at an interim storage facility may not be in the condition to allow the canisters to be safety transported. And the interim storage facilities, all of them that are currently planned, do not have the capability of repackaging the canisters, if needed due to damage, due to transportation requirements or due to disposal repository requirements.

Because there will be no disposal facility to send the spent fuel to, the design life of the interim storage facility is very likely to be significantly exceeded. Even before the design life of the interim storage facility is exceeded, spent fuel canisters can be expected to develop through-wall cracking. The through-wall cracking consequences are sure to release radioactive gases and perhaps also result in hydrogen explosions or criticalities. There is no existing capability to isolate a canister, repair a canister, or repackage the fuel into another canister. Even if "interim" storage is not "forever," it is very likely to be beyond the time that the spent fuel can be stored safely. The radiological releases may require evacuation of homes and property, perhaps permanently. This is part of the reason some spent fuel storage locations near the reactor power plants that used the fuel want this fuel out of their community. There are also terrorism threats. Some locations where the spent nuclear fuel is stored, such as on the Pacific coastline, are extremely unsafe. Why did the U.S. Nuclear Regulatory Commission approve such unsafe locations for spent fuel storage? Makes you wonder about the licensing approval effectiveness of the NRC, which is likely to easily grant a license for interim storage of spent fuel no matter how unsafe over the time that spent fuel will be stuck there.

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. [20] 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.

Two scientists from Los Alamos National Laboratory would explain how the plutonium-239 posed a particularly high criticality risk at Yucca Mountain. [21] [22] 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. [23] 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**

[20] 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.

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

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

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

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

The 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.** [24]

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

In reality, which is not where DOE spin-doctors live, there needs to be space to allow thermal heat removal to limit the heat buildup and limit the temperatures in the repository. Next, there is the need to design a container to keep a single container from going critical and this can limit the fuel assemblies that can go in a container. Then the fuel must be spaced to prevent multiple containers from going critical if one goes critical, which is not 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

[24] 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

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. [25] 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. [26] [27]

For some idea of how uranium behaves, consider that uranium in a 30-gallon inner drum inside a barrel, disposed of at the Idaho National Laboratory from the Rocky Flats weapons plant, upon excavation, ignited and material was forceable expelled, hitting the cab of the excavator. Oxygen introduced to the inner drum caused **rapid oxidation that released hydrogen from uranium hydride** and resulted in a fire and some self-propelled movement of material. [28]

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

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

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

[27] 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.

[28] 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

canisters (or 140,000 metric tons heavy metal) of spent nuclear fuel needing disposal, and a significant portion of them would be capable of going critical if water ingress occurs. [29]

The 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. [30] 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. [31] The Department of Energy's rapidly evolving waste emplacement concepts continued to evolve as every assumption about how the repository would contain the waste didn't hold up. No utility has packaged its spent nuclear fuel into DOE's recommended "transport, aging and disposal" TAD canister. The Yucca Mountain repository concept also relies on never designed titanium drip shields that no one honestly believes are feasible to install decades after the waste is emplaced.

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

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

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

[30] 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.

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

water contamination from the trickle out of radionuclides found that the Sandia models were technically indefensible. [32]

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. [33]

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 somewhere between $25 billion and $2 trillion dollars, so there was no way to determine the adequacy of the fees paid. [34]

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." [35]

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. [36]

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

[33] 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

[34] 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

[35] Ibid.

[36] 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

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. [37] [38] [39] 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. [40] [41] 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.

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

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[37] 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

[38] 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

[39] 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

[40] 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

[41] 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.

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. [42]

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. [43] 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 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. [44]

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, [45] but those that can, are referred to a dual-storage-canisters, meaning they can be stored in place and also transported.

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[42] 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

[43] 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

[44] 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.

[45] 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

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." [46]

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. [47]

In 2009, the Department of Energy Secretary Steven Chu stated that Yucca Mountain was no longer an option. [48] In 2010, President Obama created the Blue-Ribbon Commission on America's Nuclear Future and the commission issued its report in 2012. [49] The BRC's strategy included "**prompt efforts** to develop one or more geologic disposal facilities" and "p**rompt efforts** to develop one or more consolidated interim storage facilities." [50]

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." [51] And the trickle out of radionuclides from the dissolving

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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.

[46] 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

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

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

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

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

[51] 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

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.* [52]

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 researchers for this type of neutron absorber to last for thousands of years, [53] degradation has already been occurring. [54]

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." [55]

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,

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[52] 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.)

[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. See page 4-1. https://www.energy.gov/sites/prod/files/2014/10/f19/7FCRDUFD2014000069R1%20DPC%20DirectDispFeasibility.pdf

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

[55] 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

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. [56]

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. [57]

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. [58]And forget about opening a welded canister, it would lead to elevated worker radiation exposures. The full extent of the inability to open a spent fuel canister of higher enriched fuel with a potentially degraded neutron absorber in the canister internals isn't really fessed up to.

But the Department of Energy has now for some years investigated the direct disposal of these canisters, rather than remove the fuel from the canisters and repackage them into the more corrosion resistant TAD as stated in Yucca Mountain's license application to the NRC. [59]

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.

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[56] 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

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

[58] 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

[59] 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

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. [60] [61]

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. [62] 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, [63] indicating that no method has actually been fully designed or used.

And what about the dry transfer system designed for the Idaho National Laboratory that remains to be built? The environmental impact statement (EIS) for the proposed Idaho Spent Nuclear Fuel Facility addressed the need to repackage only very specific Department of Energy spent nuclear fuel: high-temperature gas-cooled Peach Bottom reactor fuel, light-water breeder reactor Shippingport fuel, and research TRIGA fuel. [64] The easy-breezy EIS assumes away fuel drop events and essentially all accidents. [65] 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.

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[60] 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

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

[62] 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/

[63] 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**

[64] 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.

[65] 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.

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." [66] 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. [67]

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 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. [68] 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,

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[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] 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

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

the issue did not affect the PFS licensing approval or the environmental impact statement for PFS. [69]

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 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. [70] 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.

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[69] 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.

[70] 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

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.

RADIATION PROTECTION STANDARDS ARE NOT PROTECTIVE

The Department of Energy's and the nuclear industry's radiation protection standards are not protective of human health. But the nuclear industry knows that tightening the radiation protection standards to lower the allowable dose to workers or the public will increase costs.

Often radionuclides with low curie levels dominate the harm to human health from radioactive waste disposal. So, when DOE states an overall curie level without stating which radionuclides and their specific curie levels, neither the radiotoxicity nor the longevity of the radioactive waste has been indicated.

As far back as 1977, the U.S. Environmental Protection Agency recognized that continued exposure over substantial portions of a lifetime near 100 mrem per year should be avoided, read more in the TENORM report. [71] In 1977, it was assumed by the ICRP that the risk of fatal cancers was 0.0001 per rem (or 1.0E-5 per millisievert in SI units). Various radiation regulations were based on this assumption. It was recognized by 1994 that the fatal cancer risk was higher, at 0.0005 per rem. Even the ICRP currently recognizes that the fatal cancer risk from ionizing radiation is now at least 0.0006 per rem. Independent experts such as John W. Gofman, M.D., have long recognized that the fatal cancer risk was higher than 0.0001 fatal cancers per rem.

[71] National Research Council, Committee on Evaluation of EPA Guidelines for Exposure to Naturally Occurring Radioactive Materials. Evaluation of Guidelines to Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials. Washington DC, National Academies Press, 1999. See page 108. https://www.nap.edu/catalog/6360/evaluation-of-guidelines-for-exposures-to-technologically-enhanced-naturally-occurring-radioactive-materials and chapters at https://www.nap.edu/catalog/6360/evaluation-of-guidelines-for-exposures-to-technologically-enhanced-naturally-occurring-radioactive-materials#toc

In 1990, John W. Gofman's review of the atomic bomb effects on Japanese survivors predicted 0.0026 fatal cancers per rem, [72] which is over 4 times higher than the current Department of Energy fatal cancers per rem value of 0.0006. But even Gofman's prediction would underestimate the cancer risk from internal radiation, such as the iodine-129, strontium-90, cesium-137, americium-241, plutonium-239, and others, which make up most of the radiation dose from ongoing Idaho National Laboratory airborne radiological releases.

Although not always delineated as "effective" whole-body radiation doses, the dose estimates in millirem (mrem) that are provided by the Department of Energy and the Nuclear Regulatory Commission (NRC) are given only in "effective" whole-body dose.

It is vital for the public and community leaders to understand the distortion of "Effective Whole-Body Doses" in millirem, which are the typical focus of routine emissions, disposal facility performance, transportation accidents or other accidents involving nuclear materials. The Department of Energy and the NRC often did not consider organ doses which may far exceed the levels from natural background.

The non-physical concept of "effective" whole body doses does not provide meaningful doses for estimating fatal cancer risk because the organ absorbed doses are unstated. In addition, the basis for assigning importance of various organs or tissues to the contribution to cancer mortality is based primarily on the external gamma dose received by survivors of the 1946 atomic bombing of Japan and it tells nothing about the cancer risks when radionuclides are inhaled or ingested and incorporated into the body. Cesium-137 mimics potassium, strontium-90 mimics calcium, plutonium-239 mimics iron, etc.

Even with accounting for the clearance of the radionuclide from the body and accounting for the tendency for the radionuclide to accumulate in certain organs such as the thyroid or in bone tissue — the harm from internal radiation is greater than from external radiation and is not accounted for by the nuclear industry's International Committee on Radiological Protection (ICRP) models because of their reliance on reviewing the radiation harm from external radiation.

The members of the ICRP are mainly nuclear weapons industry-funded folks who don't actually understand human biology. Anyone not sticking to the nuclear industry agenda would be booted out, sooner or later. The ICRP has no responsibilities to protect human health what-so-ever.

An "effective" dose in rem builds into the rem estimate various multipliers that lower the rem value based on nuclear promotor's opinions of the cancer mortality effect of radiation to various parts of your body. And this is in addition to the multipliers regarding the type of radiation, the *equivalent* dose, that increase the dose from alpha radiation and neutron exposure over that of gamma exposure.

The "effective" rem dose is lowered before the ICRP's low-balled cancer mortality rate is even applied. Effective whole-body dose in rem (or millirem which is one thousandth of a rem)

[72] John W. Gofman, M.D., Ph.D., Committee for Nuclear Responsibility, Inc., "Radiation-Induced Cancer from Low-Dose Exposure: An Independent Analysis," 1990. See more in the August 2021 Environmental Defense Institute newsletter.

starts off with an estimate of absorbed dose but then keeps reducing and further reducing the estimated dose on the basis on ICRP opinion of the likelihood of that organ to cause cancer mortality based on external exposure. Then ICRP sums the reduced organ doses, again weights the organs to reduce their importance and thus the black box spits out an "effective" whole body dose.

This method for estimating the effective whole-body dose had actually originally been called **the doubly-weighted organ doses model** or construct, according to a 2017 article by Fisher and Fahey on *Appropriate Use of Effective Dose in Radiation Protection and Risk Assessment*. [73] For additional information about how misleading the "effective dose" is, read *Burdens of Proof* by Tim Connor, Energy Research Foundation, 1997 regarding the multiple failures to attribute Hanford radiological releases to the thyroid cancers in the region.

The Department of Energy embraces only the effective whole-body dose while ignoring the far higher organ doses, such as the absorbed dose to the thyroid from of iodine-131, iodine-129, americium-241 and other radionuclides.

The Department of Energy tries to tell people they really don't need a healthy thyroid because people don't often die of thyroid cancer. But a healthy thyroid is very important to the developing fetus/embryo in utero.

In Idaho, the rates of cancer for children continue to be elevated, especially in counties surrounding the Idaho National Laboratory. The incidence of thyroid cancer is double in the counties surrounding the INL and double that of all other counties in Idaho and double the rates for the country from the SEER database. This is a consistent result over a decade. As thyroid cancer incidence was climbing everywhere, is has been consistently double in the counties surrounding the INL.

In Idaho, the Department of Energy, while accepting lower tabulated radiation doses and focusing on whole-body doses exclusively, has remained silent on the increased thyroid cancer incidence rates from various alpha emitters, and especially americium-241. Due to the low tissue weighting value, whole body dose estimates are not affected much by the elevated thyroid doses.

Bonneville County, where Idaho Falls is located, has double the thyroid cancer rate of the US and double the rate compared to the rest of Idaho, based on the Cancer Data Registry of Idaho (CDRI) for the year 2017. [74] See Table 2.

Table 2. Bonneville County thyroid cancer incidence rate compared to the rest of Idaho, 2017.

[73] Darrell R. Fisher and Frederic H. Fahey, *Health Phys*., "Appropriate Use of Effective Dose in Radiation Protection and Risk Assessment," August 2017, PMID: 28658055 and https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5878049/

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

Cancer type	Sex	Rate in Bonneville County	Adjusted Rate in Bonneville County	Rate for remainder of Idaho
Thyroid	Total	28.2	30.7	14.2
	Male	16.0	17.8	7.4
	Female	40.3	43.5	21.0

Table notes: Rates are expressed as the number of cases per 100,000 persons per year (person-years). Rates are expressed as the number of cases per 100,000 persons per year (person-years). Adjusted rates are age and sex-adjusted incidence rates for the county using the remainder of the state as standard. Data from Factsheet for the Cancer Data Registry of Idaho, Idaho Hospital Association. Bonneville County Cancer Profile. Cancer Incidence 2013-2017. https://www.idcancer.org/ContentFiles/special/CountyProfiles/BONNEVILLE.pdf

As the SEER 9 region thyroid incidence peaked at 15.7 per 100,000, and the State of Idaho thyroid incidence average was 14.2 per 100,000, Bonneville County reached thyroid cancer rates of 30.9 per 100,000. [75] But other counties near the Idaho National Laboratory also have elevated thyroid cancer incidence rates: Madison (29.3 per 100,000), Fremont (27.9 per 100,000), Jefferson (28.9 per 100,000), and Bingham (28.6 per 100,000). But let's not forget Butte County. Butte county's thyroid cancer rate of 45.9 per 100,000 puts it in a class by itself. Much of Butte County is within 20 miles of the INL and nothing says radiation exposure like Butte's leukemia rate at 3 times the state rate and myeloma at 5 times the state average rate.

The news headline for the Idaho cancer register report issued in 2018 read that "cancer trends for Idaho are stable." [76] That is what citizens were supposed to take away from the 2017 cancer rate study in Idaho. Why were citizens not told about any of the cancers in the counties in Idaho that significantly exceeded state average cancer rates and exceeded the rest of the US? [77]

The rates that are double the rest of Idaho and the US in only counties near the Idaho National Laboratory are, I believe, due to the radiological releases from INL and are perhaps aggravated by airborne chemical releases from the INL.

The Department of Energy and the State of Idaho are actively ignoring the likely environmental causes of elevated rates of cancer in the communities surrounding the INL and especially the elevated rates of childhood cancer.

[75] Environmental Defense Institute February/March 2020 newsletter article "Rate of cancer in Idaho continues to increase, according to Cancer Data Registry of Idaho."

[76] Brennen Kauffman, *The Idaho Falls Post Register*, "New cancer report on 2017 shows stable cancer trends for Idaho," December 13, 2018.

[77] https://statecancerprofiles.cancer.gov/

The forty-first annual report of the Cancer Data Registry of Idaho (CDRI) was issued in December 2019 for the year 2017. [78] While the rate of some cancers decreased, the bad news for the State of Idaho is that the overall rate of cancer incidence continues to increase.

And, very importantly, childhood cancers in Idaho continue to increase. Pediatric (age 1 to 19) cancer increased at a rate of about 0.6 percent per year in Idaho from 1975 to 2017, see https://www.idcancer.org/pediatriccancer.

Before the late 1990s, radiation risks to females were generally treated as roughly equal to the radiation risks to males. But by the late 1990s, studies of the survivors of the atomic bombing of Japan in 1945 by the International Commission on Radiation Protection (ICRP) had higher radiation risk harm to women than men, for the same dose. And the studies showed higher cancer risk to children, especially female children, than to adults for the same dose. The National Research Council BEIR VII report issued in 2006 found even higher risks to women and children. See Institute for Energy and Environmental Research (IEER.org) report, *Science for the Vulnerable*, for additional insight. [79] (Read more in the August 2020 Environmental Defense Newsletter at Environmental-Defense-Institute.org)

DOE actively ignores the current scientific evidence of radiation health harm. The Department of Energy's accepted modeling of health risk from radionuclide emissions (routine or from accidents) actively ignores diverse, compelling human epidemiology. I have been told that the reason is "that somebody high up has decided that the benefit of changing the radiation protection standards isn't worth the cost." This basic description comes from university professors and INL lab directors. Basically, the Department of Energy has decided that protecting your health, or your child's health or protecting human beings in the future from its growing inventory of radioactive waste just isn't worth the cost. It would, after all, increase the cost of nuclear waste disposal and it would require reducing airborne emissions from its facilities.

The Department of Energy has largely thwarted efforts to have epidemiology conducted near the INL.

The NRC cancelled funding of what would have been the first meaningful epidemiology study of health near US nuclear facilities. They claimed it would cost too much (at $8 million) and take too long. [80]

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

[79] Arjun Makhijani, Ph.D., Brice Smith, Ph.D., Michael C. Thorne, Ph.D., Institute for Energy and Environmental Research, *Science for the Vulnerable Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk*, October 19, 2006.

[80] NRC (Nuclear Regulatory Commission) 2010. NRC Asks National Academy of Sciences to Study Cancer Risk in Populations Living near Nuclear Power Facilities. NRC News No. 10-060, 7 April 2010. Washington, DC: NRC. The framework for the study was reported in "Analysis of Cancer Risks in Populations Near Nuclear Facilities; Phase I (2012). See cancer risk study at nap.edu.

The US NRC prefers reliance on the 1980s epidemiology study that mixed children and adults and populations near and far from nuclear plants and predictably found no harm. [81] The NRC actively ignores the irrefutable studies from Germany that found increased cancer and leukemia rates of children living near each of the plants. [82] [83] [84]

The U.S. NRC knows that if people knew the harm of living near nuclear power plants, just from routine radiological emissions, it would be the end of nuclear energy.

The internal radiation cancer harm is not based on solid epidemiological evidence and there are experts from Karl Z. Morgan to Chris Busby to Jack Valentin that understand that the accepted models may understate the cancer harm by a factor of 10, 100 or more. The nuclear industry continues to ignore the epidemiological evidence that implies tighter restrictions are needed. **Jack Valentin, former chair of the International Commission on Radiological Protection (ICRP) has admitted, before resigning from the ICRP, that the ICRP's radiation model underpredicts the harm of internal radiation by over a factor 100.**

The 100 millirem (mrem) per year all pathways radiation dose limit is greatly emphasized by the Department of Energy as the dose they consider allowable. Air permits may be regulated by the U.S. Environmental Protection Agency or by the states, but in either case, the EPA and the state, such as the State of Idaho, will often emphasize that the state cannot regulate Department of Energy radiological emissions. In Idaho, the State of Idaho Department of Environmental Quality will issue an air permit to the Department of Energy based entirely on the DOE's stated radiological release guesses or estimates, the Department of Energy contractors monitoring or lack thereof, and the State will agree to rapid records destruction of radiation monitoring of open-air radioactive waste evaporation ponds that is fully intended to cover up any radiological releases in excess of agreed to quantities.

In the Department of Energy's environmental monitoring reports, it is greatly emphasized that the DOE's derived concentration standards (DCGs) are safe as they imply a dose of 100 mrem per year. By now, you may be starting to understand why 100 mrem per year would actually guarantee a health catastrophe to the health of people, especially children.

Epidemiology that was conducted of INL workers found unexplained elevated levels of certain radiogenic cancers in both radiation and non-radiation workers. The INL-specific study

[81] NCI (National Cancer Institute) 1990. Cancer in Populations Living near Nuclear Facilities. 017-042-00276-1. Washington, DC: Superintendent of Documents, U.S. Government Printing Office.

[82] Kaatsch P, Kaletsch U, Meinert R, Michaelis J.. 1998. An extended study of childhood malignancies in the vicinity of German nuclear power plants. Cancer Causes Control 9(5):529–533.

[83] The study is known by its German acronym KiKK (Kinderkrebs in der Umgebung von Kernkraftwerken): Kaatsch P, Spix C, Schmiedel S, Schulze-Rath R, Mergenthaler A, Blettner M 2008b. Vorhaben StSch 4334: Epidemiologische Studie zu Kinderkrebs in der Umgebung von Kernkraftwerken (KiKK-Studie), Teil 2 (Fall-Kontroll-Studie mit Befragung). Salzgitter: Bundesamt für Strahlenschutz.

[84] Kaatsch P, Spix C, Schulze-Rath R, Schmiedel S, Blettner M.. 2008. . Leukemia in young children living in the vicinity of German nuclear power plants. Int J Cancer 122(4):721–726.

found radiation and nonradiation workers at the Idaho National Laboratory site had higher risk of certain cancers. [85]

The US Nuclear Regulatory Commission and the Department of Energy maintain that their 5 rem/yr worker exposure limit is protective despite compelling scientific evidence to the contrary. [86] Epidemiology of thousands of radiation workers found elevated cancer risk occurring at doses far below the allowable 5000 mrem/yr. [87]

Radiation workers are still wrongly told that there is no evidence of damage to DNA or genetic effects from radiation exposure to humans. DOE's radiation workers are not told of the infertility and increased risk of birth defects from radiation.

The DOE's and the NRC's radiation dose limit for workers in not protective. The community leaders who invite a "interim" spent fuel storage facility to their community need to acknowledge the inadequacy of the 5,000 mrem/yr limit to actually protect adult radiation workers. Also, communities need to know that there are no programs to assist radiation workers who work at NRC-licensed facilities, as the consolidated storage facility would likely be. There is an illness compensation program for certain Department of Energy contractor workers, but this does not apply to NRC-licensed facilities.

Spent nuclear fuel canisters emit high gamma doses and high neutron doses. The harm from neutron dose can be particularly harmful for gonads and may not be adequately monitored, particularly by emergency responders. Neutron dose can be high even if gamma rays are shielded. Neutron dose is difficult to monitor and the biological damage which depends on the neutron energy levels is only guessed at. Neutron shielding in transportation accidents or other configurations may be damaged. Fire or age-related degradation can damage the neutron shielding and so this is primarily an issue for radiation workers and emergency responders. The biological endpoint focus for the Department of Energy is cancer mortality and not the increased harm to reproductive health.

The public as well as radiation workers need to keep in mind that, despite what they may have been taught:

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[85] "An Epidemiology Study of Mortality and Radiation-Related Risk of Cancer Among Workers at the Idaho National Engineering and Environmental Laboratory, a U.S. Department of Energy Facility, January 2005. http://www.cdc.gov/niosh/docs/2005-131/pdfs/2005-131.pdf and http://www.cdc.gov/niosh/oerp/ineel.htm and Savannah River Site Mortality Study, 2007. http: /www.cdc.gov/niosh/oerp/savannah-mortality/

[86] "Health Risks from Exposure to Low Levels of Ionizing Radiation BEIR VII – Phase 2, The National Academies Press, 2006, http://www.nap.edu/catalog.php?record_id=11340 The BEIR VII report reaffirmed the conclusion of the prior report that every exposure to radiation produces a corresponding increase in cancer risk. The BEIR VII report found increased sensitivity to radiation in children and women. Cancer risk incidence figures for solid tumors for women are about double those for men. And the same radiation in the first year of life for boys produces three to four times the cancer risk as exposure between the ages of 20 and 50. Female infants have almost double the risk as male infants.

[87] Richardson, David B., et al., "Risk of cancer from occupational exposure to ionizing radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS), BMJ, v. 351 (October 15, 2015), at http://www.bmj.com/content/351/bmj.h5359 Richardson et al 2015] (And please note that studies of high leukemia risk in radiation workers and of ongoing studies to assess health effects of high and low-linear energy transfer internal radiation must also be studied in addition to this one on external radiation.)

- The cancer risk is not reduced when radiation doses are received in small increments, as the nuclear industry has long assumed. [88]

- Despite the repeated refrain that the harm from doses below 10 rem cannot be discerned, multiple and diverse studies from human epidemiology continue to find elevated cancer risks below 10 rem and from low-dose-rate exposure. [89]

- The adverse health effects of ionizing radiation are not limited to the increased risk of cancer and leukemia. Ionizing radiation is also a contributor to a wide range of chronic illnesses including heart disease and brain or neurological diseases.

The public and radiation workers take cues from their management that they should not be concerned about the tiny and easily shielded beta and alpha particles. DOE-funded fact sheets often spend more verbiage discussing natural sources of radiation than admitting the vast amounts of radioactive waste created by the DOE. The tone and the meta-message from the DOE, the nuclear industry, is that if you are educated about the risks, then you'll understand that the risks are low. Yet, these agencies continue to deny the continuing accumulation of compelling and diverse human epidemiological evidence that the harm of ingesting radionuclides is greater than they've been claiming.

Radiation worker training programs are typically horribly inadequate. In radworker training, there may be discussion of the fact that international radiation worker protection recommends only 2 rem per year, not 5 rem per year. There is no mention of recent human epidemiology showing the harm of radiation is higher than previously thought and at low doses, below 400 mrem annually to adult workers, increased cancer risk occurs. [90]

There is no mention of the oxidative stress caused as ionizing radiation strips electrons off atoms or molecules in the body at energies far exceeding normal biological energy levels. And there is no discussion explaining the harm of inhaling or ingesting radioactive particles of fission products such as cesium-137, strontium-90, or iodine-131; of activation products such as cobalt-60; or transuranics such as plutonium and americium; or of the uranium itself.

The biological harm that ionizing radiation may cause to DNA is mentioned sometimes but it is emphasized that usually the DNA simply are repaired by the body. And the training to radiation workers will mention that fruit flies exposed to radiation passed genetic mutations to

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[88] Richardson, David B., et al., "Risk of cancer from occupational exposure to ionizing radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS), BMJ, v. 351 (October 15, 2015), at http://www.bmj.com/content/351/bmj.h5359 Richardson et al 2015 This cohort study included 308,297 workers in the nuclear industry.

[89] US EPA 2015 http://www.regulations.gov/#!documentDetail;D=NRC-2015-0057-0436 . For important low-dose radiation epidemiology see also John W. Gofman M.D., Ph.D. book and online summary of low dose human epidemiology in "Radiation-Induced Cancer from Low-Dose Exposure: An Independent Analysis," Committee for Nuclear Responsibility, Inc., 1990, http://www.ratical.org/radiation/CNR/RIC/chp21.txt And see EDI's April 2016 newsletter for Ian Goddard's summary and listing of important human epidemiology concerning low dose radiation exposure.

[90] Richardson, David B., et al., "Risk of cancer from occupational exposure to ionizing radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS), BMJ, v. 351 (October 15, 2015), at http://www.bmj.com/content/351/bmj.h5359 Richardson et al 2015 This cohort study included 308,297 workers in the nuclear industry.

their offspring but workers are told that this phenomenon has never been seen in humans even though, sadly, the human evidence of genetic effects has continued to accumulate. Birth defects and children more susceptible to cancer are the result.

Gulf War veterans who inhaled depleted uranium have children with birth defects at much higher-than-normal rate. The same kinds of birth defects also became prevalent in the countries where citizens were exposed to depleted uranium. There are accounts to suggest that the actual number of birth defects resulting from the World War II atomic bombs dropped on Japan and by weapons testing over the Marshall Islands have been underreported. The Department of Energy early on made the decision not to track birth defects resulting from its workers or exposed populations. But people living near Hanford and near Oak Ridge know of increased birth defects in those communities.

The nuclear industry, including the Department of Energy, is wrong to use the International Commission on Radiological Protection (ICRP) treatment of heritable disease. While the ICRP continues to say that "Radiation induced heritable disease has not been demonstrated in human populations," Chis Busby writes that evidence of genetic effects *has* been found in humans and at very low radiation doses. [91] [92]

Robin Whyte wrote in the *British Medical Journal* in 1992 about the effect in neonatal (1 month) mortality and stillbirths in the United States and also in the United Kingdom. The rise in strontium-90 from nuclear weapons testing from 1950 to 1964 has been closely correlated, geographically, with excess fetal and infant deaths. The doses from strontium-90 due to atmospheric nuclear weapons testing were less than 50 millirem (or 0.5 millisievert), according the Chris Busby. Radioactive fallout from atmospheric nuclear weapons testing would not only include strontium-90, it would include iodine-131, tritium, cesium-137, and other radionuclides, including plutonium. [93] The extent of the nuclear weapons testing immorality continues to astound me and I applaud the work being done to reduce the risk of human extinction from nuclear weapons. [94]

The ICRP maintains that human evidence of genetic effects due to radiation does not exist. The ICRP then uses the study of external radiation on mice to estimate the heritable risks for humans. One study was conducted using internal radionuclides on mice and the study noted that

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[91] Chris Busby, *The Ecologist*, "It's not just cancer! Radiation, genomic instability and heritable genetic damage," March 17, 2016. https://theecologist.org/2016/mar/17/its-not-just-cancer-radiation-genomic-instability-and-heritable-genetic-damage

[92] Chris Busby, Scientific Secretary, European Committee on Radiation Risk, Presentation, *Radioactive discharges from the proposed Forsmark nuclear waste disposal project in Sweden and European Law*, September 8, 2017. Online pdf 646_Nacka_TR_M1333-11_Aktbil_646_Christopher_Busby_presentation_170908

[93] R. K. Whyte, *British Medical Journal*, "First day neonatal mortality since 1935: re-examination of the Cross hypothesis," Volume 304, February 8, 1992. https://www.bmj.com/content/bmj/304/6823/343.full.pdf

[94] Jackie Abramian, ForbesWomen, "After Her Nuclear Disaster Dress Rehearsal, Cynthia Lazaroff Has A Wake-Up Call For Our World As We Sleepwalk Into Nuclear Extinction," September 21, 2021. https://www.forbes.com/sites/jackieabramian/2021/09/21/after-her-own-nuclear-disaster-dress-rehearsal-cynthia-lazaroff-has-a-wake-up-call-as-our-world-sleepwalks-into-nuclear-extinction/?sh=6a22151d62e2 Lazaroff has founded NuclearWakeupCall.Earth due to her concern over nuclear weapons. "There are nearly 13,500 nuclear warheads in current arsenals of nine nuclear-armed states. That the U.S. has more nuclear warheads than hospitals should be a wake-up call," says Lazaroff.

"detailed research on internal radiation exposure has hardly ever been reported in the past." [95] **This limited study of microcephaly in mice found that far lower doses of <u>internal radiation</u> caused the same effect as higher doses of <u>external radiation</u>.**

It has been known now for a few decades that radiation exposure to the developing embryo and fetus "can cause growth retardation; embryonic, neonatal, or fetal death; congenital malformations; and functional impairment such as mental retardation." [96]

In 2007, the International Commission of Radiological Protection (ICRP) lowered its estimate of the risk of genetic harm of congenital malformations by 6-fold, from 1.3E-4/rem to 0.2E-4/rem. Based on the belief that the study of the Japanese bomb survivors did not detect genetic effects, **the ICRP genetic effect estimate for humans is based on studies of external radiation of mice.**

The ICRP estimate of risk of congenital malformations is a fraction of its predicted cancer risk for cancer mortality (or latent cancer fatality). The ICRP latent cancer fatality risk was 5.0E-4 LCF/rem (1991 estimate), close to the cancer mortality rate used in the Department of Energy's Versatile Test Reactor EIS of 6.0E-4 LCF/rem. [97]

While the studies of genetic injury to the Japan bombing survivors declared that they found no evidence of genetic damage, other researchers have found those studies to have been highly flawed. A report published in 2016 by Schmitz-Feuerhake, Busby and Pfugbeil summarizes numerous human epidemiology studies of congenital malformations due to radiation exposure. [98]

The 2016 report disputes the ICRP genetic risk estimate and finds that diverse human epidemiological evidence supports a far higher genetic risk for congenital malformations. **Nearly all types of hereditary defects were found at doses as low as 100 mrem.** The pregnancies are less viable at higher doses and so the rate of birth defects appears to stay steady or falls off at doses above 1000 mrem or 1 rem. The 2016 report found the excess relative risk for congenital malformations of 0.5 per 100 mrem at 100 mrem falling to 0.1 per 100 mrem at 1000 mrem.

The 2016 report's result for excess relative risk of congenital malformations of 5.0/rem is 250,000-fold higher than the ICRP estimate of 0.2E-4/rem which ICRP appears to assume has a linear dose response. (See the August 2021 Environmental Defense Institute newsletter.)

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[95] Yukihisa Miyachi, J-STAGE, "Microcephaly Due to Low-dose Intrauterine Radiation Exposure Caused by 33P Beta Administration to Pregnant Mice," 2019 Volume 68 Issue 3 Pages 105-113. https://www.jstage.jst.go.jp/article/radioisotopes/68/3/68_680303/_article/-char/en

[96] Eric J. Hall, *Radiobiology for the Radiologist*, 5th ed., 2000, p. 190.

[97] U.S. Department of Energy's Versatile Test Reactor Draft Environmental Impact Statement (VTR EIS) (DOE/EIS-0542) (Announced December 21, 2020). A copy of the Draft VTR EIS can be downloaded at https://www.energy.gov/nepa or https://www.energy.gov/ne/nuclear-reactor-technologies/versatile-test-reactor. (See discussion in VTR EIS Appendix C, page C-4).

[98] Inge Schmitz-Feurerhake, Christopher Busby, and Sebastian Pflugbeil, *Environmental Health and Toxicology, Genetic radiation risks: a neglected topic in the low dose debate*, January 20, 2016. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4870760/ The 2016 report found the "excess relative risk for congenital malformations of 0.5 per mSv at 1 mSv falling to 0.1 per mSv at 10 mSv exposure and thereafter remaining roughly constant."

In summary, the Department of Energy's dose limits are not protective of radiation workers (5,000 millirem per year) or the public (100 millirem per year).

The community leaders who accept "interim" storage in their communities must explain why 5,000 millirem per year doses to the radiation workers and 100 millirem per year to the public is considered protective.

The community leaders who accept "interim" storage in their communities must explain why DOE continues to base its regulations and decisions on the ICRP recommendations and why it considers the very inadequate ICRP models to be acceptable for the protection of human health.

The bottom line is that the nuclear industry and especially the Department of Energy is grossly underestimating the fatal cancer risk of their radiological releases, and ignoring serious adverse health effects such as cancer incidence, heart disease, reduced immune system function, fertility problems, decreased life span, as well as increased rates of infant death and birth defects And they are also grossly underestimating the risk of genetic effects of ionizing radiation exposure prior to conception that are passed on to their children and grandchildren by relying on ICRP's industry-biased recommendations.

The nuclear industry has a myopic focus on cancer, although cancer is certainly increased by the inhalation or ingestion of radiative particles and/or from "shine" from penetrating radiation. The actual rates of health harm such as infertility, increased birth defects, heart disease, dementia, shortened life span and other adverse health effects are not adequately represented in nuclear industry radiation protection standards, especially for the chronic radiation exposure of far lower radiation doses. It is known that the developing child in utero, children and the elderly are many times more vulnerable to radiation exposure.

The submitter of these comments is Tami Thatcher of Idaho Falls, Idaho. I have a degree in mechanical engineering (BSME) and I worked at the Idaho National Laboratory as a radiation worker and as an advisory engineer and nuclear safety analyst with specialty in nuclear reactor probabilistic risk assessment. I write newsletters for the Environmental Defense Institute of Troy, Idaho which entails studying Idaho National Laboratory nuclear facilities, accidents and cleanup, radiation illness compensation, radiation protection standards, and nuclear waste disposal issues. My comment submissions, including this one, are often on my own time and not funded by Environmental Defense Institute. However, my comment submittals are frequently made available on the Environmental Defense Institute website.