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NuScale's faltering 6-module SMR project at INL to be delayed

NuScale is admitting that the small modular reactor project slated for building a 6-module small modular reactor facility on the Idaho National Laboratory site is encountering difficulties and will be delayed. The project lacks subscribers to its high cost and high-risk venture. NuScale is seeking other projects outside of Idaho.

The cost for building the NuScale US460 small modular reactor UAMPS project near Idaho Falls has increased significantly, but it likely won't be the last cost increase — if the project continues.

Last January, the NuScale cost estimate increased to $89/megawatt-hour (MWh) from $58/MWh. [1] Without extremely generous government subsidies granted to NuScale, the cost would already approach $120/MWh. [2]

Originally, the project was for 12 modules but that was reduced to six 77 megawatt-electric (MWe) modules for a 462 MWe total capacity. Scaling down from 12 modules, the modified project slated at the Idaho National Laboratory is to deploy 6 reactor modules. The proposed power generation has been scaled up from 60 megawatt-electric (MWe) to 77 MWe each, and with all 6 modules operating could generator 462 MWe. The power level scale up for the NuScale US460 design has not been approved by the U.S. Nuclear Regulatory Commission.

Previously the NRC had reviewed the twelve 60 MWe module project, but had not guaranteed that the design was worthy of a construction permit. The U.S. NRC's communications to the Idaho Leadership in Nuclear Energy Commission at its October 2020 meeting[3] and to NuScale in writing regarding the original Standard Design Application for the

[1] David Schlissel, Institute for Energy Economics and Financial Analysis, "Eye-popping new cost estimates released for NuScale small modular reactor," January 11, 2023. https://ieefa.org/resources/eye-popping-new-cost-estimates-released-nuscale-small-modular-reactor

[2] David Schlissel, Institute for Energy Economics and Financial Analysis, "IEEFA U.S.: Small modular reactor 'too late, too expensive, too risky and too uncertain,' " February 2022. https://ieefa.org/articles/ieefa-us-small-modular-reactor-too-late-too-expensive-too-risky-and-too-uncertain

[3] Doug Hunter, CEO and General Manager of Utah Association of Municipal Power Systems (UAMPS), presentation to the Idaho Line Commission CFPP [Carbon Free Power Project] October 14, 2020. https://line.idaho.gov/wp-content/uploads/sites/84/2020/10/2020-1014-cfpp.pdf

12-module 60 MWe reactors stated that "… this SDA [standard design approval] does not constitute a commitment to issue a permit, design certification (DC), or license…." [4] [5]

A list of high impact technical issues yet to be resolved for NuScale's latest US460 Standard Design Approval application for the 6-pack reactor system is at https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/current-licensing-reviews/nuscale-us460.html Among various design changes, three of the issues pertain to the helical coil steam generators and the onset of density wave oscillations (DWO) induced loads.

The novel and untested helical steam generators pose a difficult challenge for the NuScale design. The unreliable performance of these proposed steam generators can cause reactor accidents that allow reactor coolant water to escape reactor containment.[6] The steam generator design is helical as opposed to the typical U-shaped or once-through steam generator tube design. The reliability of the helical steam generator tubes is unknown. The design of the helical coil steam generators is different from the design used in conventional pressurized water reactors because the primary coolant is flows on the outside of the tubes, or the shell side of the steam generator.

Failure of the helical steam generators, even without an accident, could force the premature closure of the project as these steam generators are integral to the reactor modules and may be extremely costly, if not impossible, to repair. [7] [8] Steam generator tube failure could be caused by a rapid propagation of a circumferential crack that leads to a double-ended rupture of the tube. [9]

Based on NuScale's probabilistic risk assessment, accident risk for the NuScale design, despite its natural circulation features, is still heavily influenced by loss of support systems and by operator error. These and other documents for NuScale's latest standard design approval application are at https://www.nrc.gov/docs/ML2233/ML22339A066.html

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[4] U.S. Nuclear Regulatory Commission, Letter from Anna H. Bradford, NRC to Zackary W. Rad, NuScale Power LLC, Subject: Final Safety Evaluation Report for the NuScale Standard Plant Design, August 28, 2020 at https://www.nrc.gov/docs/ML2023/ML20231A804.pdf

[5] U.S. Nuclear Regulatory Commission, Letter from Anna H. Bradford, NRC to Zackary W. Rad, NuScale Power LLC, Subject: Final Safety Evaluation Report for the NuScale Standard Plant Design, September 11, 2020 at https://www.nrc.gov/docs/ML2024/ML20247J564.pdf

[6] NuScale Final Safety Analysis Report, Probabilistic Risk Assessment, Docket No. 52-050, transmittal December 31, 2022 https://www.nrc.gov/docs/ML2236/ML22365A010.html

[7] Environmental Working Group, "Questions for NuScale VOYGR Reactor Certification: When Will It Be Done? And then, Will It Be Safe"," May 2023. Posted on the Institute for Energy and Environmental Research (IEER.org) website. https://ieer.org/resource/reports/questions-for-nuscale-voygr-reactor-certification-when-will-it-be-done-and-then-will-it-be-safe/

[8] Grant Smith and Anthony Lacey, EWG.org, "Small size, big problems: NuScale's troublesome small modular nuclear reactor plan," July 11, 2023. https://www.ewg.org/news-insights/news/2023/07/small-size-big-problems-nuscales-troublesome-small-modular-nuclear

[9] NuScale Final Safety Analysis Report, Chapter 15, Docket No. 52-050, transmittal December 31, 2022. https://www.nrc.gov/docs/ML2236/ML22365A006.html

Also, the spent nuclear fuel from NuScale's reactors will become stranded fuel and will require untold decades of storage and will disproportionately require more space in a repository. for each megawatt produced. [10]

Safety of spent nuclear fuel during long-term dry storage, as well as during transportation, still unknown

For well over a decade, the Department of Energy has been studying the problem of long-term storage of commercial spent nuclear fuel, as well as transportation after storage. The goal is to learn whether or not the spent fuel will maintain its integrity during long-term storage and transportation. They continue to assert that the fuel integrity will be maintained but they still don't have a sound basis for that conclusion.

Just how many years are meant by "long-term" storage isn't known. When spent fuel pools storing spent fuel approached capacity, spent fuel was put into dry storage casks or canisters. Because the Department of Energy was promising commercial nuclear power utilities that it would begin accepting the spent fuel for disposal by 1998, dry storage systems were not designed for the long term.

The spent fuel was not expected to remain in dry storage for more than 20 to 50 years. But there is no repository for the spent fuel and even the most optimistic view would be that obtaining a repository is at least many decades away. The Department of Energy has not had a program to obtain a permanent disposal solution for over a decade.

Spent nuclear fuel and its cladding experience far greater degradation with higher reactor burnups. Higher fuel burnup, such as adding 10 GWd/MTU or more, means greater oxide buildup and greater hydrogen buildup. The increased uranium-235 enrichment and longer burnup increase the fission products and actinide (plutonium) buildup and increase the decay heat. There are other more subtle changes such as increased fuel pellet diameter; increased fuel pellet density; and changes to core operating parameters and other changes. [11]

A conference paper by the Department of Energy in 2019 asserts that "a general assessment can be made that the high burnup fuel can be safely stored for extended periods of time and subsequently transported." [12] Just how long are "extended periods of time"? Inside their own

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[10] Lindsay M. Krall, Allison M. Macfarlane, and Rodney C. Ewing, *PNAS*, "Nuclear waste from small modular reactors," Received June 26, 2021, Published May 31, 2022, https://doi.org/10.1073/pnas.2111833119.

[11] Mark Leyse, 10 CFR 2.206 Request for the U.S. Nuclear Regulatory Commission to Order Licensees to Promptly Transfer All of the Sufficiently-cooled Spent Fuel Assemblies That Are Presently Stored in each of the Spent Fuel Pools at U.S. Nuclear Plants to Dry Cask Storage; The Density of Fuel Assemblies in Pools Must Be Reduced to the Extent That Any Pool's Remaining Assemblies (Provided They Were Properly Configured) Would Not Ignite – Starting a "Zirconium Fire" – If it were to Lose a Significant Portion or all of its Coolant Water, February 28, 2023. ML23061A054.

[12] Ned Larson (Department of Energy), Sylvia Saltzstein (Sandia National Laboratories) and Brady Hanson (Pacific Northwest National Laboratory), "Making the Case: Demonstrating the Integrity of Spent Nuclear Fuel During Long-term Storage and Subsequent Transportation: SAND2019-8749C," PATRAM 2019 Conference. (File a1418_1.pdf)

electronic document was an unresolved comment that highlighted the issue that the duration of extended periods of time may only be decades, but not centuries.

Spent nuclear fuel from a reactor is stored in a storage pool for several years until cooled long enough to be placed in dry storage. There are currently 164,840 spent fuel assemblies loaded in 3,879 dry casks at 93 different dry storage systems. [13] The push for away-from-reactor consolidated storage sites would involve the transportation of spent fuel to the consolidated storage site over long distances, by truck or rail.

Nuclear fuel enrichment has continued to increase and has allowed higher fuel burnup. The higher fuel enrichments and higher burnups increase the challenges of maintaining fuel integrity. The U.S. Nuclear Regulatory Commission has continued granting licenses for the high burnup fuels despite not knowing how these fuels will perform during storage or transportation.

The fuel cladding needs to maintain its integrity until final disposition. No one knows how long, and beyond 100 years, dry storage will be needed. The modeling of the fuel degradation in dry storage had little attention up to now and experimental efforts aimed at studying long time effects like cladding creep or hydrogen behavior are limited. [14]

The Department of Energy initiated a research program to investigate the feasibility of long-term dry storage and subsequent transportation of commercial spent fuel in 2009, states a paper in 2019. [15] Now, in 2023, there are still no answers and very little progress on key issues regarding safety of dry storage of spent nuclear fuel. [16]

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

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

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[13] Ux Consulting, Roswell, GA, *StoreFUEL and Decommissioning Report*, StoreFUEL VOL 24, No. 287, July 2022. (See NUREG/CR-7302)

[14] Piotr Konarski et al., "Spent nuclear fuel in dry storage conditions – current trends in fuel performance modeling," Elsevier, *Science Direct*, Volume 555, November 2021. https://doi.org/10.1016/j.jnucmat.2021.153138 or https://www.sciencedirect.com/science/article/pii/S0022311521003615

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

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

subjected to cyclic vibrations depends on many factors such as fuel burnup, oxide thickness, bonding efficiency and stress history. [17]

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

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

Higher burnup results in higher radionuclide inventory. Proposed advanced reactors seek far higher reactor burnups, for which there are no data to support the safety of the storage of the fuel or transportation of the fuel after storage. Average burnups for pressurized water reactors had increased to 45 giga-watt-days per metric ton uranium (GWd/MTU) by 1999 and have continued to increase. The Natrium fast breeder reactor using high-assay low-enriched uranium (HALEU) fuel is seeking burnups exceeding 150 GWd/MTU and the Xe-100 high-temperature gas-cooled reactor using TRISO fuel is seeking burnups exceeding 168.5 GWd/MTU. [18]

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

The research that has been conducted on spent fuels that were of lower enrichment in uranium-235 and of lower burnup (time in a reactor), roughly 35 GWd/MTU, has limited applicability to the higher burnup spent fuel. This applies to the study of spent fuel at the Idaho National Laboratory of low burnup fuels. [19]

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

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

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

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

greatly increasing the difficulty of attempting to study the degradation and the safety of the new spent fuels during storage and transportation. [20]

An EPRI study stated that a crack in a spent nuclear fuel canister will allow oxygen ingress and the potential for fuel pellet swelling that can significantly degrade the cladding. The burnup of the fuel and the temperature of the fuel when air ingress occurs will affect the extent of fuel pellet swelling. It was acknowledged that for certain high burnup fuel at temperatures above 390 F, this may cause significant fuel pellet swelling. At lower burnup, fuel pellet swelling may be avoided at lower temperatures, at temperatures below 300 F. [21]

Failure of the cladding can cause relocation of fuel pellets, allowing for a criticality accident. Even without a criticality, reduced cladding integrity may affect the consequences of oxygen ingress, causing a higher likelihood of ignition of the hydrides in the cladding or fuel.

The Department of Energy studies of spent fuel have focused on a small subset of fuel and cladding types and only under normal conditions. The research has not focused on what happens when there is oxygen ingress into a canister, particularly for high burnup fuels (greater than about 35 GWd/MTU), or drops or impacts to the canisters.

In summary, the nuclear industry found that they lacked essential information needed to assess the safety of long-term storage of spent fuel and transportation following long-term storage. After more than a decade, they still don't have answers. And the problem keeps expanding as different fuels, particularly higher burnup fuels are used.

The clock is ticking. Over three decades have already elapsed because commercial nuclear utilities began loading fuel into dry storage by 1986. Much of the fuel was loaded after about the year 2000. Most of the spent fuel is stored in welded-closed thin-walled canister; the rest is in bolted thick-walled casks. The general industry assumption is that dry storage of spent fuel will be acceptable for 100 years. [22]

The vulnerability of the dry storage of spent fuel depends on length of time in storage, the fuel burnup, the fuel temperature, and specific fuel and cladding designs, any off-normal conditions the fuel was exposed to, and other factors. Higher burnup fuels are more vulnerable due to increased time in the reactor and increased cladding stress due to more fission products.

Transporting the spent fuel to a consolidated interim storage site will mean that the fuel would later need to be transported again to go to a repository. There is no repository program in

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

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

[22] NorthWind, Volume II, *Strategic Plan for the Relocation of SONGS Spent Nuclear Fuel to an Offsite Storage Facility or a Repository*, March 15, 2021. https://www.songscommunity.com/strategic-plan-for-relocating-spent-fuel/spent-nuclear-fuel-solutions-a-fresh-approach

the U.S. This means that the high cost and serious safety problems with dry storage of spent nuclear fuel will become your children's or grandchildren's problem.

Radiological consequences of breach of a spent nuclear fuel canister still unknown

A Gap analysis updated in 2019 by the Department of Energy confirms that the NRC had no technically defensible documented evaluation of the consequences of spent nuclear fuel canister failure as it continued licensing dry storage of spent fuel. Regarding the lack of spent nuclear dry storage canister accident consequence research needs, a Gap acknowledging this was added identifying the need to assess radiological risk due to loss of confinement caused by stress corrosion cracking.

The hope was to develop technically defensible assessment of gaseous and particulates releases and radiological consequences through stress corrosion cracking of welded thin-walled canisters. As of 2019, and also now in 2023, this research still has not been done and there remains no technically defensible radiological consequence analysis for breach of a spent nuclear fuel canister.

No research has been conducted to validate assumptions about the radiological consequences during accident conditions such as having allowed oxygen ingress into a normally sealed and helium filled spent fuel container. The Department of Energy research that has been conducted so far has focused on a subset of fuels under normal conditions.

According to the 2021 NWTRB report, research efforts are still in the early stages of examining the potential for release of radioactive material, criticality, and radiation exposure to workers and the public from the gross breach of a dry storage spent fuel canister during dry storage or transportation. [23]

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. [24] Even if a through-wall crack was not expected within 20 years of packaging into the canister, by the time the canister would be shipped to consolidated interim storage, likely at least 20 years would have already elapsed.

[23] U.S. Nuclear Waste Technical Review Board, *Evaluation of the Department of Energy's Research Program to Examine the Performance of Commercial High Burnup Spent Nuclear Fuel During Extended Storage and Transportation - A Report to the U.S. Congress and the Secretary of Energy*, July 2021. See www.nwtrb.gov See page 29 which refers to the 2017 EPRI report.

[24] 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

A survey of the previous studies and research needs conducted by EPRI in 2017 [25] states that "The potential consequences associated with unmitigated CISCC [chloride induced stress corrosion cracking] of canisters have not been specifically analyzed." The EPRI review stated that: "Additional analysis may be required to determine bounding values of residual water content, burnup, heat load at start of storage, and storage duration prior to air ingress for which the potential for fuel oxidation and flammable hydrogen concentration can be eliminated as a concern, thereby avoiding the need to consider them as part of a consequence evaluation."

Various authors have asserted that a leaking dry canister would have only a very small leak and that subsequently, the consequences of a tiny leak from a spent fuel canister would be small because the leak rate of radionuclides from the canister would be small. By 2000, expert Marvin Resnikoff warned that the tiny leak sizes being assumed in the event of a dry canister leak were not justified. There was no leak testing and no canister inspections that would be needed to justify this assumption. [26] Furthermore, once a leak is detected, there is no known method to repair the leak or stop or slow its progression or to isolate the canister.

The NRC has accepted leak sizes that are too small and also allowed the assumption that somehow the leak stops after 30 days. [27] The breach of canisters due to load drops or sabotage could also create larger leak sizes than were being assumed. While lowering a canister into a storage vault at San Onofre, a serious canister load drop nearly occurred. For the Holtec facility proposed for New Mexico, the NRC just assumed there would be no canister leak, not even a small one. Hence, the stated criticality risk and canister accident radiological consequences may be far larger than being portrayed.

The detrimental effects of oxygen ingress into the canister of zirconium-clad high burnup spent fuel have not been assessed. Variable factors could affect the progression of conditions that could affect the radiological consequences of the breach of the canister have not been researched.

The EPRI study stated that a hydrogen detonation "is a very unlikely outcome." But that "The potential to reach a flammable hydrogen concentration following through-wall CISCC [chloride-induced stress corrosion cracking] may exist." And then states that "Ignition would not occur without an ignition source…" The study mentions that an ignition source would be provided by welding torch or grinding tools for opening of a welded-closed thin-walled canister.

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

[26] Marvin Resnikoff, Senior Associate at Radioactive Waste Management Associates, Declaration of Dr. Marvin Resnikoff in Support of State of Utah's Request for Admission of Late-Filed Modification to Basis 2 of Utah Contention L, January 26, 2000. (This was in regard to the proposed Private Fuels Storage facility, a consolidated interim spent fuel storage facility licensed by the Nuclear Regulatory Commission but never built.)

[27] Stone and Webster Engineering Corporation, Private Fuels Storage LLC/ Private Fuel Storage Facility, *Accident Dose Calculations at 500m and 3219m Downwind for Canister Leakage Under Hypothetical Accident Conditions for the Holtec MPC-68 and SNC TranStor Canisters*, 1999. ML010330302

Hydrides such as uranium hydrides are known to spontaneously ignite even at room temperature. The amount of hydrides present can vary depending of fuel burnup, cladding composition, and other factors.

The hydrogen flammability criterion of 5 volume-percent could be exceeded for certain conditions, including the higher end of the range of residual water remaining in the fuel after loading the wet fuel and conducting drying operations. Furthermore, the degree that fuel is waterlogged after drying depends on whether the fuel was damaged during reactor use or wet storage, and on the drying process. The fact is, the amount of chemisorbed bound water on the zirconium cladding isn't known.

Despite the lack of research and grossly inadequate assessment of the accident consequences, the Nuclear Regulatory Commission has been granting exemptions to liability coverage for stand-alone dry fuel storage at stranded at-reactor sites such as at San Onofre. [28]

Will the public be compensated for a radiological release from a spent nuclear fuel storage or transportation accident? Liability coverage ranges from about $13 billion to zero dollars

The Price Anderson Act of 1957 (PAA) requires that commercial nuclear power reactor licensees have insurance to compensate the public for damages arising from a nuclear incident. But there's plenty of devil in the details.

The requirements of PAA depend on whether the nuclear operation is under the Department of Energy — or not. While some Department of Energy operations actually have a license from the Nuclear Regulatory Commission, these are still considered as conducted under the Department of Energy. Commercial nuclear reactor operations are conducted under an NRC license and are non-DOE operations. I'll refer to these as licensees.

For NRC licensees, the amount of liability coverage required depends on whether or not the licensee still has an operating reactor; the electricity generation capability of the reactor being above 100 MWe; evolving NRC regulations; and exemptions granted by the NRC.

At stranded fuel sites where the commercial nuclear reactor is no longer operating, the NRC can reduce or waive the liability coverage requirement for Independent Spent Fuel Storage Installations using dry storage of spent nuclear fuel. In the event of an accident or sabotage, there may be zero dollars for compensation available to the public.

Currently, the Price Anderson Act does not require insurance coverage for non-DOE Independent Spent Fuel Storage Installations and these can include consolidated interim storage

[28] Northwind, Volume II, *Strategic Plan for the Relocation of SONGS Spent Nuclear Fuel to an Offsite Storage Facility or a Repository*, March 15, 2021. https://www.songscommunity.com/strategic-plan-for-relocating-spent-fuel/spent-nuclear-fuel-solutions-a-fresh-approach

facilities. See also the 2021 report by the U.S. Nuclear Regulatory Commission discussing the Price-Anderson Act [29] and the 2023 report by the Department of Energy. [30]

Citizens cannot count on any compensation or adequate compensation following a nuclear accident for a variety of reasons including evidence of harm will likely be limited to the radiation monitoring conducted by those at fault for the accident.

Whether or not a facility is covered by the Department of Energy may be vague depending on the contractual arrangement with DOE. Should a serious accident occur at an away-from-reactor consolidated interim storage facility or an at-reactor dry storage facility called an Independent Spent Fuel Storage Installation, the existence of any, let alone adequate, financial compensation to citizens who lose homes, vehicles, and/or health may be doubtful.

The Department of Energy could take ownership of the spent nuclear fuel at the boundary of the commercial utilities facility and should an accident occur as the spent fuel is transported to the boundary of the facility, the utility could be liable for the accident, rather than DOE.

The NRC concluded based on inadequate accident evaluations that dry spent fuel storage poses no risk of offsite radiological contamination, or less than 1 rem. The NRC's evaluation of dry canister accident risk is based on the faulty logic that since the spent fuel in dry storage can be air-cooled, no radiological release from spent fuel in dry storage is possible. [31] But the NRC failed to adequately address sabotage, transportation, load drops during loading or unloading canisters into storage vaults, canister leakage with water ingress such as known rising groundwater levels at San Onofre, canister leakage with hydride explosion or fire and perhaps other accident types. Apparently, it will up to community leaders to review currently unresolved issues for dry storage spent fuel systems licensed in the U.S. [32]

There are currently three separate efforts to create consolidated interim storage facilities for spent nuclear fuel. Two private consolidated interim storage facilities have been licensed by the U.S. Nuclear Regulatory Commission for "interim" storage of spent fuel, one in New Mexico by Holtec and another in Texas by Interim Storage Partners. The Department of Energy has a separate effort to build one or more consolidated interim storage facilities.

From Table 1, for a non-DOE stand-alone Independent Spent Fuel Storage Installation such as the proposed consolidated interim storage (CIS) facilities proposed by private companies for New Mexico and Texas, the Price Anderson Act would not require or provide liability coverage. The NRC may request some amount of liability coverage and can modify or exempt the licensee from carrying this coverage at a later time even if coverage was initially required. An accident at

[29] H. Arceneaux et al., U.S. Nuclear Regulatory Commission, *The Price-Anderson Act: 2021 Report to Congress – Public Liability Insurance and Indemnity Requirements for an Evolving Commercial Nuclear Industry*, NUREG/CR-7293, December 2021. [ML21335A064]
[30] U.S. Department of Energy, *The Price-Anderson Act Report to Congress*, January 2023.
[31] Federal Register, Volume 83, Number 8, January 11, 2018 at Page 1385.
[32] Seirra Club letter to the U.S. Nuclear Regulatory Commission, RE:Advanced Notice of Proposed Rulemaking (ANPR): Regulatory Improvements for Decommissioning Power Reactors, Docket ID NRC-2015-0070, March 21, 2016. https://www.nrc.gov/docs/ML1608/ML16082A004.pdf

the proposed Holtec CIS in New Mexico or Interim Storage Partners CIS in Texas could occur with no compensation for the public because the Price Anderson Act does not require it of the NRC-licensed private facility.

Both private facilities proposed for New Mexico and Texas have now faced state legislation prohibiting the facilities. Texas has also successfully challenged the legal authority of the NRC to authorize an away-from-reactor facility. While the NRC has licensed dry spent fuel storage at commercial nuclear reactor licensed by the NRC, at issue is that the regulations governing the storage and disposal of spent nuclear fuel laid out specific regulations for spent fuel in the NWPA. The NRC has asserted that the agency can ignore the NWPA provisions passed by Congress and authorize spent fuel storage anywhere and without regard to NWPA provisions.

Table 1. Requirements for financial protection and the availability of indemnification for NRC Part 50 licensees and DOE contractors.

Entity	**Primary Tier Financial Protection**	**Secondary Tier Financial Protection**	**Indemnification**
Large (>100 MWe) Operating Reactor: NRC Part 50 [Reactor] Operating Licensee (including SNF stored onsite at an ISFSI under an NRC Part 72 license)	$450 million provided through private insurance.	$13.21 billion provided through deferred premium payments from all operating licensees.	If the secondary tier financial protection is depleted, Congress is committed to review the incident, and take any actions determined to be necessary for fuel and prompt compensation of all public liability claims.
Permanently Shut down Reactor: NRC Part 50 Shutdown [Reactor] Plant Licensee Applicable to SONGS (including SNF stored onsite at an ISFSI under an NRC Part 72 license)	$100 million provided through private insurance.	No secondary tier required per PAA.	NRC indemnified licensee for an additional $460 million, for a total financial protection of $560 million. Beyond this amount, Congress is committed to review the incident, and take any actions determined to be necessary for full and prompt compensation of all public liability claims.
DOE Contractor (General)	As may be determined by the Secretary of Energy.	Not applicable.	DOE indemnifies contractor up to $13.70 billion total. Beyond this amount, Congress is committed to review the incident, and take any actions determined to be necessary for full and prompt compensation of all public liability claims.
DOE Contractor (Performing Activities Funded by the NWF)	As may be determined by the Secretary of Energy.	Not applicable.	Public liability claims are paid from the Nuclear Waste Fund, in an amount not to exceed $12.58 billion. Beyond tis amount, Congress is committed to review

Entity	Primary Tier Financial Protection	Secondary Tier Financial Protection	Indemnification
			the incident, and take any actions determined to be necessary for full and prompt compensation for all public liability claims.
NRC Part 72 Stand-Alone Independent Spent Fuel Storage Installation	As may be determined by the NRC and implemented through a site license condition.	Not applicable.	**$ 0, Zero dollars** NRC regulations do not provide NRC indemnification for 10 CFR Part 72 stand-alone ISFSIs. Such facilities do not have PAA protection available to them.

Table notes: Northwind, Volume II, *Strategic Plan for the Relocation of SONGS Spent Nuclear Fuel to an Offsite Storage Facility or a Repository*, March 15, 2021. https://www.songscommunity.com/strategic-plan-for-relocating-spent-fuel/spent-nuclear-fuel-solutions-a-fresh-approach See Appendix C, Table on page C-7. And see H. Arceneaux et al., U.S. Nuclear Regulatory Commission, *The Price-Anderson Act: 2021 Report to Congress – Public Liability Insurance and Indemnity Requirements for an Evolving Commercial Nuclear Industry*, NUREG/CR-7293, December 2021. [ML21335A064]. Note that in the event there is no coverage, Congress could decide to provide coverage after an accident.

The Department of Energy is also seeking one or more federal consolidated interim storage facilities. The specific types of spent fuel or high-level waste, whether for commercial spent fuel or non-commercial spent fuel, is not being disclosed but is indicated to include commercial spent nuclear fuel. The DOE's effort has been funded under the Consolidated Appropriations Act of 2021 and 2023.

There is interest is sending spent fuel currently stored at electric utilities to interim storage facilities such as the proposed private consolidated interim storage facilities in New Mexico and Texas. **But despite electrical utilities wanting the spent fuel sent away from their communities, these utilities do not want the cost of transporting the fuel. They did not want the cost of providing insurance or the liability for accidents during transportation or storage at these away-from-reactor sites. And no one even knows what the annual storage fees at these sites would be.**

The utilities wanting the spent fuel sent to consolidated interim storage sites want the Department of Energy to take ownership of the spent fuel, to pay for the transportation away from the reactor site, to accept the liability for transportation and for storage, and to pay for storage fees at the away-from-reactor storage site.

Read about one electric utility's survey of the high cost and many difficulties associated with trying to relocate the San Onofre spent nuclear fuel away from the vulnerable Pacific Ocean coastline. [33] These private facilities have a mysterious business model that seems to be an attempt to go around existing Nuclear Waste Policy Act (NWPA), 1982 and as amended in 1987. The NWPA regulations constrain the interim spent fuel storage facility(s) with regard to capacity and also require that a construction license has been obtained for a disposal facility.

The Department of Energy, which has no permanent disposal program is seeking a community to engage with, and is enlisting many universities and others in the consortia to find a community and identify who to convince and how to bribe them. The DOE admitted at the August 2023 NWTRB meeting that the communities will only be provided with carefully filtered information but the consortia members would have access to the "unfiltered" information. See more about that meeting, as well as my comment submittal at https://www.nwtrb.gov/meetings/past-meetings/summer-2023-board-meeting---august-30-2023

No community can provide informed consent when the length of time the fuel will be stored at the consolidated interim storage facility is unknown. Statements that the NRC's license for the storage is limited to a certain duration, whether 20 or 40 years, are not meaningful. The refusal to renew the license would not remedy the situation if there is no way to remove the spent fuel. Furthermore, no community can provide informed consent when the potential accident consequences being asserted are based on optimistic fiction and are not technically defensible.

Despite the lack of actual research or sound technical basis for understanding the radiological releases possible from dry storage of spent fuel or its transportation, the NRC is asserting that the risk posed from dry storage of spent fuel is low so that it can save the licensees from having to buy insurance coverage.

U.S. Senate Bill S.2443 proposes funding for Department of Energy consolidated interim storage of spent nuclear fuel

Senate Bill S.2443, Energy and Water Development and Related Agencies Appropriations Act, 2024, Section 307, 118th Congress, bypasses the Nuclear Waste Policy Act of 1982 (42 U.S.C. 10101) to allow the Department of Energy to conduct a pilot program to license, construct, and operate one or more Federal consolidated storage facilities to provide interim storage as needed for spent nuclear fuel and high-level radioactive waste, with priority for storage given to spent nuclear fuel located on sites without an operating reactor. [34]

While the Department of Energy would authorize the facility, a license from the Nuclear Regulatory Commission for its construction and operation may still be needed.

[33] Northwind, Volume II, *Strategic Plan for the Relocation of SONGS Spent Nuclear Fuel to an Offsite Storage Facility or a Repository*, March 15, 2021. https://www.songscommunity.com/strategic-plan-for-relocating-spent-fuel/spent-nuclear-fuel-solutions-a-fresh-approach

[34] https://www.congress.gov/bill/118th-congress/senate-bill/2443/

By calling this a "pilot program," this proposal side-steps legal requirements regarding the Idaho Settlement Agreement regarding shipping of naval spent fuel or DOE-owned spent fuel at the Idaho National Laboratory.

The plan is to demonstrate the safe transportation of spent nuclear fuel and safe storage, apparently without needed research to evaluation how fragile the fuel cladding is on the higher burnup fuels now used in commercial nuclear reactors. The condition of the spent fuel and its containers are variable and demonstrating one safe trip is not necessarily an indicator of the safety of every spent fuel container.

The proposed law requires the Secretary of Energy to obtain consent to host the facility from the Governor of the State; each unit of local government within the jurisdiction of which the facility is proposed to be located; and each affected Indian tribe.

The bill asks that DOE submit a plan with "recommendations for a mechanism to ensure that any spent nuclear fuel or high-level radioactive waste stored at a consolidated storage facility pursuant to this section shall move to deep geologic disposal capacity, following a consent-based approval process for that deep geologic disposal capacity consistent with subsection (d) [State Governor, local government and each affected tribe], within a reasonable time after the issuance of a license to construct and operated the consolidated storage facility."

In a competing bill, H.R. 4394, Section 604, 118th Congress, [35] this bill does not promote the DOE's bypassing of proper legislation to side-step NWPA. HR 4394 takes funding away from the effort to site private away-from-reactor consolidated interim storage and states "No federal monies shall be expended in furtherance of any agreement among private entities for consolidated interim storage of spent nuclear fuel that is not specifically authorized under federal law until such time that host state and local governments and any affected Indian tribes have formalized their consent." The bill does not apply to facilities presently storing commercial spent nuclear fuel. The proposed private consolidated interim storage facilities in New Mexico and Texas would, on the surface, seem to be private enterprise. But it should be noted that the two private consolidated storage facilities were probably obtaining, at least to some degree, federal funding.

How much ionizing radiation dose do you get from routine storage of spent nuclear fuel in dry storage?

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

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[35] https://www.congress.gov/bill/118th-congress/house-bill/4394/

Unshielded, the thin-walled canister used prevalently for dry storage of spent fuel in the U.S. are enormous and can exceed 100,000 rad/hr. [36] For external dose, you can assume 1 rad is equivalent to 1 rem, even though the details of depth of the dose into the body, versus the dose at the surface of the body, which depend on the gamma ray energy, complicate this. A lethal dose often being defined as 400 rem, an unshielded spent fuel canister presents a large hazard, a lethal dose in about 14 seconds. With shielding, the doses are far lower, but still pose a chronic dose health hazard.

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

After a 40-year cooling time, at 1 meter, the total dose rate is 4.73 mrem/hr. At 100 meters, the total dose rate is 3.13E-3 mrem/hr. And at 1,600 meters, the total dose rate is 1.6E-8 mrem/hr. However, for the 40-year cooling time, at 1,600-meter, secondary gamma contributes over 90 percent to the total dose. Also, at 1000 meters, primary dose is equivalent to neutron dose and neutron dose won’t be measured without a neutron detector. [37] The low energy beta radionuclides of carbon-14 and tritium, also will not be detected by typical radiation monitoring metering or TLD badges.

For a hypothetical concrete cask loaded with pressurized water reactor fuel, the external radiation dose rate increases with increasing fuel burnup. The dose rate decreases with increasing distance from the cask and with increasing air density. The dose rate also decreases with years of cooling time.

Estimating the radiation dose that people receive from being near the spent fuel in dry storage is complex. The radiation external dose from being near spent fuel in a cask for transportation or in dry storage is of interest, both to the public and to workers.

The primary gamma radiation that passes through the cask or canister system creates a range of gamma energies. The radionuclides confined inside the cask or canister that contribute to primary gamma outside the container are cerium-144, ruthenium-106, cesium-134, europium-154, strontium-90 and cesium-137. [38]

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

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

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

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

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

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

For a 70 GWd/MTU average assembly burnup value and a 40-year cooling time, secondary gamma radiation dominated total dose rate at distances beyond 700 meters. A 10 percent decrease in air density produced a total dose rate increase at 1,600 meters from the cask of about 110 percent for fuel with a 5-year cooling time. [39]

Air density and soil composition affect radiation dose rates from the spent fuel in dry storage, particularly the far-field dose rates. Small air density variations can have a large affect on radiation dose rates at long distances from a cask. The dose rate increases with decreasing air density. Depending on soil type, the groundshine dose is affected by the various scattering, neutron moderation, and absorption characteristics of the elements in the soil. The concentration of hydrogen in the soil as the hydrogen reduces the neutron energy and increases the probability of radiative capture reactions. This decreases the neutron groundshine but generates new secondary gamma sources. [40]

To recap, gamma radiation from the dry cask or canister systems occurs as gamma rays escape the cask. This occurs without external contamination of the cask or canister and without the lost of containment of the cask or canister. In addition to the gamma rays streaming from the cask or canister, neutrons are escaping from the cask or canister. While steel helps to shield gamma rays, neutrons are not stopped by steel. Neutron shielding typically includes material with hydrogen. Some neutron shielding materials may be vulnerable in a fire. The escaping neutrons are not detected by gamma radiation detectors. The neutrons, however, to do create

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

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

secondary gamma rays by interactions with the elements in soil. The neutrons also activate and make radioactive metal and concrete in the cask system. [41]

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

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

Not usually mentioned regarding dry spent fuel storage is that the neutrons activate air and dust that can be inhaled. [42] Nor is the potential surface contamination from contamination in the spent fuel pool mentioned. Based on the allowable surface contamination from radionuclides in spent fuel pool water that could contaminate the metal canister lowered into the pool to load the spent fuel, those radionuclides can pose an inhalation dose as well.

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

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

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

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

Carbon-14 production from nuclear reactors, reprocessing and dry storage

While Carbon-14 is produced in small amounts naturally by cosmic ray neutrons, Carbon-14 is produced by nuclear weapons testing and by the operation of nuclear reactors. Carbon-14 is also produced by spent fuel reprocessing and by storage of spent nuclear fuel in dry cask or canister systems. [43]

The radioactive carbon-14 is formed due to the absorption of neutrons by carbon, nitrogen or oxygen. These may be present in the nuclear fuel, in a moderator such as graphite, the coolant such as water, or structural hardware. Carbon-14 released as carbon dioxide or any other chemical form can be inhaled or ingested as food and incorporated into the body. [44]

Naturally occurring carbon includes the non-radioactive carbon-12 and carbon-13 and a very small fraction of radioactive carbon-14. Carbon-14 is radioactive and decays by a low energy beta particle that is difficult to detect. Radioactive carbon-14 has six protons and eight neutrons in its nucleus, whereas carbon-12 has six protons and six neutrons and is not radioactive. The half-life of carbon-14 is 5730 years and so it remains a problem in the environment for 7 to 10 half-lives, over 57,000 years. Carbon-14 decays into nitrogen.

The carbon-14 levels estimated in 2006 were about 1 atom of C-14 to 700,000,000,000 atoms of stable carbon. [45] Carbon-14 is produced naturally by cosmic ray neutrons absorbed by nitrogen-14. The nitrogen-14 absorbs a neutron and kicks out a proton, becoming carbon-14. It is then readily converted to radioactive carbon dioxide which is then available to be incorporated in the food chain by photosynthesis.

Carbon-14 is highly mobile in the environment. While some carbon-14 remains in the spent fuel (cladding and matrix of the fuel), it would be released by fuel reprocessing and after disposal. Carbon-14 is also created in the reactor coolant and is released to the environmental through gaseous and liquid discharges. Carbon-14 collected in filters at nuclear plants is also difficult to confine following disposal. Different reactor designs produce and release differing amounts of carbon-14, see Table 2. [46]

Carbon-14 is produced by neutrons escaping from dry storage of spent nuclear fuel; however, it is rarely estimated and difficult to measure. However, for large spent fuel storage installations,

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[43] Holtec International, The HI-STORE CIS FACILITY, USNRC Docket # 72-1051, undated. (ML231025A112), (Search for C-14.)

[44] Wallace Davis, Jr., *Carbon-14 Production in Nuclear Reactors*, ORNL NUREG TM-12, 1977. (IAEA INIS Library 832818)

[45] Man-Sung Yim, and Francois Caron, *Progress in Nuclear Energy*, Volume 48, Issue 1, Pages 2-36, "Life cycle and management of carbon-14 from nuclear power generation," January 2006. https://www.sciencedirect.com/science/article/abs/pii/S0149197005000454

[46] International Atomic Energy Agency, *Management of Waste Containing Tritium and Carbon-14*, Technical Reports Series no. 421, 2004. https://www.iaea.org/publications/6634/management-of-waste-containing-tritium-and-carbon-14

particularly near where plants are grown for food, the carbon-14 production should be included in safety and NEPA documentation.

Table 2. An estimate of Carbon-14 production and releases from various types of reactors.

Reactor type	Installed capacity (MWe)	Gaseous waste (Gbq/a)	Liquid effluent (GBq/a)	Solid waste (decommissioning) (GBq/a)
Pressurized water reactor - light-water reactor	1000	129.5	1.3	647.5
Boiling water reactor – light-water reactor	1000	259.0	1.3	1165.5
CANDU - Heavy water reactor	600	3108	Small	703
High-temperature gas-cooled reactor	600	14.8	Small	Small
Fast breeder reactor	1250	0.65	Small	Small

Table notes: Adapted from International Atomic Energy Agency, *Management of Waste Containing Tritium and Carbon-14*, Technical Reports Series no. 421, 2004. Various would occur within each reactor type. Giga-becquerel per annual (Gbq/a). 1 Giga is a billion or 1.0E+9. 1 curie is 37E+9 bq.

Department of Energy continues the coverup of ionizing radiation health harm

Government agencies beginning with the Atomic Energy Agency that later became the Department of Energy that promoted nuclear energy as well as nuclear weapons, continue to ignore the full extent of human health harm from the radioactive releases from their operations.

Recently, the Department of Energy has begun a campaign of advertising, emphasizing that bananas are radioactive, to further misinform people about the harmful effects of ionizing radiation. [47]

When the AEC was conducting nuclear weapons testing at the Nevada Test Site, the AEC suppressed epidemiology findings of excess thyroid cancers. There were multiple projects of radiation worker epidemiology work that was terminated if adverse findings were discovered that the DOE could not convince the authors to modify.

The National Council on Radiation Protection and Measurements estimates that the average member of the population of the United States receives an annual effective dose equivalent (whole-body dose) of approximately 311 mrem from natural background radiation. About 33 mrem comes from cosmic radiation, 21 mrem from terrestrial radiation, 29 mrem from radioactivity in the body and 228 mrem from inhaled radon and its decay products. Consumer

[47] Department of Energy, Office of Nuclear Energy, 5 Radioactive Products We Use Every Day, September 12, 2023. https://www.energy.gov/ne/articles/5-radioactive-products-we-use-every-day

products, activities and occupational exposure contribute an average 10 mrem. Medical radiation was assessed based on the total medical procedures and the population, and is estimated as 300 mrem per year. [48] [49] But it isn't pointed out that 300 mrem to the child in utero would significantly increase childhood cancer and leukemia risk.

Increased infant mortality due to elevated radiological releases was so well understood by the AEC, now the Department of Energy, that the agency took a role in manipulating infant mortality statistics to hide disturbing data. Jay M. Gould and Benjamin A. Goldman would write in their book *Deadly Deceit – Low Level Radiation High Level Cover-Up* of excess infant deaths near the Department of Energy's Savannah River Site and near the 1979 Three Mile Island nuclear accident. [50]

Elevated rates of infant mortality and birth defects were found in communities near the Department of Energy's Hanford site, but workers were not told of these epidemiology results and newspapers did not report the findings. [51]

Following the 1986 Chernobyl nuclear disaster, a comprehensive study also found a spike in perinatal mortality (still-births plus early neonatal deaths) in several countries that received airborne radioactivity from Chernobyl. The amount of airborne radioactivity to cause this was far smaller than generally assumed. [52]

Both the Department of Energy who oversees nuclear weapons material production and other nuclear research and the Nuclear Regulatory Commission who oversees commercial nuclear energy and uranium cycle facilities have a large role in saying that the operations they oversee do not have a significant impact on human health and the environment. Both agencies claim to understand ionizing radiation health harm. And both agencies actively ignore the reality of actual health harm to radiation workers and to citizens living within 50 miles of nuclear reactors.

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[48] Fluor Marine Propulsion, LLC, Prepared for the U.S. Department of Energy, *Naval Reactors Facility, Environmental Monitoring Report – Calendar Year 2021*.

[49] Natural Background and Man-made Radioactivity, Oak Ridge Associated Universities, circa 2009. ML11229A695. Uses National Council on Radiation Protection and Measurement (NCRP), NRCP Report No. 160, "Ionizing Radiation Exposure of the Population of the United States," 2009. (Medical exposure based on 2006.)

[50] Jay M. Gould and Benjamin A. Goldman, *Deadly Deceit – Low Level Radiation High Level Cover-Up,* Four Walls Eight Windows New York, 1990. ISBN 0-941423-35-2. The finding of excess infant deaths near the Department of Energy Savannah River site around the 1970s and near the 1979 Three Mile Island nuclear accident are described in Jay Gould's book *Deadly Deceit*.

[51] Kate Brown, *Plutopia – Nuclear Families, Atomic cities, and the Great Soviet and American Plutonium Disasters,* Oxford University Press, 2013. ISBN 978-0-19-985576-6. Note that many publications use spelling variation Mayak instead of Maiak. *Plutopia* documents the elevated percentage of deaths among infants in the Richland population in the 1950s. Elevated fetal deaths and birth defects in Richland were documented by the state health reports, yet Hanford's General Electric doctors and the Atomic Energy Commission that later became the Department of Energy failed to point these statistics out. The local newspapers failed to write of it. The Department of Energy has continued to fail to tell radiation workers and the public of the known risk of increased infant mortality and increased risk of birth defects that result from radiation exposure.

[52] Alfred Korblein, "Studies of Pregnancy Outcome Following the Chernobyl Accident," from *ECRR Chernobyl: 20 Years On – Health Effects of the Chernobyl Accident*, Editors C.C. Busby and A. V. Yablokov, 2006.

The Department of Energy likes to imply that an annual dose of 5,000 mrem/yr is safe because that is the dose allowed to adult radiation workers. The nuclear industry likes to point to the high average annual doses reviewed by the public from medical radiation as though that radiation dose is benign.

The development of radiation protection standards that limit annual radiation doses to the public of 100 mrem/yr, in various Department of Energy, Nuclear Regulatory Commission and Environmental Protection Agency regulations have not considered the harm to the unborn child developing in utero who is harmed even by this dose, especially for internal radiation due to inhalation, and food and water contamination. The harm of radionuclides entering the body by inhalation and ingestion pose greater harm than external radiation and the harm is currently underestimated by the nuclear industry. The organ doses can be very high even when the whole-body dose is stated as low. High thyroid organ doses to the unborn child, for example, impede the child's development both before birth, and if the baby survives, impedes the child's health.

Articles by Tami Thatcher for October 2023.