Environmental Defense Institute

News on Environmental Health and Safety Issues

June 2024 **Volume 35** **Number 6**

Small Modular Reactor Rhetoric Doesn't Match the Reality: Reactor Licensing Status of Unaffordable NuScale and X-Energy Small Modular Reactors

Iceberg Research has written an article [1] that NuScale's marketing leans heavily on the one claim that it is the first and only SMR design certified by the NRC. However, the design certification was for the original 50-megawatt-electric reactor design and the company was forced to upsize its SMR to 77-MWe after it found that the economics of the 50-MWe version didn't work. Iceberg writes that the increasing the power output to 77-MWe is not a simple update of the previous design. And while NuScale has applied for a Standard Design Approval for the 77-MWe design, it is not complete and it is not a full certification.

The previous 50-MWe design had issues that still have to be addressed including design of the shield wall, containment leakage from the combustible gas monitoring system, and steam generator stability. The propaganda ignored the U.S. NRC's communications to the Idaho Leadership in Nuclear Energy Commission at its October meeting[2] and to NuScale in writing state that "… this SDA [standard design approval of the 50-MWe] does not constitute a commitment to issue a permit, design certification (DC), or license…." [3] [4] The 77-MWe design has the added difficulty of higher reactor power levels which adds heat load and increases safety challenges.

Fluor has invested more than $600 million in NuScale and has sought to divest from NuScale according to Iceberg Research.

According to Edwin Lyman of Union of Concern Scientists, the now-cancelled NuScale project to build a 460-megawatt, 6-unit small modular reactor in Idaho "was estimated to cost

---

[1] Iceberg Research, NuScale ($SMR) Has Deceived Investors about the Certification of its Reactor, May 16, 2024. https://iceberg-research.com/2024/05/16/nuscale-smr-has-deceived-investors-about-the-certification-of-its-reactor/

[2] 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

[3] 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

[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, September 11, 2020 at https://www.nrc.gov/docs/ML2024/ML20247J564.pdf

over $20,000 per kilowatt, which is greater than the actual cost of the Vogtle large reactor project of over $15,000 per kilowatt." Also, "The levelized cost of electricity for the now-cancelled NuScale project was estimated at around $119 per megawatt-hour (without federal subsidies), whereas land-based wind and utility-scale solar now cost below $40/MWh." [5]

The levelized cost of electricity is the cost of building and operating a power plant over an assumed lifetime. If the nuclear plant closes prematurely or experiences long unplanned shutdowns, the levelized cost can be far higher.

Other small modular reactors are not likely to be more affordable, even as safety features are jettisoned. **And microreactors will be even more expensive, [6] perhaps two or three times as costly as unaffordable SMRs according to Lyman.** This is without the cost of long-term management and disposal of the spent nuclear fuel.

The nuclear boosters are scrambling to give the impression that they are solving the problem of high construction for advanced reactors. The Idaho National Laboratory has released *A Tool to Quantify Capital Cost Reduction Pathways for Advanced Nuclear Reactors*, a new tool designed to help lower the escalating cost of new nuclear builds. [7] However, the tool in no way lowers the cost of new nuclear builds – but it does allow a comparison of the hypothetical and escalating costs between competing designs. The user can input a guess at the design maturity and the supply chain proficiency, for example. Garbage in, garbage out tool at best.

U.S. Nuclear Regulatory Commission has issued an audit report of NuScale's Standard Design Approval Application (ML23306A033). [8] The NRC's audit report lists items that remain to be resolved including seismic design issues, steam generator design issues and others. The NRC staff continue to review NuScale's responses to 86 items and 153 items have not been responded to.

NuScale's small modular reactor isn't the only SMR with rising cost estimates. X-Energy's high-temperature gas-cooled reactor construction cost estimates continue to climb. [9] But add forever storage of X-Energy's TRISO fuel that is not practical to reprocess and will pose unique

---

[5] Edwin Lyman, *Union of Concerned Scientists*, "Five Things the 'Nuclear Bros' Don't Want You to Know About Small Modular Reactors," April 30, 2024. https://blog.ucsusa.org/edwin-lyman/five-things-the-nuclear-bros-dont-want-you-to-know-about-small-modular-reactors/

[6] Abdalla Abou-Jaoude et al. Nuclear Science & Technology Directorate, Idaho National Laboratory, *Literature Review of Advanced Reactor Cost Estimates*, INL/RPT-23-72972, Revision 3, October 2023. https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_66425.pdf

[7] Chandrakanth Bolisetti et al., Prepared for U.S. Department of Energy, *A Tool to Quantify Capital Cost Reduction Pathways for Advanced Nuclear Reactors*, May 29, 2024. 5 pages and link to a spread sheet. No report number. Download "Nuclear-Reactor-Capital-Cost-Reduction-Pathway-Tool.pdf

[8] U.S. Nuclear Regulatory Commission letter to NuScale Power, LLC, Subject: Audit Status – The Staff Review of the NuScale Power, LLC Standard Design Approval Application – NuScale US460, May 24, 2024. Docket No. 05200050 https://nrc.gov/ML2413/ML24138A200.pdf

[9] David Schlissel and Dennis Wamsted, *Institute for Energy Economics and Financial Analysis*, "Small Modular Reactors: Still too expensive, too slow and too risky," May 29, 2024. https://ieefa.org/resources/small-modular-reactors-still-too-expensive-too-slow-and-too-risky

disposal problems and the costs beyond construction and operating costs will, though unstated, will be costing electricity rate payers and taxpayers in the future.

The X-energy Xe-100 reactor is a pebble-bed, high-temperature gas-cooled reactor (HTGR). Each reactor module is to generate 200 megawatts-thermal and approximately 80 megawatts-electric. The standard Xe-100 will be a "four-pack" plant that generates approximately 320 MWe. Because each module is below 100 MWe, no Price Anderson coverage will apply, no matter what the unknown level of safety of the modules is or a terrorism event that affects all of the modules and stored spent fuel at the plant.

Airborne radiological releases from the proposed X-Energy HTGR may be low when the fuel is initially used. But at the Fort St. Vrain high-temperature gas-cooled reactor that used TRISO fuel, airborne radiological releases increased unexpectedly as the fuel burnup increased. [10] "The increase in the fission gas release is most likely due to an increase in the in-service fuel particle failure which has reached a high enough level to have a noticeable impact on fission gas release…" The elevated airborne radiological releases occurred at the Fort St. Vrain reactor despite operations not exceeding normal temperatures. See information about the design of the Fort St. Vrain nuclear reactor in GAO/RCED-88-8 from 1987. [11] [12] [13]

Citizens will be told selected propaganda about the X-Energy safety and routine releases. And citizens won't be told the truth about the cost of long-term storage of the spent fuel, the storage needed long after the 80 years its storage might be licensed for.

A 2021 Department of Energy presentation stated that "Triso and other designs will need a different test plan to quantify their mechanical properties, if further testing is warranted." And "Triso and other designs will not fit into the current storage and transportation container designs. New containers will need to be designed, tested, and manufactured." [14] Triso [or TRISO] fuel is tri-structural isotropic fuel that X-energy plans to use in high-temperature gas-cooled reactors. The TRISO fuel would use high-assay low-enriched uranium (HALEU) fuel, see my comments on the Department of Energy's promotion of HALEU feedstock on the Environmental Defense Institute website home page. [15]

---

[10] V. Jovanovic, General Atomics, Radionuclide Methods Validation with FSV Data, DOE-HTGR-88358, September 1989.

[11] U.S. General Accounting Office, *Nuclear Safety Reactor Design, Management, and Emergency Preparedness at Fort St. Vrain*, GAO/RCED-88-8, November 1987.

[12] International Atomic Energy Agency, High Temperature Gas Cooled Reactor Fuels and Materials, IAEA-TECDOC-1645, 2010.

[13] Public Service Company of Colorado, Fort St. Vrain Nuclear Station, *Annual Radioactive Effluent Release Report, January – December 1995*, March 1996. https://nrc.gov/ML2010/ML2010F186.pdf

[14] Sylvia Saltzstein et al., Office of Nuclear Energy presentation, "Accident Tolerant and Advanced Nuclear Fuels: Back End Key Findings and Plans," Nuclear Waste Technical Review Board meeting, May 12-13, 2021. https://nwtrb.gov

[15] Tami Thatcher, Public Comment Submittal on the Draft Environmental Impact Statement for Department of Energy Activities in Support of Commercial Production of High-Assay Low-Enriched Uranium (HALEU), DOE/EIS-0559, April 22, 2024. www.environmental-defense-institute.org/publications/CommentDOEhaleu2024.pdf

The high-enriched low-assay uranium (HALEU) that is attractive for theft for nuclear weapons and the fuel poses a nuclear weapons proliferation threat. But no matter — its an "advanced reactor" and that means taxpayer money will be generously offered to it and nuclear regulatory oversight will be gutted more in the future by nuclear promotion schemes, including the ADVANCE bill.

X-energy's licensing status is that it is "engaged" with the U.S. NRC pre-licensing activities and has been since 2018. See https://www.nrc.gov/reactors/new-reactors/advanced/who-were-working-with/licensing-activities/pre-application-activities/xe-100.html

China has built a high-temperature gas-cooled reactor, but there is little information being released about its operation. Typically, good news is shared and negative news is suppressed. Past operations of high-temperature gas-cooled reactors such as the Fort St. Vrain reactor in Colorado were financial failures. And the spent nuclear fuel generated continues to cost taxpayer money every year.

The U.S. Nuclear Regulatory Commission is betting on small reactors being safer and has allowed reduced physical containment structures, offsite emergency evacuation planning and reduced exclusion zones. Yet, the small modular and micro reactors will be more vulnerable to terrorism even if they manage to be safer or as safe as existing reactors. The NRC has also removed Price Anderson Act liability coverage for reactors that generate less than 100 megawatts-electric. Citizens should keep in mind that Price-Anderson Act liability coverage will not necessarily cover damages at all for consolidated spent nuclear fuel storage, transportation or reactors smaller than 100 megawatts. [16] [17]

TerraPower's Natrium Construction Permit Application Docketed by the NRC; And the games begin with Natrium's heavily redacted accident methodology

On May 23, the U.S. Nuclear Regulatory Commission accepted TerraPower's construction permit application for review. On April 10, TerraPower, LLC had submitted a construction permit application for the Natrium sodium fast reactor that would be constructed near Kemmerer, Wyoming, under the U.S. Department of Energy's Advanced Reactor Demonstration Program (ARDP) demonstration pathway.

TerraPower and the U.S. NRC are already busy playing games. The document for providing TerraPower's Natrium "Major Accident Methodology" is just 19 pages long and 8 pages are

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

[17] Michael Franco, *Newatlas*, "Small modular nuclear reactors get a reality check," May 31, 2024. https://newatlas.com/energy/modular-nuclear-reactors/

redacted. [18] TerraPower won't even state the radiological source term for its worst potential accident. "The major accident event source term is identified as [[ ]](a)(4), which is an Unprotected Loss of Heat Sink (ULOHS) event." So, the NRC puts documents on its website, implying that there is meaningful information there, and yet essential information is fully redacted.

The NRC is helping TerraPower hide the truth from citizens and Congress is seeking to undermine NRC's already inadequate nuclear regulatory oversight.

TerraPower has also requested exemptions [19] from certain regulatory requirements such as the financial qualification of the applicant (TerraPower). TerraPower won't have to explain how it plans to cover estimated construction costs and related fuel cycle costs. This is egregious. TerraPower just gives a wink and a nod to the right people and the rules don't apply to them. TerraPower won't give estimated project costs to NRC or to the public — **apparently because the costs would be too obscene to discuss.**

TerraPower has submitted a 13-chapter preliminary safety analysis report. Important documents submitted by TerraPower as of April 10, 2024 are listed at https://www.nrc.gov/docs/ML2408/ML24088A059.html including the Preliminary Safety Analysis Report (PSAR) (1702 pages).

The sodium-cooled fast neutron Natrium reactor is to be a 345-megawatt electric reactor that includes an energy storage system to temporarily boost output up to 500 MWe, when needed. [20] The Natrium reactor is expected to routinely release airborne radionuclides include xenon-133, xenon-135, iodine-131, krypton-88, cesium-134 and cesium-137, see the Kemmerer Unit 1 PSAR.

The Natrium is being called "small" because the 345-MWe reactor is less than a 1000-MWe conventional lightwater reactor. But, with the higher enriched fuel comes higher burnup (or longer operating time in the reactor). With higher burnup comes higher fission product inventory in the spent fuel.

An accident occurring after the fuel had been used in the reactor and it was nearing time to refuel the reactor would have its maximum radiological inventory or "source term" for an

[18] TerraPower, Natrium ENCLOSURE 6, Major Accident Methodology Report, Public, TP-LIC-RPT-0010, March 26, 2024. 19 pages plus a cover sheet with 8 pages HEAVILY REDACTED. "The major accident event source term is identified as [[ ]](a)(4), which is an Unprotected Loss of Heat Sink (ULOHS) event." See https://www.nrc.gov/docs/ML2408/ML24088A059.html

[19] TerraPower, Natrium ENCLOSURE 4, Regulatory Exemptions, Public. See https://www.nrc.gov/docs/ML2408/ML24088A059.html

[20] Federal Register, Nuclear Regulatory Commission, US SRF Owner, LLC; Construction Permit Application, May 21, 2024, https://www.federalregister.gov/documents/2024/05/21/2024-10726/us-sfr-owner-llc-construction-permit-application On March 28, 2024, TerraPower, LLC, on behalf of US SFR Owner, LLC, a wholly owned subsidiary of TerraPower, filed an application for a construction permit for a single-unit power reactor facility located in Lincoln County, Wyoming. The single unit facility is to be identified as KemmererPower Station, Unlit 1 and would be based on the TerraPower and General Electric-Hitachi Natrium reactor design which is a pool-type sodium fast reactor using metal fuel.

accident. Because conventional reactors use less than 5 percent enriched fuel and Natrium would use close to 20 percent enriched fuel, the Natrium reactor can have about 4 times as high of radiological inventory as a conventional reactor. This means that potentially the 345-MWe Natrium poses accident consequences exceeding a 1000-MWe conventional light-water reactor.

The Natrium will be unlike any nuclear reactor the U.S. NRC has licensed, and is being called an "advanced reactor" that is based on the Department of Energy's Experimental Breeder Reactor II (EBR-II) and is based on General Electric-Hitachi Natrium sodium fast reactor technology. The fuel will be metallic uranium-zirconium (U-10Zr) high-assay low-enriched uranium (HALEU) with a sodium bond to HT9 cladding, so disposal will require special treatment that can be expected to be an additional cost not factored into the construction costs.

The Department of Energy is defining "advanced reactor" in a way that does not assure advanced reactors will be safer than conventional light-water reactors. (See the definition of "advanced nuclear reactor" in a later article in this newsletter.)

The NRC's website states that the balance-of-plant (BOP) systems (the steam turbine and generator) proposed for Kemmerer Unit 1 are like those used in the current fleet of light-water reactors (LWRs), with the exception of the molten salt tanks. The containment type is "functional containment" that will be whatever TerraPower wants the containment to be. There are no hard requirements as long as TerraPower says that their reactor doesn't need much of a containment (see SECY-18-0096). Bill Gates need not worry — if there is any revealing information, the NRC will redact it so citizens can't see it. Anyway, the NRC can make up new rules just for Bill Gates and for other so-called "advanced reactors."

TerraPower has already submitted a preliminary CP [construction permit] application which the U.S. Nuclear Regulatory Commission (NRC) staff found generally contained the expected information. The NRC staff had identified about 125 items requiring additional information but it isn't clear what submittal satisfied the information requests. [21]

Nuclear Boosters sneak nuclear promotion bill (ADVANCE) into a Fire Protection bill (S.870), seeking to further undermine nuclear regulatory oversight in the U.S.

In a Senate bill, S.870, titled "An Act to amend the Federal Fire Prevention and Control Act of 1974 to authorize appropriations for the United States Fire Administration and firefighter assistance grant programs," nuclear boosters are sneaking in their pro-nuclear ADVANCE act bill. [22]

---

[21] U.S. Nuclear Regulatory Commission letter to TerraPower, LLC, Subject: TerraPower, LLC, - Preapplication Readiness Assessment Report for Kemmerer Power Station Unit 1 Preliminary Construction Permit Application, March 19, 2024. https://nrc.gov/ML2406/ML24060A227.pdf

[22] See Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act, or https://docs/house.gov/billsthisweek/20240506/S 870 Peters updated.pdf

The nuclear-at-any-cost nuclear boosters want to get the Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act passed and are willing to do whatever they can to sneak it through. This bill seeks to boost nuclear deployment by "streamlining" the U.S. Nuclear Regulatory Commission's licensing process for advanced reactors. Fixing this bill to the Federal Fire Prevention and Control act bill to sneak it through isn't the way to do it.

This short-sighted bill doesn't seek to address existing problems with the U.S. Nuclear Regulatory Commission's oversight of existing and new nuclear reactors. Any positive aspects of the ADVANCE bill are watered down and made ineffective.

The NRC is already more focused on saving electric utilities money on their nuclear reactors then on public safety. The NRC is already granting premature and misleading licensing approvals as it did when it partially approved NuScale's application despite serious deficiencies in its license application for its earlier lower power version. NuScale then submitted an application for higher power levels, yet kept touting the previous NRC approval of the earlier NuScale design, an approval had left important issues unresolved. In other words, the NRC ended its review based on a time schedule and not on it actually completing its review work. The NRC approved the NuScale design on schedule while leaving important safety issues unresolved, putting off resolution of the issues for later. [23]

The U.S. Nuclear Regulatory Commission (NRC) and the U.S. Department of Energy played propaganda games with regard to propping up the proposed NuScale small modular reactor.

When the Department of Energy issued its press release in August 2020 that said the U.S. Nuclear Regulatory Commission had approved the NuScale design, DOE's website stated "The final safety evaluation report [FSER] issued by the NRC is the first of its kind for a SMR and represents the technical review and NRC staff's approval of the NuScale SMR design." [24]

Former NRC commissioner and former Assistant Secretary for the Department of Energy Office of Nuclear Energy Pete Lyons weighed in writing that "The NRC's issuance of the final safety evaluation report for NuScale's small modular reactor means that issues and questions related to the safety of NuScale's design have been resolved and affirms that the technology meets the United States' highest nuclear regulatory requirements. As former members of the regulatory bodies responsible for these types of review, we can assure the Post Register's readers that the NRC would not have issued NuScale's approval if it did not have every assurance the technology was safe." [25]

---

[23] Environmental Defense Institute's November 2020 Newsletter article "U.S. Nuclear Regulatory Commission cautions that its recent NuScale approval does not mean NRC will approve a NuScale construction permit or an operating license" at http://www.environmental-defense-institute.org/publications/News.20.Nov.pdf

[24] U.S. Department of Energy, Office of Nuclear Energy, NRC Approves First U.S. Small Modular Reactor Design at https://www.energy.gov/ne/articles/nrc-approves-first-us-small-modular-reactor-design

[25] Peter Lyons and Luis Reyes, Opinion editorial, *The Idaho Falls Post Register*, "Trusted and ready – the CFPP [Carbon Free Power Project that NuScale would power] is a success in the making," October 18, 2020.

But the U.S. NRC's communications to the Idaho Leadership in Nuclear Energy Commission at its October meeting[26] and to NuScale in writing state that "… this SDA [standard design approval] does not constitute a commitment to issue a permit, design certification (DC), or license…." [27] [28]

The U.S. NRC issued the FSER with numerous exclusions because NRC did not have sufficient information to approve various aspects of standard design. What this means is that the NRC did not finish its work and prematurely issued the FSER. The reason the NRC issued the incomplete FSER is apparently only because the NRC had a scheduled milestone to complete that phase of the NuScale review. [29] Two main parts of NRC's approval are to issue the FSER and then to review any the site-specific application for a combined operating license which is what UAMPS intends to do, that is, if it ever decides on a specific site at the Idaho National Laboratory. The NRC, by having left many unresolved safety issues, will leave these issues to be addressed by a future combined license (COL) applicant, namely, UAMPS.

The aspects of the NuScale design that the NRC excluded from approval in the FSER that it issued August 2020 are whoppers in terms safety and the potential for spirally costs. The full NRC Final Safety Evaluation Report (FSER) can be found at the NRC website. [30] NuScale has also requested numerous exemptions from NRC regulations. [31]

The NRC was provided insufficient information from NuScale's design certification application [32] regarding: (1) the shielding wall design in certain areas of the plant; (2) the potential for containment leakage from the combustible gas monitoring system; and (3) the

---

[26] 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

[27] 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

[28] 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

[29] Anna Bradford, U.S. Nuclear Regulatory Commission, PowerPoint Presentation on Design Certification of the NuScale Small Modular Reactor, May 28-29, 2018. https://www.ifnec.org/ifnec/upload/docs/application/pdf/2018-06/20.a_bradford_design_certification_of_the_nuscale_small_modular_reactor.pdf The presentation gives the schedule for the NRC to complete the review of its Final Safety Evaluation Report for NuScale as September 8, 2020. Is schedule the main reason NRC issued the FSER in August while leaving many safety issues unresolved?

[30] U.S. Nuclear Regulatory Commission website, Phase 6 – NuScale DC Final Safety Evaluation Report (Complete with Appendices) at https://www.nrc.gov/docs/ML2002/ML20023A318.html

[31] Anna Bradford, U.S. Nuclear Regulatory Commission, PowerPoint Presentation on Design Certification of the NuScale Small Modular Reactor, May 28-29, 2018. https://www.ifnec.org/ifnec/upload/docs/application/pdf/2018-06/20.a_bradford_design_certification_of_the_nuscale_small_modular_reactor.pdf The presentation lists fifteen specific NuScale requested exemptions from NRC regulations on page 10.

[32] NuScale's Standard Plant Design Certification Application to apply for standard design approval can be found at https://www.nrc.gov/reactors/new-reactors/smr/nuscale/documents.html

ability of the steam generator tubes to maintain structural and leakage integrity during density wave oscillations in the secondary fluid system…" [33]

Again, what this means is that the NRC issued its approval of NuScale with exclusions that involve important safety issues and the Department of Energy is providing propaganda to the public by failing to acknowledge these exclusions.

The NRC, after the 2011 Fukushima nuclear disaster, put a high priority on NOT improving the safety of proposed but not-yet-built nuclear plants. The NRC's belated and tepid response to the 2011 nuclear accident at Fukushima are described in Gregory Jaczko's *Confessions of a Rogue Nuclear Regulator*. [34]

In 2021, U.S. Nuclear Regulatory Commissioner Kristine Svinicky touted that more former Department of Energy employees are taking key roles at the NRC. And Congressmen like Mike Simpson press for streamlined licensing of new reactor designs. And the experience with NuScale's U.S. Nuclear Regulatory Commission licensing shows that the time allotted and the outcome of the licensing review are both predetermined. This does not bode well for nuclear reactor safety in the U.S.

The U.S. Nuclear Regulatory Commission has continued to license unsafe storage of spent nuclear fuel in systems by using the excuse that the NRC doesn't have to worry about what happens after the short licensing period expires. The U.S. NRC has long put a high priority on electric utility financial interests — and virtually no concern for rate payers and taxpayers.

The U.S. Department of Energy has the responsibility for research to show that long-term storage and transportation of spent nuclear fuel can be conducted safely. The DOE admits that it is falling farther and farther behind of needed research for the spent nuclear fuel already generated.

The Department of Energy is indiscriminately promoting any and every possible nuclear technology and wants this wide variety of immature technologies to have a greased approval by the U.S. NRC that approves licenses. The ADVANCE bill advances the ill-conceived no-nuclear-reactor-behind approach, no matter what the cost to electricity rate payers, the cost to tax payers in promoting the technologies nor the cost to future generations who will pay for managing and disposing of the spent nuclear fuel — or face mass evacuations and long-term environmental contamination.

Energy leaders have been working to get the "Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act," to the president's desk for months. The

---

[33] 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 (Don't bother looking at the letter NRC made easily accessible from its webpages for NuScale at https://www.nrc.gov/docs/ML2023/ML20231A804.pdf)

[34] Gregory B. Jaczko, *Confessions of a Rogue Nuclear Regulator*, Simon & Schuster, 2019. ISBN 978-1-4769-5576-2 Jaczko is a former chairman of the U.S. Nuclear Regulatory Commission.

legislation, a compromise agreement between the House Energy and Commerce and Senate Environment and Public Works committees, aims to help the NRC boost nuclear deployment by increasing hiring at the agency, streamlining the licensing process for advanced reactors and promoting the development of fusion technology.

According to the ADVANCE bill, the definition of an advanced reactor is as defined by 951(b) of 42 USC 16271(b) https://www.govinfo.gov/content/pkg/BILLS-116hr6097ih/html/BILLS-116hr6097ih.htm and it means any nuclear reactor or fusion reactor. The definition of advanced reactor does not mean it meets any particular safety standard. The definition given, of an advanced nuclear reactor, means

(A) A nuclear fission reactor, include a prototype plant (as defined in sections 50.2 and 52.1 of title 10, Code of Federal Regulations (or successor regulations)), with significant improvements compared to reactors operating on the date of enactment of the Nuclear Energy Research and Development Act, including improvements such as –

(i) Additional inherent safety features;

(ii) Low waste yields;

(iii) Increased fuel performance;

(iv) Increased tolerance to loss of fuel cooling

(v) Enhanced reliability;

(vi) Increased proliferation resistance;

(vii) Increased thermal efficiency;

(viii) Reduced consumption of cooling water and other environmental impacts;

(ix) The ability to integrate into electric applications and nonelectric applications;

(x) Modular sizes to allow for deployment that corresponds with the demand for electricity;

(xi) Operational flexibility to respond to changes in demand for electricity and to complement integration with intermittent renewable energy; or

(xii) Improved resilience; and

(B) A fusion reactor

In others words, an “advanced nuclear reactor” is in no way clean, safe, affordable, or likely to be deployable in time to combat climate change. It is just a way to shuffle taxpayer money to Bill Gates and other influential recipients.

The House has already passed the Fire Protection combined with the added nuclear booster ADVANCE language. The Senate has come close to obtaining a unanimous consent agreement

for passage. If the Senate doesn't pass the patched-up bill, expect it to be hitched to the 2025 National Defense Authorization Act. [35]

House and Senate members are misinformed by the Department of Energy and the public is uninformed as the mainstream media won't print the truth about nuclear energy.

So-called advanced nuclear reactors are not proven to be as safe as conventional reactors, let alone safer. Putting pressure on the U.S. Nuclear Regulatory Commission to shortcut nuclear reactor regulation will further undercut safety of nuclear reactors, whether large, small, or micro-sized. Cutting the regulatory costs will do little to lower the construction costs and won't lower the costs of managing and disposing of the spent nuclear fuel.

Small and micro-sized reactors do not reduce the "back-end" nuclear waste problems – they increase the nuclear waste problems. Reprocessing is polluting and expensive. The potential ability of a deep geologic repository to safely confine the waste remains a speculative and obscenely expensive experiment. Replacement power for nuclear energy will remain needed for unreliable nuclear energy when safety or reliability problems arise. And despite the hype, nuclear energy deployment will rely on fossil fuel plants. The so-called advanced reactors remain vulnerable to terrorism and warfare. Routine radiological emissions from nuclear plants have already caused more health harm to Americans than the nuclear industry is admitting. Compensation for the property damage and health harm to citizens adversely affected by radiological releases may be nil, especially for reactor modules below 100 MWe based on the Price Anderson Act. The plethora of technically immature advanced reactors being promoted by the Department of Energy assures only the maximum burden on the U.S. taxpayer, and is a diversion away from appropriate solutions.

Airborne radiological releases from routine operation of nuclear reactors ignored by 2022 NAS report

Although a tardy and incomplete report, the 2022 National Academy of Sciences report, *Leveraging Advances in Modern Science to Revitalize Low-Dose Radiation Research in the United States,* stated that "There is also increasing evidence that low-dose radiation exposure may be associated with non-cancer health outcomes such as cardiovascular disease, neurological disorders, immune dysfunction, and cataracts." [36] While that statement seemed hopeful and the 2022 NAS report does contain some useful information, the report overall reveals that NAS is far more interested in the health of the nuclear industry than the health of humans.

---

[35] Zach Bright and Nico Portuondo, *Eenews*, "White House makes push for large nuclear reactors," May 30, 2024. https://www.eenews.net/articles/white-house-makes-push-for-large-nuclear-reactors/?utm_medium=email

[36] National Academies of Sciences, Engineering, and Medicine, *Leveraging Advances in Modern Science to Revitalize Low-Dose Radiation Research in the United States*, Washington, DC: The National Academies Press, 2022. http://nap.nationalacademies.org/26434 or https://doi.org/10.17226/26434.

The 2022 NAS report, by ignoring the airborne radiation long known to be released from pressurized water and boiling water reactors, has ignored the tremendous problem in internal radiation. The 2022 NAS report simply states that routine operation of nuclear reactors gives radiation doses far below 1 millirem annually, stated as "<< 0.01 mSv" (see Table 2.1 of the report which says this figure includes inhalation, ingestion and external exposure). Yet, an earlier 2012 NAS report acknowledges far higher radiation doses near operating nuclear power plants. Dresden, for example, gave a 14 mrem/yr whole body dose just from the noble gases (see Table 3.2).

The earlier 2012 NAS report often gave external radiation doses as measured as absorbed dose in air and these doses were typically below 1 millirem per year. But these external doses do not include the inhalation dose or ingestion doses. And importantly, whole body external doses tell only part of the story.

Internal doses and specifically the organ doses are what really reveal the harmful radiation doses. No wonder the nuclear industry does not want to talk about the internal doses or the actual organ doses. The developing child in utero needs a healthy thyroid in order to be ready to breath when born — that thyroid dose matters and it can be FAR above natural background levels near nuclear operations.

The 2022 NAS report basically ignores the known occurrence of nuclear reactor radiological airborne emissions that historically have contaminated air, food and water. Cows graze on contaminated pastures and then the milk that mothers and children drink is contaminated. Monitoring of milk was conducted and yet limits on radioactive contamination was not based on sound science, certainly not for the developing child in utero.

Some radiological releases from nuclear reactor operations are ongoing and other releases are sporadic. Monitoring programs, even when properly designed, tend to be conducted in a manner to conceal the full extent of radiological contamination.

The earlier 2012 NAS study acknowledged the airborne and liquid effluent radiological releases, stating "At present, nuclear plants typically release between a few curies and several hundred curies per year in airborne effluents." [37]

To the nuclear industry, averaging the contamination levels throughout the year is adequate. And to the nuclear industry, emphasizing the average release from a nuclear plant is acceptable. But the variability matters, especially the maximum levels that the unborn, developing child in utero is exposed to. There is variability due to differing plant designs, variability due to particular operating modes (such as refueling a boiling water reactor), and variability to due plant degradation such as steam generator tube ruptures in pressurized water reactors.

[37] Committee on the Analysis of Cancer Risks in Populations near Nuclear Facilities, Nuclear and Radiation Studies Board Division of Earth and Life Studies, National Research Council of the National Academies, *Analysis of Cancer Risks in Populations Near Nuclear Facilities: Phase 1*, 2012. ISBN 978-0-309-25571-4

Airborne radiological releases at the Fort St. Vrain high-temperature gas-cooled reactor that used TRISO fuel increased unexpectedly as the fuel burnup increased. [38] "The increase in the fission gas release is most likely due to an increase in the in-service fuel particle failure which has reached a high enough level to have a noticeable impact on fission gas release…" The elevated airborne radiological releases occurred at the Fort St. Vrain reactor despite operations not exceeding normal temperatures. See information about the design of the Fort St. Vrain nuclear reactor in GAO/RCED-88-8 from 1987. [39] [40] [41]

The Fort St. Vrain reactor appears to have not adequately monitored its airborne radiological releases, especially its iodine releases.

Most of the airborne effluents are from radioactive iodines, krypton, xenon, argon fission and activation gases, and radioactive particulates such as cobalt-58, and cobalt-60, cesium-134 and cesium-137, chromium-51, manganese-54 and niobium-95, and tritium, see Table 1.

Table 1. Common radionuclides in reported airborne effluent releases from nuclear plants.

Category	**Commonly Reported Radionuclides**
Fission and activation gases	Krypton-85, Krypton-85m, Krypton-87, Krypton-88 Xenon-131, Xenon-131m, 133, 133m, 135, 138 Argon-41
Iodines/halogens	Iodine-131, Iodine-132, 133, 134, 135 Bromine-82
Particulates	Cobalt-58, Cobalt-60 Cesium-134, Cesium-137 Chromium-51 Manganese-54 Niobium-95
Tritium	Hydrogen-3

[38] V. Jovanovic, General Atomics, Radionuclide Methods Validation with FSV Data, DOE-HTGR-88358, September 1989.

[39] U.S. General Accounting Office, *Nuclear Safety Reactor Design, Management, and Emergency Preparedness at Fort St. Vrain*, GAO/RCED-88-8, November 1987.

[40] International Atomic Energy Agency, High Temperature Gas Cooled Reactor Fuels and Materials, IAEA-TECDOC-1645, 2010.

[41] Public Service Company of Colorado, Fort St. Vrain Nuclear Station, *Annual Radioactive Effluent Release Report, January – December 1995*, March 1996. https://nrc.gov/ML2010/ML2010F186.pdf

Table source: U.S. Nuclear Regulatory Commission, *Radioactive Effluents from Nuclear Power Plants, Annual Report 2007*, Office of Nuclear Reactor Regulation, 2007. See also NAS Analysis of Cancer Risks in Populations Near Nuclear Facilities: Phase I, 2012, page Table 2.1.

Pressurized water reactors (PWRs) generally released more tritium than boiling water reactors (BWRs). Both PWRs and BWRs release fission/activation gases and tritium. However, BWRs generally released greater quantities of radionuclides than PWRs prior to about 1980, according to the 2012 *Analysis of Cancer Risks in Populations Near Nuclear Facilities: Phase I* report. BWRs release more iodine and "particulates," such as cesium-137, than PWRs.

Both BWRs and PWRs exhibit significant variability in releases of all airborne effluent categories, about six orders of magnitude of variability in noble gas releases, over seven orders of magnitude of variability in iodine releases; over four orders of magnitude of variability in particulates releases; and about three orders of magnitude variability in tritium releases. In general, the variability differences are greater among PWRs than BWRs.

Problems were noted by citizens but ignored by the nuclear regulators around the Limerick plant. [42] [43] Concerned citizens asked not to be ignored. But that is exactly what has happened. The elevated cancer incidence, childhood cancer deaths, elevated infant and neonatal mortality and learning disabilities didn't matter to the nuclear promoters.

That 2022 NAS report ignored the variable airborne radiological releases from pressurized water and boiling water reactors as it cited a selected and low-balled radiation exposure of 1 millirem dose to the public from nuclear power plants. [44] It ignored the tremendous problem in internal radiation, especially for children and the unborn, developing child. The 2022 NAS report has proven one thing: NAS cannot be trusted to study anything as precious as human health.

[42] Dr. Lewis Cuthbert, Alliance for a Clean Environment, *More Protective Radiation Standards – PRM-51-11* (comment submittal), January 29, 2007. https://www.nrc.gov/docs/ML0703/ML070300663.pdf

[43] Dr. Lewis Cuthbert, Alliance for a Clean Environment, *Tooth Fairy Research Results Reported, Child Cancer Soars in Montgomery, Philadelphia Counties Rising Radiation from Limerick Nuclear Plant May Be Cause, April 14, 2005 (and more) (Comment submittal)*. https://www.nrc.gov/docs/ML1130/ML11306A245.pdf " 'High local levels of Sr-90 and childhood cancer after Limerick began operations must be taken seriously by plant operators and regulators.' Limerick, a plant with two reactors, began operations in December 1984 and reached full capacity in January 1990. During the early years of operation, cancer and leukemia death rates for children under age 15 in both Montgomery and Philadelphia Counties were well below the national rate. But in the post-startup period (1991-2002), cancer mortality jumped 48.0% and 22.3 %, respectively, compared to a national decline of 20.3 %. For leukemia deaths, rates rose 16.0 % and 46.4 %, compared to a national decline of 27.6 %. Montgomery and Philadelphia counties lie southeast of Limerick, which is the downwind direction for much of the year."

[44] National Academies of Sciences, Engineering, and Medicine, *Leveraging Advances in Modern Science to Revitalize Low-Dose Radiation Research in the United States*, Washington, DC: The National Academies Press, 2022. http://nap.nationalacademies.org/26434 or https://doi.org/10.17226/26434.

Improper comparisons of fossil fuel pollution to nuclear energy's health harm are being made to booster nuclear energy

Time magazine had an article this May 2024 that wrongly called nuclear energy "clean" and then improperly compared the nuclear industry's claimed historic fatalities from accidents to estimated deaths from air pollution from burning fossil fuels. [45]

The article stated that burning fossil fuels is estimated to cause 5 million deaths every year while the civil nuclear industry's historic fatalities across seven decades are in the low thousands. The Time article did not cite specific references for these fatality estimates but it appears to be a 2023 article from the BMJ which states: "An estimated 5.13 million (3.63 to 6.32) excess deaths per year globally are attributable to ambient air pollution from fossil fuel use…" [46]

The countries most harmed by burning fossil fuels appear to be India and China, not the United States. Also, the article does not distinguish coal from other fossil fuels, does not address the reduction in pollution from scrubber installation, for example. [47]

The article in *Time* cited civil nuclear industry accident deaths which low-balls the estimated deaths from nuclear accidents, completely ignores the deaths from routine emissions and the uranium fuel cycle, and ignores the future generations that will be harmed by future releases of radioactivity from nuclear waste storage and disposal.

The article should have said that fossil fuels had very few accident deaths and that the 1986 Chernobyl accident alone is responsible for over one million deaths according the independent analysis rather than estimates from nuclear energy promotors. [48]

The study of deaths caused by nuclear energy would have been useful. But the U.S. NRC cancelled what would have been the first meaningful epidemiology study of health effects near US nuclear reactors, [49] despite the German epidemiology study of children living near nuclear plants have roughly double the incidence of cancer and leukemia and similar findings resulted

---

[45] Charlie Campbell, *Time*, "Uranium dreams," May 27, 2024.

[46] Jos Lelieveld et al, BMJ, "Air pollution deaths attributable to fossil fuels: observational and modelling study," doi: 10.1136/bmj-2023-077784, November 2023. https://www.bmj.com/content/383/bmj-2023-077784 See also https://www.bmj.com/company/newsroom/air-pollution-from-fossil-fuel-use-accounts-for-over-5-million-extra-deaths-a-year/ Air pollution from fossil fuel use accounts for over 5 million extra deaths a year.

[47] L. Henneman et al., *Science* 382(6673);941-946; doi: 10.1126/science.adf4915, Mortality risk from United States coal electricity generation, November 24, 2023. PMID: 37995235 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10870829/ and https://www.nih.gov/news-events/nih-research-matters/deaths-associated-pollution-coal-power-plants

[48] Alexey V. Yablokov, Vassily B. Nesterenko, and Alexey V. Nesterenko, Consulting Editor Janette D. Sherman-Nevinger, *Chernobyl – Consequences of the Catastrophe for People and the Environment*, Annals of the New York Academy of Sciences, Volume 1181, 2009.

[49] 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.

from the study of clusters of childhood leukemia near nuclear sites including Sellafield, Dounreay and La Hague where an excess of 300-fold infant leukemia were found. [50] [51] [52]

Nuclear promotors have focused on cancer deaths, ignoring other adverse health outcomes and then refused to adequately study even the cancer deaths.

Airborne radiological releases from nuclear power plants affect downwind residents but contaminated foods are distributed unevenly. Radioactive contamination that lands on pastures grazed by dairy cattle results in radioactively contaminated milk. Radioactive contamination also affects garden produce. Thus, the inhalation and ingestion of radionuclides varies according to location as well as diet. The harm depends on gender and the age of exposure and it is known that women are more vulnerable than men, and children are more vulnerable than adults. Radiological sampling of milk that was conducted in the U.S. allowed levels of radioactivity that we now know were harmful. Diminishing radioactivity levels in the diet were accompanied by immediate and significant morbidity and mortality reductions among infants and young children, from 1965 to 1970.

Joseph J. Mangano and others published a study, "Infant Death and Childhood Cancer Reductions after Nuclear Plant Closings in the United States. The study found that following nuclear power plant closures, decreases in the radioactivity of milk has been noted and reductions in deaths among infants who had lived downwind and within 64 km of each nuclear plant were noted. Cancer incidence in children younger than 5 years of age were also noted to fall significantly after the shutdowns. [53]

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. [54]

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. [55]

---

[50] P Kaatsch et al., Int J Cancer, "Leukaemia in young children living in the vicinity of German nuclear power plants," 2008 Feb 15;122(4):721-6. http://www.ncbi.nlm.nih.gov/pubmed/18067131

[51] Spix C, Schmiedel S., Kaatsch P, Schulze-Rath R, Blettner M., Eur J Cancer, "Case-control study on childhood cancer in the vicinity of nuclear power plants in Germany 1980-2003." 2008 Jan;44(2):275-84.Epub 2007 Dec 21. http://www.ncbi.nlm.nih.gov/pubmed/18082395

[52] Chris Busby, "Infant Leukaemia in Europe after Chernobyl and its Significance for Radioprotection; a Meta-Analysis of Three Countries Including New Data from the UK," Chapter 8 of *ECRR Chernobyl: 20 Years On – Health Effects of the Chernobyl Accident*, Editors C.C. Busby and A. V. Yablokov, 2006.

[53] Joseph J. Mangano, Jay M. Gould, Ernest J. Sternglass, Janette D. Sherman, Jerry Brown and William McDonnell, Radiation and Public Health Project, "Infant Death and Childhood Cancer Reductions after Nuclear Plant Closings in the United States," *Archives of Environmental Health*, Vol. 57 (No.1), January/February 2002.

[54] 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.*

[55] 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

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. [56]

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. [57]

NWTRB holds meeting on spent nuclear fuel disposal research to discuss spent nuclear fuel degradation far in the future inside a repository – as near-term spent nuclear fuel storage degradation of canisters and fuel actively ignored

The U.S. Nuclear Waste Technical Review Board (NWTRB) held a meeting at Oak Ridge on spent nuclear fuel disposal on May 21 and 22, 2024. [58] Since the defunding of effort on the proposed Yucca Mountain repository in 2010, the Department of Energy has been conducting generic research of geologic disposal of spent nuclear fuel.

David Sassani, Spent Fuel and Waste Science and Technology (SFWST) National Technical Director at Sandia National Laboratories presented an overview of geologic disposal research and development activities at the meeting. [59]

The research includes investigations of three host rock types: argillite, crystalline and salt; geologic disposal safety assessment; investigation of direct disposal of dual-purpose canisters now being used at commercial nuclear power plants; engineered barrier systems R&D; and inventory and waste form characteristics and performance. Also, under SFWST R&D is spent

---

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.

[56] 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.

[57] 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

[58] U.S. Nuclear Waste Technical Review Board, created by to review nuclear waste programs and report to Congress and the President. See reports, meeting presentations and meeting transcripts at https://www.nwtrb.gov

[59] David Sassani, Sandia National Laboratories, Spent Fuel and Waste Science and Technology, For the U.S. Department of Energy, Overview of Disposal R&D Activities, Presented at the U.S. Nuclear Waste Technical Review Board meeting May 21, 2024. https://www.nwtrb.gov

nuclear fuel storage and transportation research, including dry storage canister stress corrosion cracking research. The main message he offered is that the spent fuel and waste science and technology research and development structure is "EVOLVING."

The disposal research is at the Concept Evaluation stage. Later stages are Site Selection and Site Characterization and then Repository Development. There has been no movement beyond the Concept Evaluation stage since 2010 and no particular plan to move to the contentious site selection phase.

Geologic disposal safety assessment (GSDA) uses a code called PFLOWTRAN to model the waste radionuclide inventory, waste package degradation, radionuclide release flow and transport, and exposure pathways and radiation dose calculations.

Features, Events, and Processes (FEP) Evaluations are identified for the repository system. "Features" are physical components of the repository system such as the host rock and engineered barrier systems. "Processes" are phenomena that act continually over a long time scale. "Events" are phenomena that occur over a short time scale, such as seismic events, igneous events (volcanic or basalt flow events), criticality events, rock fall, deflagrations, etc.

Criticality events are made more likely by higher enriched in uranium-235 nuclear fuels and by waste packages that contain more spent fuel. The "direct disposal" of existing spent nuclear fuel canisters poses a far higher criticality risk than was assumed with the proposed use of TADs in the Yucca Mountain concept, with lower enriched fuel and a lower quantity of fuel in each TAD. The criticality potential of stored spent nuclear fuel does not peak for 25,000 years. Screening of FEPs has typically led to efforts to exclude difficult problems by application of dicey low probability arguments.

Research for the Department of Energy is being conducted on a variety of potential geologic repository types such as crystalline, clay or salt, but isn't focused on any particular sites. Research is addressing limited types of spent nuclear fuel, but the Department of Energy is promoting a variety of new fuel types that will require management and disposal. Discussion of the real problems and the costs would be a buzz kill for nuclear energy — and so, in my opinion, presenters at the meeting carefully avoided candid discussion of the problems.

Presentations of geological repository studies conducted in other countries often don't discuss why their total inventory of spent fuel, type of spent fuel and its burnup differ greatly from the situation in the U.S. In fact, presenters seem to go out of their way to avoid admitting some of the significant differences between their spent fuel type and total inventory versus the United States. They also seem to stress how safe their programs are – without a basis for doing so.

The research is not being coupled with actual tests using realistic conditions. The research can address types of spent fuel the U.S. already has, but may never keep up with the expanding variety of new spent nuclear fuels.

Obtaining a repository design that will actually confine the waste may become another expensive, failed experiment conducted at tax payer expense to the detriment of all living beings on the planet.

There is much work and research to be done. And there are brilliant people doing this work. But with the Department of Energy at the helm, there appears to be more interest in creating the illusion of a solution than in actually obtaining a solution.

This meeting made little mention of the Department of Energy's push to use "direct disposal" of the existing spent fuel canisters. These canisters can't be expected to last more than 80 years, yet, the Department of Energy does not want to admit the cost of repackaging for continued storage of spent nuclear fuel.

The DOE and its contractors make jumbled statements to avoid stating just how long the existing dry storage spent nuclear fuel canisters will last. DOE refuses to put too fine a point on the estimated time to spent nuclear fuel canister breach at the over 70 spent nuclear fuel storage sites in the U.S. The truth is forbidden — because it would make it more difficult to connive and bribe a community into selling out their land for consolidated interim storage of spent nuclear fuel that has no repository to send the spent fuel to.

The Yucca Mountain repository program was ended – but has never actually been taken off the table of Department of Energy's potential plans. Continued research may show, over time, just how flawed the Yucca Mountain design by the Department of Energy and the regulatory review by the Nuclear Regulatory Commission was.

The benefits of salt repository disposal and borehole disposal were extolled at the meeting.

In 2019, James Jerden and other reported on spent nuclear fuel matrix degradation in a repository. [60] The report listed the most important hydrogen-producing alloys present within a waste package might include stainless steel, carbon steel, and aluminum alloys and Zircaloy fuel cladding. The need for experimental data from electrochemical corrosion tests was recognized in 2019.

Some testing is being conducted to study the effect of individual variables on surface reaction kinetics. [61] These closely controlled experiments may provide needed and useful information. But "accurately" predicting long-term spent nuclear fuel corrosion rates seems an odd focus when spent fuel exposed to oxygen splits the cladding and relocates, releasing gases and volatiles and allowing criticalities, and the severe oxidation of spent nuclear fuel can occur so rapidly in spent nuclear fuel storage now.

It should not be mistakenly thought that the U.S. is getting any closer to siting one or more repositories, let alone designing one, for the growing inventory of spent nuclear fuel in the U.S.

---

[60] James Jerden et al., Argonne National Laboratory, *Fuel Matrix Degradation Model Development Update: Alloy Corrosion Rates, Hydrogen Generation*, ANL/CFCT-19/12, September 30, 2019.

[61] Paul Mariner and Sara Thomas, U.S. NWTRB Meeting May 22, 2024, Knoxville, Tennessee, *Fuel Matrix Degradation Modeling and Electrochemical Testing*. See https://nwtrb.gov

Damaged spent nuclear fuel exposed to oxygen can "unzip" the cladding - Why it matters for dry storage of spent fuel as well as disposal

Light-water reactors use nuclear fuel made of uranium oxide fuel surrounded by a thin cladding. "When in an air environment, UO_2 fuel with cladding breaches has been observed to oxidize and generate U_3O_8 powder given sufficient time at an elevated temperature. During the oxidation process, **the oxidized fuel swells and may cause further degradation of the CSNF [commercial spent nuclear fuel] cladding (a process known as clad unzipping).** The potential consequence of fuel oxidation is the loss of containment of radioactive materials and the resultant contamination inside the fuel handling facilities or waste container, the potential for unforeseen criticality scenarios, and increased dose rates to the public and workers." [62]

Nuclear fuel in commercial light-water nuclear reactors use uranium pellets about 0.37 inches in diameter and about 0.6 inches in length. The pellets are stacked end to end, to perhaps 12 feet in length. The pellets are surrounded by very thin cladding that is about 0.024 inches thick.

The long stack of small uranium oxide pellets, surrounded by thin cladding is called a fuel pin (or fuel rod). The number of fuel pins make up a fuel assembly. A pressurized water reactor may have over 39,000 fuel pins and over 217,000 lbs of uranium oxide. (Fuel specifications vary.)

The cladding protects the uranium pellets and provides a barrier for fission product releases from the pellet, but only if the cladding is not damaged or cracked. The cladding holds the pellets in their configuration and without the cladding, the pellets can relocate into a heap. A change in fuel pellet configuration could make it harder to cool the fuel. Any change in fuel pellet configuration may also pose a criticality concern.

When spent nuclear fuel is placed in a dry storage canister, the fuel has been removed from a reactor, cooled in a fuel storage pool perhaps for many years, and then dried and placed in a dry storage canister. Helium is put into the canister to create an oxygen-free environment for the spent nuclear fuel stored in a canister.

It may be necessary to repackage the spent nuclear fuel or the canister could be breached. Therefore, it is important to understand what happens if the spent nuclear fuel — the uranium oxide pellet and the cladding — is exposed to oxygen.

[62] Bechtel SAIC Company, LLC, Prepared for U.S. Department of Energy, *Commercial Spent Nuclear Fuel Handling in Air Study*, 000-30R-MGR0-00700-000-000, March 2005. https://www.nrc.gov/docs/ML0522/ML052200168.pdf

The Department of Energy acknowledged the gaps in the technical basis for continued storage of spent nuclear fuel, first in 2012. [63] Then in 2019, an additional gap was identified that was the lack of technical basis for understanding what the radiological consequences of a spent nuclear fuel canister breach would be. [64] The Department of Energy acknowledges that it is already behind in researching the technical basis for fuel already in storage. [65]

The Department of Energy knows that the radiological consequences of a breached spent nuclear fuel dry storage canister even from a single spent nuclear fuel canister may be severe, but knows that disclosing the actual magnitude of the hazard won't help it con the public into accepting nuclear energy or consolidated "interim" storage of spent nuclear fuel.

Therefore, the Department of Energy prefers false advertising to claim that spent nuclear fuel is stored safely, rather than to actually present defensible technical information about the potential radiological consequences of dry storage canister breach.

The U.S. Nuclear Regulatory Commission simply falls back on its excuse: the licensing period is short, i.e., 20 years, and we don't worry about what happens after that. The NRC, after all, licensed the dry storage canisters without concern about how long the canisters would be used for spent fuel storage. The NRC actually forbade any risk assessment of the dry storage canisters to consider aging mechanisms or corrosion failure modes – arguing that the limited licensing period meant there was no need to worry about it.

An analysis prepared for the proposed but never built Yucca Mountain repository studied the exposure of uranium dioxide fuel (UO_2) to oxygen. **Failed cladding or just the presence of undetected pinhole leaks or hairline cracks in the cladding would allow spent nuclear fuel exposed to oxygen to expose the uranium fuel pellet inside the cladding.**

The exposure of the fuel pellet UO_2 would allow oxidation of the UO_2. As the UO_2 oxidizes, it changes from a sintered pellet form to U_3O_8 powder, consisting of micron-sized particles. It the U_3O_8 powder is released from the fuel cladding, it will result in high levels of radioactive contamination of casks, waste packages, and fuel transfer areas of waste handling facilities. [66] If not confined to a building, the radiological airborne release exposes the public. Commercial spent nuclear fuel in the U.S. is not stored inside buildings. In other countries and with the naval spent nuclear fuel, that fuel is stored in buildings. This can protect the storage casks or canisters

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

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

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

[66] Bechtel SAIC Company, LLC, Prepared for U.S. Department of Energy, Commercial Spent Nuclear Fuel Handling in Air Study, 000-30R-MGR0-00700-000-000, March 2005. https://www.nrc.gov/docs/ML0522/ML052200168.pdf

and could allow for filtering of radionuclides if there was a radiological release. But in the U.S., saving electric utilities money is the U.S. NRC's primary concern.

The 2005 study for the Department of Energy's proposed Yucca Mountain repository estimated that only 4 percent of fuel assemblies would have some failed fuel rods and that 90 percent of failed fuel would be identified. But 10 percent of the failed fuel would not have been identified important pinhole leads and hairline cracks. This estimate is not necessarily accurate, but it does show the need to know how much of the fuel has been mishandled or has been operated in extreme conditions in a reactor.

The oxidation rate depends on fuel temperature and how many hours of oxygen exposure during transfer operations. The basis for estimating the fuel clad unzipping rate was recognized to need further evaluation.

The 2005 study also recognized that further study was needed to estimate the release fractions of gaseous fission products, volatile fission products, and oxidized fuel fines from the fuel during oxidation. Failed fuel when exposed to air will oxidize and fuel fines and volatile radionuclides will be released from the fuel cladding.

Unzipping of cladding could be a criticality concern if enough of the fuel rods in an assembly are involved.

A 2021 presentation by Sandia National Laboratories described the efforts to evaluate knowledge gaps in understanding existing spent nuclear fuels. The presentation stated that oxidation to U_3O_8 can rupture the cladding and result in fuel release and relocation. Furthermore, in addition to the need to study existing spent nuclear fuels, the long-term, lower temperature oxidation kinetics **of various new accident tolerant fuels and advanced fuels "ATF/AF"** and their susceptibility of cladding rupture are not known.

The higher density and higher enrichment ATF/AF fuels (such as those above about 5 percent enrichment in uranium-235) may increase the risk of criticality if the cladding unzips and the enough of the fuel pellets relocate within a cask or if the cask floods. Also, higher burnup fuels, above perhaps 60 Gigawatt Day/MetricTonsUranium (GWd/MTU) result in finer particles that can be dispersed upon cladding breach. The release fractions of radionuclides from the higher burnup spent nuclear fuel may differ from lower burnup fuel, yet the release fractions are not characterized for high burnup fuel.

The DOE's 2021 presentation also stated that "Triso and other designs will need a different test plan to quantify their mechanical properties, if further testing is warranted." And "Triso and other designs will not fit into the current storage and transportation container designs. New containers will need to be designed, tested, and manufactured." [67] Triso [or TRISO] fuel is tri-structural isotropic fuel that X-energy plans to use in high-temperature gas-cooled reactors. The

[67] Sylvia Saltzstein et al., Office of Nuclear Energy presentation, "Accident Tolerant and Advanced Nuclear Fuels: Back End Key Findings and Plans," Nuclear Waste Technical Review Board meeting, May 12-13, 2021. https://nwtrb.gov

TRISO fuel would use high-assay low-enriched uranium (HALEU) fuel, see my comments on the Department of Energy's promotion of HALEU feedstock on the Environmental Defense Institute website home page. [68]

A 2019 study [69] by the Oak Ridge National Laboratory considered spent nuclear fuel from dry storage where fuel elements are potentially at risk of exposure to air and elevated temperatures. While spent fuel is generally stored in an inert environment (such as helium) inside a bolted-lid cask or welded closed canister, removal of the spent nuclear fuel would involve handling operations that could be performed in an air environment. Oxygen could also enter cask or canister if damaged by incident or corrosion such as chloride-induced stress corrosion cracking. If any damaged fuel elements are present, the fuel exposed to oxygen could begin to oxidize for UO2 to U3O8. If the oxidation is severe, volume expansion from oxidation could result in large-scale cladding failure and large radiological releases. The 2019 Oak Ridge study considered the intentional handling of spent nuclear fuel in an oxygen environment and concluded that "Depending on the design of the fuel handling facility, any SNF [spent nuclear fuel] release could have an impact on off-site dose."

The 2019 Oak Ridge study listed the following phenomena that appear to warrant further study to determine how they affect spent fuel oxidation:

- Uranium oxide grain size
- Spent fuel burnup
- High burnup structure
- Cladding behavior for various cladding alloys, zircaloy-4 vs zircaloy-2, for example.
- Fuel pellet size (BWR pellets are larger than PWR pellets)
- Other factors, including cladding alloy creep and fracture toughness.

An additional and important factor is the amount of moisture in the air. [70]

Nothing much seems to have happened since 2019.

In 2006, the U.S. Nuclear Regulatory Commission found that a Department of Energy National Laboratory, LLNL, had never calibrated its measurements of humidity in corrosion tests. [71] This resulted in about 10 years of research for corrosion studies becoming worthless.

---

[68] Tami Thatcher, Public Comment Submittal on the Draft Environmental Impact Statement for Department of Energy Activities in Support of Commercial Production of High-Assay Low-Enriched Uranium (HALEU), DOE/EIS-0559, April 22, 2024. www.environmental-defense-institute.org/publications/CommentDOEhaleu2024.pdf

[69] Jason M. Harp and Andrew T. Nelson, Oak Ridge National Laboratory, Prepared for U.S. Department of Energy, *Oxidation of Spent Fuel During Fuel Handling Accidents Test Plan*, ORNL/LTR-2019/1299, September 2019. [Pub133310.pdf]

[70] Jason M. Harp and Andrew T. Nelson, Oak Ridge National Laboratory, Prepared for U.S. Department of Energy, *Oxidation of Spent Fuel During Fuel Handling Accidents Test Plan*, ORNL/LTR-2019/1299, September 2019. [Pub133310.pdf]

So, leaving the Department of Energy to conduct research does not mean the research will be conducted in a timely manner nor in a reliable manner. That is one reason why the Nuclear Waste Technical Review Board needs to play an important role in asking questions of DOE's contractors who conduct research at national laboratories. But with the NWTRB increasingly stacked with unquestioning nuclear boosters, the intended role of the NWTRB, to understand what the status is and tell it like it is, is being compromised.

INL's Integrated Waste Treatment Unit operated briefly in March before being shut down for bypassing filters and leaking waste drum problem still unresolved

Radioactive operations were restarted at the Idaho National Laboratory's Integrated Waste Treatment Unit this year in early March but were soon shutdown due to problems with the plant. The IWTU was built to treat the remaining liquid sodium-bearing radioactive waste now stored in aging tanks. The process offgas filter (PGF) was clogged up and so radioactive gases were bypassing the filter. Repairs at the IWTU could require challenging radiological work. [72]

The Department of Energy cancelled its previously planned April Idaho Cleanup Project citizens advisory board meeting, bringing the number of meetings for the year from four down to three.

The Idaho Cleanup Project managed by Idaho Environmental Coalition (IEC) oversees transuranic waste drum shipments from Idaho to the Waste Isolation Pilot Plant (WIPP) in New Mexico. Leaking transuranic waste drums previously had to be returned to Idaho after being shipped to WIPP. A specific waste packaging campaign resulted in liquid residual in waste drums and rapid corrosion of the drums, allow liquid to leak from the drums. WIPP decided that it needed the Idaho Cleanup Project to put the drums in special packaging and efforts have been made to procure flexible packing bags.

Between January 31, 2024 and February 7, 2024, addition waste drums were found to be leaking liquid at the Idaho Cleanup Project's AMWTP facility. Twenty-four drums had been previously identified as potentially containing residual liquids, which by the way, are prohibited at WIPP. One of the drums found had leaked previously and was "repaired." The leaking drums were generated about 6 or 7 years ago and involve the BN510 waste stream. [73]

---

[71] Richard P. Rechard, Michael D. Voegele, Evolution of repository and waste package designs for Yucca Mountain disposal system for spent nuclear fuel and high-level radioactive waste, Reliability Engineering and System Safety 122 (2014) 53-73, July 2013. http://dx.doi.org/10.1016/j.ress.2013.06.018

[72] U.S. Defense Nuclear Facilities Safety Board monthly reports for the Idaho National Laboratory for March and April, 2024 at https://www.dnfsb.gov

[73] U.S. Defense Nuclear Facilities Safety Board monthly reports for the Idaho National Laboratory for February and March 2024 at https://www.dnfsb.gov

The Defense Nuclear Facilities Safety Board (DNFSB) also reported that there are problems with new equipment at WIPP in New Mexico. [74] [75] The Board is concerned about inadequacies of the continuous air monitor, or CAM, in the WIPP underground mine. If the CAM detects radiological airborne contamination, damper closures that would divert air flow to high efficiency particulate air (HEPA) filters are supposed to be activated in order to reduce the radiological release from the facility to the environment. The nearly $500 million ventilation system installed after the WIPP radiological release in 2014, according to the Board, will not work with the CAMs properly in its current state. The CAM system has not been designed or demonstrated to perform its safety function in the WIPP's airborne salt and potential smoke-filled environment.

I want to note that the Idaho Cleanup Project's CAMS failed during the 2018 accident. The CAMS failed to work because of waste drum expulsion of material that clogged up and failed the CAM when four waste drums popped their lids in 2018. Emergency responders to the transuranic waste handling facility had no idea that a radiological event had occurred. The concern about reliability of CAMS during fires or off-normal conditions is very real. The Idaho National Laboratory has also had events where radiation monitors did alarm but were ignored due to improper understanding of error messages and the need for proper set up. The alpha alarms were calibrated for plutonium-239 but not for americium-241 which was released. This led to workers being bio-assayed, but 30 days late when hours matter.

Articles by Tami Thatcher for June 2024.

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

[74] Concerned Citizens for Nuclear Safety, DNFSB Still Concerned about Flaws in Emergency Air Monitoring at WIPP, May 23, 2024. http://nuclearactive.org/ and see https://www.dnfsb.gov/sites/default/files/document/30566/WIPP%20SSCVS%20Cam%20Design.pdf

[75] U.S. Defense Nuclear Facilities Safety Board, Letter to the Secretary of Energy, May 15, 2024 with attached staff report *Final Design of the Continuous Air Monitor (CAM) System for the Safety Significant Confinement Ventilation System (SSCVS) at the Waste Isolation Pilot Plant (WIPP)*, March 21, 2024 at https://www.dnfsb.gov