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RE: Comment on DOE "Notice of Intent to Prepare an Environmental Impact Statement for High-Assay Low-Enriched Uranium (HALEU) Availability Program Activities in Support of Commercial Production of HALEU Fuel"

Dear Mr. Lovejoy:

The undersigned organizations represent thousands of members concerned about civilian and military development of High-Assay Low-Enriched Uranium (HALEU), which is indelibly intertwined with another nuclear power plant technology renaissance. We hereby offer our comments in response to DOE's "Notice of Intent to Prepare an Environmental Impact Statement for High-Assay Low-Enriched Uranium (HALEU) Availability Program Activities in Support of Commercial Production of HALEU Fuel" that appeared in the June 5, 2023 Federal Register.[1] We are commenting for purposes of the scoping record for preparation of a congressionally-ordered Environmental Impact Statement on HALEU production and availability, and hereby request that our comments be made publicly available. We further ask that the within issues be considered in any Draft Environmental Impact Statement (Draft EIS) that may be prepared and that the Department of Energy publish formal responses as required by the National Environmental Policy Act (NEPA).

I. AMERICA'S HALEU FUEL PROGRAMS REQUIRE CUMULATIVE EFFECTS ANALYSIS BECAUSE THEY WILL INCREASE LOST LIVES AND HEALTH

In the Federal Register notice for this proceeding,[2] DOE solicited scoping comments that address:

• Potential effects on public health from exposure to radionuclides under routine . . . scenarios. . . .

• Potential impacts on surface and groundwater, floodplains and wetlands, and on water use and quality.

[1] https://www.govinfo.gov/content/pkg/FR-2023-06-05/pdf/2023-11877.pdf
[2] 88 Fed. Reg. at p. 36575.

• Potential impacts on air quality (including climate change) and noise.
• Socioeconomic impacts on potentially affected communities.
• Potential disproportionately high and adverse effects on minority and low-income populations.
• Potential cumulative environmental effects of past, present, and reasonably foreseeable future actions.

A. *Mounting Scientific Evidence Of Civilian Casualties Of Uranium Fuel Manufacture*

Recent "citizen science" has been putting proof to the proposition that America can no longer afford its civilian and military nuclear power and weapons programs. Around the PORTS facility at Piketon, Ohio, for example, recent chemical sampling of soil and air suggests that there is widespread regional contamination by radionuclides, while epidemiological analysis reveals surprising incidents of cancer among local residents which are difficult to explain away with a neighbor that has for nearly seven decades created a legacy of nuclear fuel enrichment and and nuclear weapons downblending for fuel.

- ☐ Present plans to scale up HALEU production will take place at existing, already contaminated nuclear industrial complexes. The new enrichment and/or downblending of radioactive materials projects will thus add to pre-existing radiological contamination and damage being caused to property and people's health and life prospects. Unlike non-radiological chemicals, radioisotopes can be extremely long-lived, causing contamination as heavy metals with the additional punch of irradiating flesh and making property unusable, and real property uninhabitable.

1. *The Poisoned PORTS Plant Complex*

Take the former Portsmouth (Ohio) Gaseous Diffusion Plant (PORTS), located near Piketon, Ohio. . Historically, the PORTS complex enriched Uranium for U.S. nuclear weapons and to fuel commercial nuclear reactors.

In May 2019, Zahn's Corner Middle School, located within four miles of PORTS, was permanently closed and slated for demolition after local officials reported enriched uranium and transuranic radionuclides were detected in dust inside the school. These significant radioactive contaminants were scientifically identified by Michael Ketterer, Ph.D., professor emeritus at Northern Arizona University.[3]

Dr. Ketterer has since documented additional residences contaminated by airborne radionuclides from PORTS, including a private house in Lucasville, Ohio, 10 miles from the

[3] https://www.ans.org/news/article-4481/report-links-u235-found-in-ohio-home-to-portsmouth/

PORTS site.[4] At Lucasville, Ketterer found unusual levels of U-235 and U-234 in dust samples from the home's attic, at concentrations elevated to a factor of 3.4, compared with natural levels.

The Zahn's Middle School revelations, together with Dr. Ketterer's ongoing investigative forensic work caused DOE to fund a larger sampling campaign, the Human Health Risk Assessment, on properties within a six-mile radius of PORTS. The study was overseen by the Pike County General Health District and Scioto Valley-Piketon Area Council of Governments**.** Following two years of gathering samples, the consultants Solutient and Auxier announced in their report[5] the presence of radioactive contamination in the form of Americium, multiple isotopes of Uranium, Neptunium, Technetium and Plutonium at, or exceeding, the risk-based screening level present on hundreds of sampled sites within the six-mile radius around PORTS. The two radionuclides contributing the most to the calculated health risks appeared to be Technetium-99 (Te-99) and Plutonium-238 (Pu-238).[6]

Further, an independent epidemiologist, Joseph Mangano, has analyzed public health and mortality data for Pike County, where PORTS is located, and also data for seven Ohio counties adjoining Pike County. In August 2022, Mangano determined that Pike County's cancer incidence from 2010-2019 was 15% higher than the U.S. and the highest rate of all 88 Ohio counties;[7] and that in the 1950s when PORTS opened, county cancer mortality was 12% below the U.S. He also determined that by 1993, the Pike rate surpassed the U.S. cancer rate and that the largest gap (+32.8%) occurred in 2019-2020. Mangano verified that in 2009-2020, the cancer death rate in the county exceeded the U.S. by about 50% for all age groups, except for persons over age 75 (0.5% below the U.S. average); that county all-cause mortality was <5% above the U.S. in the 1980s and early 1990s. By 2019-2020, however, the county rate was 42.3% greater. Finally, among persons 0-74, all-cause mortality in Pike County soared to 85.0% above the U.S. in 2017-2020, nearly twice that of the nation.[8]

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In his second, 2023, analysis, Mr. Mangano evaluated the public health and mortality data of seven Ohio counties downwind of PORTS. He compared those seven Ohio counties closest to/downwind of PORTS with six Ohio counties further from the plant ("control" counties). All 13 counties had similar population densities, racial/ethnic composition; and rates of poverty, education, unemployment, and health insurance. PORTS is located in the generally-impoverished Appalachian region within Ohio.

Mr. Mangano found that in the late 1990s, cancer incidence in both multi-county areas was 0.4% below the U.S. rate, but that by 2015-2019, the study counties rate exceeded the U.S.

[4] https://www.scribd.com/document/604959982/Ketterer-Lawson-18Oct2022-002
[5] https://drive.google.com/file/d/1rGW5SoanpDzcokutQFKHk-nuNPG74e-9/view
[6] https://drive.google.com/file/d/1zGDeRfkIbvUYh_MfwvedjRMDNMAkWumZ/view, Slides 11-18, 32.
[7] https://radiation.org/rphp-report-finds-soaring-death-rate-near-ohio-uranium-plant/
[8] *Id.*

by 17.5%, versus 8.8% in control counties.[9] In the 1970s, infant death rates were slightly above the U.S. in both areas (+4.4% and +1.6%). However, by 1999-2020, the excesses were +31.9% (study) and +9.9% (control). In the early 1970s, all-cause mortality rates in both areas were slightly above the U.S. But by 2017-2021, mortality in the study counties far exceeded the rate in the U.S. and control counties.[10] Mangano opined that:

> The large and growing gaps between study and control areas indicate that socio-economic factors – which have likely undergone similar changes over time - cannot account for most of the high rates near PORTS. Nevertheless, with 13,138 "excess" premature deaths (under age 75) in the seven study counties since 1974, a thorough evaluation of contamination from PORTS and the plant's current decommissioning process are in order.[11]

2. *Erwin, Tennessee and Nuclear Fuel Services: Another Sacrifice Zone*

A similar story is unfolding in Erwin, Tennessee, a town of 5000 adjoining the site of Nuclear Fuel Services (NFS), a 66-year-old nuclear fuel fabrication plant under DOE contract that has manufactured high-enriched Uranium (HEU) fuel for the nuclear Navy and also has down-blended nuclear weapons material for nuclear fuel. NFS admits there are traces of plutonium and other radionuclides routinely released from the plant into the adjoining Nolichucky River.[12] And Dr. Michael Ketterer has scientifically traced plutonium from NFS for a distance of 95 miles down the Nolichucky.[13] Ketterer has tested dust from the attic of a residence located roughly a mile from the NFS plant and found enriched uranium pollution present.[14]

Additionally, epidemiologist Joseph Mangano has undertaken a recent analysis of public health and mortality data for Unicoi County, Tennessee, where NFS is located. He determined that until the late 1990s, Unicoi County's all-cause death rate was about equal to the nation's. The Unicoi County rate has risen since, and is now 44% above the U.S. rate.[15] The premature mortality rate since the 1990s has risen to 61% above the U.S. rate. Since the early 1990s, Unicoi County's cancer death rate is now 39% above the U.S. rate. Mangano suggests that this trend was "unexpected" and that "No change in demographics, health behaviors, or access to medical care that could account for this trend is obvious, so further investigation is merited. . . . One potential

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[9] All citations in this paragraph are from Mangano's report, https://radiation.org/wp-content/uploads/2023/06/Portsmouth-2nd-report-final.pdf
[10] See table at p. 1 of Mangano's 2023 report, revealing stunning variations.
[11] *Id*.
[12] https://www.nrc.gov/materials/fuel-cycle-fac/fuel-fab/nfs-faqs.html#3d
[13] "Declaration of Michael Ketter, Ph.D.," ADAMS No. ML22319A251, p. 3, https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML22319A251
[14] https://www.erwinrecord.net/news/local/nuclear-regulatory-commission-hears-from-concerned-citizens-during-nfs-performance-presentation/article_29fe9ef0-f64e-11ed-9d66-e31d2668d3ea.html
[15] https://radiation.org/wp-content/uploads/2023/06/Nuclear-Fuel-Services-w-ltrhead.pdf

cause is the continued operation of NFS and the greater accumulation of radioactivity in local air, water, and food."

B. DOE Policy Requires Maximum Steps Be Taken To Protect Citizens' Public Health

The DOE Nuclear Safety Program mission at PORTS "is to support the design, construction, operation, and deactivation and decommissioning of the . . . Portsmouth nuclear facilities in a manner that ensures adequate protection of workers, the public, and the environment."[16] To that end, DOE and its contractors are to "[e]nsure operations are conducted such that: Individual members of the public are provided a level of protection from risks associated with DOE operations that equates to no significant additional risk to life and health than that to which members of the general population are normally exposed. . . ."[17]

C. NEPA Requires Cumulative Effects Analysis Of The HALEU Burden When Added To Past And Present Radioactive Contamination

The continuing presence, movement and effects of past long-lasting radioactive toxins, plus the toxic effects of the current activities at PORTS must be added to the projected effects of HALEU production. A significant current activity at PORTS that is emitting radionuclides is a Depleted Uranium Product Line added to Depleted Uranium (DU) solidification plant at PORTS to manufacture components for nuclear weapons internals,[18] and it obviously must be accounted for in a cumulative effects analysis wherein HALEU is introduced into the local environment at PORTS.

NEPA requires "an agency to evaluate 'cumulative impacts' along with the direct and indirect impacts of a proposed action." *TOMAC, Taxpayers of Michigan Against Casinos v. Norton*, 433 F.3d 852, 864 (D.C. Cir. 2006) (citing *Grand Canyon Tr. v. FAA*, 290 F.3d 339, 345 (D.C. Cir. 2002)). A cumulative impact is "the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." 40 C.F.R. § 1508.7. "Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." *Id.* § 1508.7. A NEPA cumulative impact analysis must include discussion of "other actions — past, present, and proposed, and reasonably foreseeable — that have had or are expected to have impacts in the same area," "the impacts or expected impacts from these other actions," and "the overall impact that can be expected if the individual impacts are allowed to accumulate." *Grand Canyon Tr.*, 290 F.3d at 345.

II. <u>HALEU INVITES NUCLEAR WEAPONS PROLIFERATION</u>

A. ***Expanded Global Use of HALEU Would Exacerbate Security And Proliferation Risks***

[16] https://www.energy.gov/pppo/nuclear-safety
[17] *Id.*
[18] At Piketon, components are made with a DU-niobium alloy to provide parts for the DOE's nuclear weapons stockpile modernization program. https://www.gao.gov/assets/gao-21-16.pdf

In the Federal Register notice of this rulemaking,[19] DOE solicited scoping comments on the topic of "Compliance with all applicable Federal, state, and local statutes and regulations, and with international agreements, and required Federal and state environmental permits, consultations, and notifications."

As discussed below, there are international agreements and federal laws requiring compliance, particularly as to nuclear proliferation potential, and they must be addressed in the Draft EIS.

In Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors,[20] the National Academies of Science Committee on Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactor made these findings and recommendations:

> **Finding 19**: *Expanding the global use of high-assay low-enriched uranium (HALEU) would potentially exacerbate proliferation and security risks because of the potentially greater attractiveness of this material for nuclear weapons compared with the low-enriched uranium used in light water reactors.* The increased number of sites using and states producing this material could provide more opportunity for diversion by state or nonstate actors.
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> > **Recommendation M:** *The U.S. National Nuclear Security Administration, in coordination with the U.S. Department of Energy's Office of Nuclear Energy, should assess proliferation and security risks associated with high-assay low-enriched uranium (HALEU) and its potential for expanded global use*. In parallel, the U.S. government should foster an international effort, which could be facilitated by the International Atomic Energy Agency, to examine and address these risks.
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> **Finding 20:** All of the advanced reactor fuel cycles will require rigorous measures for safeguards and security commensurate with the potential risks they pose. Issues requiring special attention include the following:
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> • *Material accountancy* (*i.e.,* tracking and quantification) is more difficult for molten salt and pebble-bed technologies than for reactor systems that use stationary solid fuels because of the technical challenges in performing measurements with online fuel and bulk-handling facilities. Containment and surveillance will also be more challenging to implement for these types of reactors. Thorium/uranium-233 fuel cycles require development of safeguards technology because of the large number of variants in their systems. Moreover, safeguards tailored to traditional uranium/plutonium fuel cycles are not applicable to these systems.
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> • *Fuel cycles involving reprocessing and separation of fissile material that could be weapons usable pose greater proliferation and terrorism risks* than the once-through uranium fuel cycle with direct disposal of spent fuel, as the separated fissile material would not be uniformly mixed with highly radioactive fission products. Separated, potentially weapons-usable materials could include fissionable materials other than the

[19] 88 Fed. Reg. at p. 36575.

[20] National Academies of Sciences, Engineering, and Medicine, Washington, DC: The National Academies Press. https://doi.org/10.17226/26500.

“traditional” special nuclear materials of highly enriched uranium, plutonium, and uranium-233. Thus, for these closed fuel cycles, specific safeguard technologies will likely be required to meet the International Atomic Energy Agency’s goal of timely detection.

> **Recommendation N:** The U.S. government should support the International Atomic Energy Agency’s (IAEA’s) development and application of effective safeguards for advanced reactor technologies by authorizing, via the U.S. interagency process, IAEA access through the eligible facilities list, especially to those advanced reactor systems for which the IAEA does not currently have safeguards experience. Developers of these types of advanced reactors and fuel cycle facilities should provide facility information to the IAEA to help with integration of safeguards considerations into the design process.
> **Recommendation O**: *The U.S. Nuclear Regulatory Commission should initiate a rulemaking to address the security and material accounting measures for high-assay low-enriched uranium (HALEU)* and other attractive nuclear materials that may be present in advanced reactor fuel cycles.[21]

We commend these findings and recommendations to DOE for investigation and analysis in the Draft EIS.

B. The Proliferation Potential Of Globalized SMR Marketing

1. Mounting Pressure For Global Trafficking In Next-Generation Reactors

There is growing pressure to amend the Atomic Energy Act to allow U.S. companies to compete globally in sales of advanced reactors and SMRs. Economists forecast growth and speculation in this country for decades to come, predicting a $295 billion U.S. SMR industry by 2043.[22]

Globalization of nuclear power will bring what are, in a major sense, nuclear weapons proliferation machines, within the reach of authoritarians and autocratic governmental leaders. Saudi Arabia’s prince bin Salman has expressed his intention that Saudi Arabia will develop an “Arab bomb” if he believes Iran is also building weapons.[23] Saudi Arabia is close to completion of an experimental reactor and is considering having a Korean firm build its first SMR.[24] The United Arab Emirates, another authoritarian state, has a four-unit reactor complex nearing

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[21] *Id.*, § 6.1, pp. 191-192 (Emphasis added).
[22] https://www.idtechex.com/en/research-report/nuclear-small-modular-reactors-smrs-2023-2043/934
[23] https://www.reuters.com/article/us-saudi-iran-nuclear/saudi-crown-prince-says-will-develop-nuclear-bomb-if-iran-does-cbs-tv-idUSKCN1GR1MN
[24] https://www.neimagazine.com/news/newssaudi-arabia-to-use-domestic-uranium-for-nuclear-development-10529986

completion, totaling 5.6 GWe. Unit 1 of the complex, at Barakah, was connected to the grid in August 2020, followed by unit 2 in September 2021 and unit 3 in October 2022.[25]

The concept of high-stakes global trafficking in nuclear power plant construction, operation, disposing of nuclear waste and fuel will inevitably spawn the spread of nuclear weapons well beyond the existing nine countries worldwide. Because some of those plants will be designed, built and/or operated by U.S. firms, and the fuel is likely in many instances to be HALEU, DOE must assess the weapons proliferation aspects of HALEU fuel in the Draft EIS.

NEPA § 4332(2)(f)[26] expressly requires Federal agencies to recognize the worldwide and long-range character of environmental problems and to support appropriate initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of humankind's world environment. Further, Executive Order 12114[27] requires Federal officials to consider major Federal actions significantly affecting the environment of the global commons as well as the environments of foreign nations.

2. *Possible Banking And Concealment Of Unobligated Uranium*

Another relevant aspect of a weapons proliferation assessment was mentioned in DOE's public notice of scoping, that "initial sources of uranium to meet the requirements of the [HALEU Availability Program] could be existing DOE stockpiles of highly enriched uranium (HEU) that would be processed or down-blended into HALEU (*e.g.*, activities conducted outside of the Proposed Action and that are covered by separate existing or pending NEPA documentation)."[28] This raises the prospect that "unobligated" Uranium*,* which carries no "obligation" restricting it to be used only for nonmilitary purpose**s,** might be concealed or stored/banked under civilian U.S. HALEU management. It is possible that the National Nuclear Security Administration (NNSA) of DOE might stockpile military Uranium to evade disclosure and scrutiny under the NPT and other treaties.

Notably, SRS-Watch, another commenter in this scoping proceeding, has requested review under NEPA "if any new HALEU production facility would be utilized to process unobligated uranium into fuel to use in TVA reactors that produce tritium for use in U.S. nuclear weapons."[29] The signatories to this letter concur in SRS-Watch's request, but further, believe that the pathways to hiding unobligated HEU (or HALEU down blended from unobligated HEU) should be investigated and the possibility be publicly mentioned to deter such misconduct. This

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[25] https://world-nuclear.org/information-library/country-profiles/countries-t-z/united-arab-emirates.aspx
[26] 42 U.S.C. § 4332.
[27] https://www.energy.gov/nepa/downloads/executive-order-12114-environmental-effects-ab road-major-federal-actions
[28] 88 Fed. Reg. at p. 36573.
[29] *See* Savannah River Site Watch comments made earlier in this scoping proceeding.

potentiality must be disclosed to fulfill the NEPA aim of informed public decision-making under NEPA. *Robertson v. Methow Valley Citizens Council,* 490 U.S. 332, 349-50 (1989).

3. *NEPA and AEA Interpretations Support A Proliferation Assessment*

Nuclear weapons proliferation and security issues have been encompassed within NEPA environmental impact assessments and statements since the inception of NEPA. See *Scientists' Institute for Public Information, Inc. v. Atomic Energy Commission*, 481 F.2d 1079 (D.C. Cir. 1973) (AEC required to prepare a programmatic environmental impact statement (PEIS) on the Liquid Metal Fast Breeder Reactor (LMFBR) Program in part to address nonproliferation and terrorism in the subsequent LMFBR EIS). In *West Michigan Environmental Action Council v. AEC*, Dkt . No . G-58-73 (W.D. Mich. 1974), the AEC settled the litigation by preparing a generic Programmatic EIS on plutonium recycling, which later came to be known as the "Generic Environmental Statement on Mixed Oxide Fuel" (GESMO), No. RM-50-1.

In 2009, DOE tried to address issues of nuclear nonproliferation in its "Draft Global Nuclear Energy Partnership Programmatic Environmental Impact Statement" (GNEP PEIS, DOE/EIS-0396) by relying on a separate "Nonproliferation Impact Assessment: Companion to the Global Nuclear Energy Partnership Programmatic Environmental Impact Statement," prepared by the Office of Nonproliferation and International Security of the National Nuclear Security Administration (NNSA). This artificial separation of the NEPA discussions was challenged in the public comments phase. Subsequently, DOE published the "Draft Nonproliferation Impact Assessment: Companion to the Global Nuclear Energy Partnership Programmatic Environmental Impact Statement," DOE 2008.

NEPA's requirement that environmental effects be identified and disclosed has been followed and applied to programs involving storage of nuclear missiles,[30] the testing of nuclear weapons,[31] the destruction of excess nuclear weapons pursuant to a treaty,[32] and transporting chemical weapons.[33] The U.S. Air Force has compiled environmental impact statements as part of its compliance with the Strategic Arms Reduction Treaty II commitments to dismantle missile

[30] *See, e.g., Concerned About Trident v. Rumsfeld*, 555 F.2d 817 (D.C. Cir. 1976); *Weinberger v. Cath. Action of Hawai'i,* 454 U.S. 139 (1981).

[31] *See Comm. for Nuclear Resp., Inc. v. Seaborg*, 463 F.2d 783 (D.C. Cir. 1971).

[32] *See, e.g*., U.S. Dep't of the Army, "Environmental Assessment for the Proposed Elimination of Intermediate-Range and Shorter-Range Missiles Pursuant to the INF Treaty" (1988); Corps of Engineers, Dep't of the Army, "Pershing Missiles, Elimination, Pueblo, Co., et al.: Finding of No Significant Impact," 53 Fed. Reg. 6189 (March 1, 1988).

[33] *See Greenpeace USA v. Stone*, 748 F. Supp. 749, 758-61 (D. Haw. 1990) (NEPA did not apply to a presidential agreement with West Germany to transport nerve gas to a Pacific atoll for destruction but suggesting the impact statement may be needed for actions taken abroad that affect this country or where there is a total lack of environmental assessment).

launching facilities.[34] The Air Force's Global Strike Command recently assessed under NEPA whether updating of the United States' 400 nuclear missile launch silos meets the requirements of the Nuclear Posture Review (NPR), the Nuclear Non-Proliferation Treaty (NPT), the New Strategic Arms Reduction Treaty (New START), and the Comprehensive Test Ban Treaty.[35] In its 1995 "Record of Decision: Tritium Supply and Recycling Programmatic Environmental Impact Statement," DOE, while producing a Programmatic Environmental Impact Statement for the Strategic Arms Reduction Treaty II Protocol, determined that "it was necessary to reevaluate the Reconfiguration Program to insure that alternatives which reflected requirements of a greatly downsized nuclear weapons stockpile would be assessed in the PEIS."[36]

In its 1999 "Consolidated Record of Decision for Tritium Supply and Recycling," DOE discussed at length the nonproliferation policy implications of using civil commercial light water reactors to produce tritium used in creating nuclear weapons triggers.[37] In its "Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex,"[38] DOE analyzed the implications that various production activities at the agency's Y-12 nuclear weapons facility might have on United States compliance with the Nuclear Non-Proliferation Treaty.

The point of developing a nuclear weapons nonproliferation analysis as part of the HALEU Environmental Impact Statement is to ensure that DOE decisions in a world newly full of HALEU production and utilization will conform to U.S. nuclear weapons policies.

III. HALEU GREATLY INCREASES SECURITY RISKS IN NEXT-GENERATION REACTORS

The National Academies Committee also analyzed the different proposed reactor designs that would be fueled with HALEU and identified areas of concern regarding the implementation of International Atomic Energy Agency (IAEA) and U.S. Nuclear Regulatory Commission (NRC) safeguards requirements under the Nuclear Nonproliferation Treaty (NPT), to which the U.S. has been a signatory for 55 years.[39]

Ramping up production of HALEU will increase the potential for malevolent acts using radioactive or nuclear materials by substate actors. *Radiological terrorism* is an act that would

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34 https://apps.dtic.mil/sti/pdfs/ADA414685.pdf
35 "Draft Environmental Impact Statement for the Ground Based Strategic Deterrent Deployment and Minuteman III Decommissioning and Disposal," https://drive.google.com/file/d/1aKCcvEq92PdKShP5qWzIxrvwNN9P7zo7/view, at pp.1-5 to 1-7.
36 63 Fed. Reg. 63878 (December 12, 1995).
37 64 Fed. Reg. 26369, 26373-26374 (May 14, 1999).
38 https://www.energy.gov/sites/prod/files/EIS-0387-FEIS-Summary-2011.pdf, pp. S-14 through S-16.
39 The NPT is codified as a federal statute at 22 U.S.C. § 3201 *et. seq.* The NRC's safeguards requirements are found generally at 10 CFR Part 73, aimed at preventing sabotage, theft and weapons proliferation.

lead to dispersal of radioactive materials, such as sabotage of a nuclear reactor, whereas *nuclear terrorism* is the theft of a nuclear weapon or the fissionable materials that could be used in making improvised nuclear explosive devices.

HALEU lends itself to both radiological and nuclear terrorism. At 19.75% enrichment levels, HALEU could be incorporated into a “dirty” radiological bomb. And at 19.75% U-235 content, it doesn’t require a great deal more energy in centrifuge operations to produce weapons-grade Uranium. The energy to enrich Uranium is measured in Separative Work Units (SWU). Enriching Uranium from its natural state (0.7% U-235) to weapons grade (> 90% U-235) takes a certain amount of energy, but to go from 0.7% to HALEU at 19.75% enrichment represents about 85% of that required energy. So HALEU at 19.75% enrichment, once stolen, would require only 15% additional SWU to be enriched to 90% U-235 density, which weapons grade. Clearly, HALEU is much more desirable to thieves, terrorists and weapons proliferators than the 5%-enriched fuel in today’s commercial power reactors.

The National Academies Committee observed that “The IAEA has only had limited experience safeguarding fast reactors, and none at all with such designs as the Natrium reactor, which uses high-assay low-enriched uranium (HALEU)–based metallic fuel. . . . Similarly, the IAEA has had little opportunity historically to demonstrate safeguards approaches at the few pebble-bed high-temperature gas-cooled reactors that have operated. . . . Notably, molten salt–fueled reactors are completely unexplored territory for IAEA safeguards.”[40]+

A. Sodium-Cooled Reactors

The Natrium and ARC-100 reactors (TerraPower and ARC Clean Technology, respectively), as well as the Oklo Aurora microreactor, are all descendants to some degree of the Experimental Breeder Reactor (EBR)-II. Factors that affect their proliferation risks compared with the once-through cycle of light water reactors are the types and quantities of nuclear material in their fresh and spent fuels, and the potential diversion and misuse pathways for obtaining weapon-usable material throughout the fuel cycle.

The 345-MWe Natrium demonstrator reactor will initially use nuclear fuel with an average enrichment of 18.5% HALEU. Later, larger-scale versions supposedly will use lower-enriched fuel, below 10%. As a pool-type sodium-cooled fast reactor, there is a spent fuel storage area within the reactor vessel, where spent fuel discharges are first sent for cooling for up to 3 years before they are removed from the reactor vessel, cleaned of sodium, and either transferred to a water-filled spent fuel storage pool outside of the vessel or loaded into a dry canister and stored. With sodium pool–type reactors, the fuel’s location within the vessel and the opacity of the sodium limit direct visual inspection, for safeguards purposes. And depending on

[40] *Id.*, § 6.3.1.1, p. 204.

the reactor design and fueling strategy, the Natrium reactor's spent fuel could contain significant plutonium and residual U-235, which over time could require increased safeguards and security measures.[41]

Both the ARC-100 and the Aurora sodium-cooled designs also plan to use HALEU, but they differ from Natrium in that they would use a single-batch core with a 20-year cycle length instead of periodic refueling cycles. This comprises both advantages and disadvantages for safeguards. Reduced core access and reduced refueling frequency makes misuse of the facility and diversion of spent fuel much more difficult at reactors with sealed, long-life cores. But despite their small size, these reactors will require substantial quantities of HALEU to achieve criticality.[42] Based on a planned burnup of 1%, the 1.5-MWe Aurora will require several MT (metric tons) of HALEU assemblies with enrichments of up to 19.75% — greatly exceeding the NRC's minimum quantity to be treated as Category II nuclear material.[43]

Depending on the dose rate during irradiation, the Aurora fuel may require Category II security not only before the reactor starts operation, but also at times during operation and after shutdown. It could require an on-site security force to ensure prompt response measures should adversaries attempt "gross theft" of HALEU — especially given plans for deployment in remote locations where off-site local law enforcement response may be slow or insufficient. The plutonium in the Aurora spent fuel would also drive an enhanced level of protection.[44]

Even the scrap metal stream associated with fabricating HALEU fuel raises concerns of theft and illegal trafficking. The throughput of an industrial-scale fuel fabrication facility capable of supplying 1 GWe for Natrium reactors would be on the order of 6.4 MT of HALEU per year (taking into account total scrap generation), and would therefore require NRC Category II security to address the risk of "gross theft" of low-enriched uranium.[45]

B. Pebble-Bed Reactors

Pebble-bed reactors fueled by HALEU include the Xe-100 high-temperature gas-cooled reactor (HTGR) and the Kairos fluoride-cooled high-temperature reactor. Their fuel would be graphite pebbles containing TRISO fuel particles. The fuel kernels for both reactor designs consist of UCO (uranium-carbon-oxygen), with equilibrium average uranium enrichments of 15.5 percent for the Xe-100 (Mulder, 2021) and 19.55 percent for Kairos (Blandford and

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[41] *Id.*, § 6.3.1.1, p. 205.
[42] *Id.*, § 6.3.1.2, p. 206.
[43] Category II for NRC purposes is defined as 10,000 grams or more of U-235 in the form of Uranium enriched to 10% or more, but less than 20%.
[44] Merits and Viability of Different Nuclear Fuel Cycles, § 6.3.1.2, p. 206.
[45] *Id.*, § 6.3.1.3, p. 207.

Peterson, 2021).[46] Pebble-bed reactors do not necessarily require HALEU, but can also use stronger forms of low-enriched Uranium (LEU+), below 10%. The use of HALEU will affect both international security and domestic material accounting and security requirements. The risks will be partly offset by the large numbers of "pebbles" needed to acquire weapons-relevant quantities of material, as well as the lack of methods for reprocessing TRISO fuel.[47] On a single-reactor-unit basis, there is not great concern, but the total material inventory at a multiunit site, including fresh and spent fuel storage, can be substantial.

More worrisome is that pebble-bed reactors would be refueled while actively operating, which is a major obstacle to adequate safeguards. Online-refueled reactors such as Canadian deuterium uranium reactors (CANDUs) require greater safeguards resources than batch-refueled reactors such as LWRS, because fuel would not be loaded and unloaded while the reactor is held in discrete shutdown periods when inspectors typically conduct a physical inventory. Pebble-beds present greater challenges than CANDUs for material accountancy because of the large number of pebbles containing fissionable material, the portability of these individual items, and the nearly continuous fueling and refueling cycles.[48]

The potential for undetected diversion or misuse exists if the system of accounting for nuclear material lacks integrity. The volume of material at a multi-reactor site could cause large problems. In addition to each reactor module, inspectors would need to verify the inventories of fresh fuel and spent fuel storage areas. Each Xe-100 core (which would contain approximately 224,000 pebbles when fully fueled) is planned to be fully replaced approximately every 3.5 years, so a nuclear plant containing four reactor modules (the Xe-100 standard design to produce 320 MWe) will receive 10 million fresh fuel pebbles over a 40-year plant lifetime (plus replacements for damaged pebbles).[49] Pebbles cannot be assigned a unique identifier over their operational lives.[50] Pebble counting alone will be insufficient to accurately determine and verify nuclear material inventories at reactors.[51] The anticipated use of multiple modules at a single site compounds the accounting problems.

C. Once-Through Molten Salt Reactors

The challenges of accounting for fuel in once-through molten salt–fueled reactors using LEU will be even greater than for pebble-bed reactors. While individual pebbles can at least be counted, the special nuclear material in a salt-fueled reactor constantly flows through and outside of the core. For safeguards purposes, molten salt–fueled reactors should be seen as bulk-handling

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[46] *Id.*, § 6.3.2, p. 207.
[47] *Id.*
[48] *Id.*
[49] *Id.*, § 6.3.2, p. 208.
[50] *Id.*
[51] *Id.*

facilities similar to reprocessing plants. Such reactors include the Terrestrial Energy IMSR (integral molten salt reactor) and ThorCon thermal-spectrum designs, and the fast-spectrum MCFR (molten chloride fast reactor).[52]

It will be quite difficult to accurately and timely account for radioactive material at bulk-handling reactors. The total inventory cannot be measured directly during operation, but only extrapolated through such means as sampling and destructive assay, nondestructive assay, and process monitoring. The very large throughput of special nuclear material of an industrial-scale bulk-handling facility, coupled with technical limits on the accuracy and precision of measurement techniques, can fail to account for a lot of material.[53] Also, the nuclear material inventory within a salt-fueled reactor changes over time. It may not be possible to precisely estimate the reactor inventory as a function of time, even if inputs and outputs are accurately measured.[54] Further, molten salt reactors are designed to separate protactinium-233 to maximize uranium-233 production. Separated Uranium-233 would be comparable to plutonium in its attractiveness for weapons.[55]

D. HALEU Is Usable Directly In A Nuclear Explosive Device

Despite HALEU's U-235 enrichment below 20%, it is possible to use it directly in a nuclear explosive device. Any nuclear material with a finite bare critical mass can be used, in theory, to make an explosive device. HALEU's less-attractive material form does present greater technical challenges than stolen high-enriched Uranium (HEU). But mainly, the nuclear terrorist threat posed by HALEU is "whether a given quantity can be used by a subnational group to build a sufficiently practical and deliverable nuclear explosive device to achieve the group's desired nuclear yield and reliability," which depends on the technical sophistication of the group in question as well as its objectives.[56] The emerging global competition over SMRs requires rigorous analysis and disclosure of proliferation, theft and terrorism potential of HALEU fuel.

Thank you very much.

Very truly yours,
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52 *Id.*, § 6.3.3, p. 210.
53 *Id.*.
54 *Id.*, § 6.3.3, p. 211.
55 *Id.*, § 6.3.3.2, p. 212.
56 *Id.*, § 6.3.4.1, p. 214.