UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE COMMISSION

In the Matter of:	§	
	§	**Docket No. 50-614-CP**
Long Mott Energy, LLC	§	
	§	**August 11, 2025**
(Long Mott Generating Station)	§	
	§	

SAN ANTONIO BAY ESTUARINE WATERKEEPER'S
PETITION TO INTERVENE AND REQUEST FOR HEARING

NOW COMES San Antonio Bay Estuarine Waterkeeper ("Waterkeeper" or "Petitioner"), by and through counsel, and submits this Petition to Intervene and Request for Hearing in the above-captioned proceeding.

I. INTRODUCTION

Pursuant to 10 C.F.R. § 2.309, and the hearing notice published at 90 Fed. Reg. 24428 (June 10, 2025), Petitioner San Antonio Bay Estuarine Waterkeeper ("Waterkeeper" or "Petitioner"), hereby requests the U.S. Nuclear Regulatory Commission ("NRC" or "Commission") to grant a hearing and leave for petition to intervene regarding Long Mott Energy, LLC ("LME")'s Construction Permit Application for the proposed Long Mott Generating Station.[1] LME submitted the Long Mott Construction Permit Application ("LM-CPA") to the NRC on March 31, 2025. The NRC released the LM-CPA to the public on April 16, 2025, and it accepted the LM-CPA for review on May 12, 2025. It published

[1] Long Mott Energy, LLC, Submittal of Construction Permit Application for Long Mott Generating Station, April 16, 2025, https://www.nrc.gov/docs/ML2509/ML25090A057.html.

a Federal Register notice of opportunity to request a hearing and petition for leave to intervene on June 10, 2025.

The proposed facility would be located in Seadrift, Texas, adjacent to Seadrift Operations ("SDO"), which is owned and operated by Union Carbide Corporation, a subsidiary of the Dow Chemical Company ("TDCC"). The LM-CPA proposes a novel reactor design—as the proposed four-unit, high-temperature gas-cooled, pebble bed reactors (HTGRs) would not only be some of the first of their kind internationally, but the proposed facility would be the first grid-scale advanced nuclear facility at an industrial site in North America.

Petitioner contends that the NRC should not grant the LM-CPA because LME has failed to demonstrate with reasonable assurance that the proposed functional containment will control the release of radioactivity to the environment under all "postulated accident conditions" sufficiently to fulfill the safety design objectives under 10 C.F.R. § 50.34. Additionally, Petitioner contends that the proposed functional containment fails to include beyond-design basis events (BDBEs) in the functional containment evaluation. Petitioner also contends that LME has failed to demonstrate its financial qualifications to build and operate the Long Mott Generating Station. Lastly, Petitioner contends that LME's Environmental Report erroneously minimizes the adverse environmental impacts of the proposed facility, undermining any required assessment under the National Environmental Policy Act (NEPA).

Petitioner's contentions are supported by the expert declarations of Dr. Edwin Lyman, an expert in nuclear power safety and security,[2] and Jeffrey T. Mitman, a nuclear engineer with a significant level of expertise in risk analysis.[3]

The remainder of this Hearing Request and Petition for Leave to Intervene proceeds as follows: Section II contains a demonstration that Petitioner Waterkeeper has standing to participate in this proceeding. Section III presents the legal framework for Petitioner's Hearing Request and Petition for Leave to Intervene. Section IV presents Petitioner's Contentions.

II. PETITIONING PARTY AND THE BASIS FOR LEGAL STANDING

A. San Antonio Bay Estuarine Waterkeeper

San Antonio Bay Estuarine Waterkeeper ("Waterkeeper") is a Calhoun County, Texas, membership organization founded in 2012 as a project of the non-profit Calhoun County Research Watch. Waterkeeper is a member of the national network of organizations in the Waterkeeper Alliance. Its mission is to monitor and protect the San Antonio, Matagorda, and Lavaca Bays by investigating and reporting violations of environmental permits, participating in the pollution permitting process, coordinating community actions and visits, and educating the public on the sources of pollution that impact Calhoun County. Commercial fishermen, marine biologists, volunteers, environmental advocates, and other community members work from within and with Waterkeeper to ensure compliance with

[2] Declaration of Dr. Edwin Lyman (Aug. 11, 2025). Dr. Lyman's Declaration is attached as Exhibit E.

[3] Declaration of Jeffrey T. Mitman (Aug. 11, 2025). Mr. Mitman's Declaration is attached as Exhibit F.

environmental laws and support recovery and cleanup projects in regional bays and waterways.

Waterkeeper advocates for the preservation of local waterways and wetlands for commercial fishing, sport, and other recreational uses, often working with shrimpers and oystermen who earn their livelihood fishing in waterbodies within 50 miles of the site of the proposed Long Mott Generating Station. Waterkeeper also regularly conducts outreach activities and communicates with the public through email newsletters, press releases, interviews, and its public social media accounts with almost 1,000 direct followers. Waterkeeper includes members who reside, recreate, and work within 50 miles of the proposed reactors and who will be affected by the reactor facility that is the subject of Long Mott Energy's Construction Permit Application.

Waterkeeper's address is 600 Ramona Road, Seadrift, Texas 77983, and it may be contacted at its phone number (361) 218-2353, email wilsonalamobay@aol.com, and website https://sanantoniobaywaterkeeper.org/.

Waterkeeper opposes the Construction Permit Application for the Long Mott Generating Station in Calhoun County, Texas. Waterkeeper's representational standing to participate in this proceeding is demonstrated by the attached declarations of its members: Declaration of Diane Wilson (August 11, 2025) (Exhibit A); Declaration of Mauricio Blanco (August 11, 2025) (Exhibit B); Declaration of Curtis Miller (August 11, 2025) (Exhibit C); and Declaration of John Daniel (August 11, 2025) (Exhibit D). Ms. Wilson, Mr. Blanco, Mr. Miller, and Mr. Daniel have designated Waterkeeper to represent their respective interests in this proceeding, including their health and safety and that of their

family members, the integrity of their real property, homes, and businesses, and the quality of the marine and estuarine environment from which their livelihoods, recreational uses, and aesthetic appreciation derive. They assert that they will not be adequately represented unless Waterkeeper is allowed to participate as a party on their behalf.

B. Legal Basis for Standing

Pursuant to the Atomic Energy Act, the Commission must grant a hearing in a licensing proceeding "upon the request of any person whose interest may be affected by the proceeding, and shall admit any such person as a party to such proceeding."[4] To support the request, a petitioner must provide the Commission with information regarding "(1) the nature of the petitioner's right under the governing statutes to be made a party; (2) the nature of the petitioner's property, financial, or other interest in the proceeding; and (3) the possible effect of any decision or order on the petitioner's interest."[5] "The NRC generally uses judicial concepts of standing in interpreting this regulation."[6] Thus, a petitioner may intervene if it can specify facts showing "that (1) it has suffered or will suffer a distinct and palpable harm constituting injury-in-fact within the zone of interests arguably protected by the governing statutes, (2) the injury is fairly traceable to the action being challenged, and (3) the injury will likely be redressed by a favorable determination."[7] In determining

[4] 42 U.S.C. § 2239(a)(1)(A).
[5] *Entergy Nuclear Vermont Yankee, LLC, and Entergy Nuclear Operations, Inc.* (Vermont Yankee Nuclear Power Station), 60 N.R.C. 548, 552 (2004) (citing 10 C.F.R. § 2.309(d)(1)).
[6] *Entergy Nuclear Vermont Yankee*, 60 N.R.C. at 552.
[7] *Id.* at 552-53.

whether a petitioner has met the requirements for standing, the Commission "construe[s] the petition in favor of the petitioner."[8]

A petitioner seeking leave to intervene must show the potential for injury-in-fact to its interests before intervention can be granted.[9] A petitioner need not establish that injury will inevitably result from the proposed action to show an injury-in-fact, but only that it may be injured in fact by the proposed action.[10]

An organization that wishes to intervene in a proceeding may do so either in its own right by demonstrating harm to its organizational interests, or in a representational capacity by demonstrating harm to its members.[11] Organizations such as the Petitioner in this case may act as representational entities by demonstrating harm to their members.

An organization seeking representational standing must demonstrate how at least one of its members may be affected by the licensing action (such as by activities on or near the site), must identify that member by name and address, and must show that the organization is authorized to request a hearing on behalf of that member.[12] Even in the

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[8] *Id.* at 553.
[9] *Nuclear Eng'g Co., Inc.* (Sheffield, Ill. LowLevel Radioactive Waste Disposal Site), 7 N.R.C. 737, 743 (1978).
[10] *Gulf States Utils. Co., et al.* (River Bend Station, Unit 1), 40 N.R.C. 43 (1994).
[11] *See Hydro Resources, Inc.* (2929 Coors Road, Suite 101, Albuquerque, NM 87120), LBP-98-9, 47 N.R.C. 261, 271 (1998).
[12] *Warth v. Seldin*, 422 U.S. 490, 511 (1975) ("There is no question that an association may have standing in its own right to seek judicial relief from injury to itself and to vindicate whatever rights and immunities the association itself may enjoy. Moreover, in attempting to secure relief from injury to itself the association may assert the rights of its members, at least so long as the challenged infractions adversely affect its members' associational ties.") (citing *NAACP v. Alabama*, 357 U.S. 449, 458-460 (1958)); *Anti-Fascist Committee v. McGrath*, 341 U.S. 123, 183-87 (1951) (Jackson, J., concurring)).

absence of injury to itself, an association may have standing solely as the representative of its members.[13]

In this case, Waterkeeper is petitioning on behalf of its members, and it has submitted declarations from four of them. One member resides at 1714 FM2235, less than four miles northeast of the site of the proposed Long Mott Generating Station. The others reside in Port Lavaca (approximately 10 miles from the site of the proposed Long Mott Generating Station), Seadrift (approximately 15 miles from the site of the proposed Long Mott Generating Station), and Victoria (approximately 29 miles from the site of the proposed Long Mott Generating Station). Petitioner thus has presumptive standing by virtue of the location of its members' residences and property within 50 miles of the proposed LME reactors.[14] Further, they each have frequent contact with an area within a 50-mile radius of the proposed nuclear reactor.[15]

As each of the member declarants explains, they will suffer (or will be under threat of suffering) concrete and particularized injuries from granting of a Construction Permit Application for the Long Mott Generating Station. If the Construction Permit is denied, the potential threats or actual harms from the Long Mott Generating Station will not occur. By intervening in this proceeding, Petitioner seeks to protect its members' health and safety,

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[13] *E.g.*, *National Motor Freight Assn. v. United States*, 372 U.S. 246 (1963).
[14] *See, e.g., Florida Power & Light Co.* (Turkey Point Nuclear Generating Plant, Units 3 & 4), LBP-08-18, 68 N.R.C. 533, 539 (2008); *Pacific Gas & Electric Co.* (Diablo Canyon Power Plant Independent Spent Fuel Storage Installation), LBP-02-23, 56 N.R.C. 413, 426-27 (2002) (petition for review denied, CLI-03-12, 58 N.R.C. 185 (2003)) (citing *Florida Power & Light Co.* (Turkey Point Nuclear Generating Plant, Units 3 and 4), LBP-01-06, 53 N.R.C. 138, 146, *aff'd*, CLI-01-17, 54 N.R.C. 3 (2001)); *Amergen Energy Co., LLC* (Oyster Creek Nuclear Generating Station), LBP-06-7, 63 N.R.C. 188, 195 (2006).
[15] *Florida Power & Light Co.*, 68 N.R.C. at 539.

as well as protection of the environment. It seeks to ensure that LME's Construction Permit Application is not approved unless and until LME demonstrates full compliance with all applicable requirements.

III. LEGAL FRAMEWORK

The NRC's regulation and licensing of reactors is governed by two statutes: the Atomic Energy Act[16] and NEPA.[17] While the substantive concerns of these statutes overlap,[18] they impose independent procedural obligations.[19] Even where the NRC purports to have resolved safety issues through its Atomic Energy Act-based regulatory process, it must nevertheless comply with NEPA's procedural obligations for addressing those issues in its decision-making processes.[20] Additionally, contentions must be admissible under 10 C.F.R. § 2.309(f).

A. Atomic Energy Act and NRC Safety Regulations

Under § 103(d) of the Atomic Energy Act, the NRC may not issue a commercial license for a nuclear plant if it would be "inimical to the common defense and security or to the health and safety of the public."[21] Section 161 of the Atomic Energy Act also

[16] 42 U.S.C. § 2011, *et seq.*
[17] 42 U.S.C. §§ 4321-4370h.
[18] *Citizens for Safe Power v. NRC*, 524 F.2d 1291, 1299 (D.C. Cir. 1975).
[19] *Limerick Ecology Action v. NRC*, 869 F.2d 719, 729-31 (3rd Cir. 1989).
[20] *Limerick Ecology Action*, 869 F.2d at 729-31; *see also State of New York v. NRC*, 681 F.3d 471, 478 (D.C. Cir. 2012) ("a finding that 'reasonable assurance exists that sufficient mined geologic repository capacity will be available when necessary' . . . does not describe a probability of failure so low as to dismiss the potential consequences of such a failure.").
[21] 42 U.S.C. § 2133(d).

empowers the NRC to set standards "to protect health or to minimize danger to life or property," *inter alia*.[22]

NRC regulations under 10 C.F.R. Part 50, "Domestic Licensing of Production and Utilization Facilities," govern the criteria for construction permit applications. Among the many regulatory standards promulgated by the NRC for the safe construction and operation of nuclear power reactors, the General Design Criteria for Nuclear Power Plants ("GDCs") in Appendix A to 10 C.F.R. Part 50 are fundamentally important. These GDCs "are generally applicable to [non water-cooled] types of nuclear power units and are intended to provide guidance in establishing the principal design criteria for such other units," such as the one proposed here by LME.[23] These principal design criteria, in turn, establish:

> the necessary design, fabrication, construction, testing, and performance requirements for structures, systems, and components important to safety; that is, structures, systems, and components that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public.[24]

B. NEPA

NEPA implements a "broad national commitment to protecting and promoting environmental quality."[25] NEPA has two key purposes: to ensure that the agency "will have available, and will carefully consider, detailed information concerning significant environmental impacts" before it makes a decision; and to guarantee that "the relevant

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[22] 42 U.S.C. § 2201(b).
[23] 10 C.F.R. Part 50, App. A, Introduction.
[24] *Id.*
[25] *Louisiana Energy Services, L.P.* (Claiborne Enrichment Center), CLI-98-3, 47 N.R.C. 77, 87 (1998) (quoting *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 348 (1989) and citing 42 U.S.C. § 4331).

information will be made available to the larger audience that may also play a role in the decision-making process and implementation of that decision."[26] A NEPA analysis must address harms that are "reasonably foreseeable," even if they are indirect.[27] The analysis must address "both the probabilities of potentially harmful events and the consequences if those events come to pass."[28]

C. Standard for Admissibility of Contentions

Section 189(a) of the Atomic Energy Act, 42 U.S.C. § 2239, provides:

> In any proceeding under this Act, for the granting, suspending, revoking, or amending of any license or construction permit, or application to transfer control, and in any proceeding for the issuance or modification of rules and regulations dealing with the activities of licensees, and in any proceeding for the payment of compensation, an award, or royalties under section 153, 157, 186c., or 188, the Commission shall grant a hearing upon the request of any person whose interest may be affected by the proceeding.

To carry out the provisions of the statute, the NRC has adopted a regulation, 10 C.F.R. § 2.309, regarding hearing requests and petitions to intervene. The regulation authorizes any person whose interest may be affected by a proceeding to intervene in the proceeding. Additionally, the petitioner must submit and have admitted at least one contention.

Pursuant to 10 C.F.R. § 2.309(f), a petitioner's contentions must: (1) provide a specific statement of the issue of law or fact to be raised or controverted; (2) provide a brief explanation of the basis for the contention; (3) demonstrate that the issue raised in the

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[26] *Robertson*, 490 U.S. at 349.
[27] *State of New York*, 681 F.3d at 476, 482.
[28] *State of New York*, 681 F.3d at 482 (rejecting environmental analysis of spent fuel pool fire risks because it did not consider consequences as well as probability of fires in spent fuel storage pools).

contention is within the scope of the proceeding; (4) demonstrate that the issue raised in the contention is material to the findings the NRC must make to support the action that is involved in the proceeding; (5) provide a concise statement of the alleged facts or expert opinions which support the petitioner's position on the issue and on which the petitioner intends to rely at hearing, together with reference to specific sources and documents on which the petitioner intends to rely; and (6) provide sufficient information to show that a genuine dispute exists with the licensee on a material issue of law or fact.

The NRC has made clear that the burden on a petitioner in stating its contentions is not heavy. In *Dominion Nuclear Conn., Inc.* (Millstone Nuclear Power Station, Units 2 & 3), 54 N.R.C. 349 (2001), the NRC described the contention admissibility standards as "insist[ing] upon some 'reasonably specific factual and legal basis' for the contention."[29] The NRC further explained in *Millstone* that the standards for contention admissibility were meant to prevent contentions based on "little more than speculation" and intervenors who had "negligible knowledge of nuclear power issues and, in fact, no direct case to present."[30] Rather, petitioners are required only to "articulate at the outset the specific issues they wish to litigate."[31]

The NRC and the courts have also made clear that the burden of persuasion is on the applicant, not the petitioner. The petitioner only needs to "com[e] forward with factual

[29] *Id.*, 54 N.R.C. at 359.
[30] *Id.* at 358.
[31] *Id.* at 359.

issues, not merely conclusory statements and vague allegations."[32] The NRC described the threshold burden in stating a contention as requiring a petitioner to "raise any specific, germane, substantial, and material factual issues that are relevant to the . . . request for a license. . . and that create a basis for calling on the [applicant] to satisfy the ultimate burden of proof."[33]

The standards are not meant to be insurmountable.[34] The rule serves to assess the scope, materiality, and support provided for a proposed contention, to ensure that the hearing process is "properly reserve[d] . . . for genuine, material controversies between knowledgeable litigants."[35]

IV. CONTENTIONS

CONTENTION 1: LME's proposed functional containment fails to demonstrate compliance with applicable regulations.

A. Statement of Contention

LME's proposed functional containment fails to satisfy the minimum criteria to demonstrate compliance with 10 C.F.R. § 50.34. Specifically, the LM-CPA fails to demonstrate with reasonable assurance that the proposed functional containment will control the release of radioactivity to the environment under all "postulated accident

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[32] *Northeast Nuclear Energy Company* (Millstone Nuclear Power Station, Unit 3), 53 N.R.C. 22, 27 (2001).
[33] *Id.*
[34] *Duke Energy Corp.* (Oconee Nuclear Station, Units 1, 2, and 3), 49 N.R.C. 328, 335 (1999) (explaining that the rule should not be used as a "fortress to deny intervention") (internal quotation marks and citation omitted); *see Entergy Nuclear Operations, Inc.* (Palisades Nuclear Plant and Big Rock Point Site), 96 N.R.C. 1, 104-05 (2022) (admitting for hearing portions of a contention that raised a genuine material dispute with the application).
[35] *FirstEnergy Nuclear Operating Co.* (Davis-Besse Nuclear Power Station, Unit 1), 75 N.R.C. 393, 396 (2012) (internal quotation marks omitted).

conditions" sufficiently to fulfill the safety design objective of meeting "10 CFR 50.34 offsite dose requirements at the plant's exclusion area boundary with margins," as stated in the NRC Regulatory Guide 1.232.

B. Basis

1. Principal Design Criteria

NRC Rule 10 C.F.R. § 50.34 requires applicants seeking construction permits to include a preliminary safety analysis report (PSAR), which must include the principal design criteria (PDC) for the facility.[36] The PDC establish the necessary requirements for structures, systems, and components (SSCs) that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public.[37]

The rule includes General Design Criteria (GDC), which establish minimum requirements for the PDC for water-cooled nuclear power plants. These GDC are also generally applicable to non-water-cooled facilities, and they provide guidance in establishing the PDC for such other units.[38]

NRC staff have issued Regulatory Guidance for developing PDC for non-light-water reactors.[39] The regulatory guidance document includes a chart that lists the GDC (from Part 50, Appendix A) and indicates whether and how the staff propose to modify the GDC for non-light-water reactor facilities, including for modular high-temperature gas-

[36] 10 C.F.R. § 50.34(a)(3).
[37] 10 C.F.R. Part 50, App. A.
[38] *Id.*
[39] Regulatory Guide 1.232, Rev. 0, "Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors" (April 2018) (hereinafter, "RG 1.232") (ML17325A611).

cooled reactors (MHTGRs), such as the one proposed by the LM-CPA.[40] The chart also includes staff's rationale for any proposed modifications to the GDC.

In addition, the Interim Staff Guidance (ISG), Review of Risk-Informed, Technology-Inclusive Advanced Reactor Applications—Roadmap, DANU-ISG-2022-01 (March 2024) (ML23277A139) (hereinafter, cited as DANU-ISG-2022-01) provides criteria used to evaluate the adequacy of proposed mechanistic source terms for the functional containment demonstration.

Together, the above regulation and regulatory guidance documents inform the evaluation of the LM-CPA's preliminary safety analysis report.

2. The Xe-100 reactor design in the Long Mott Construction Permit Application fails to meet the PDC for "Containment Design."

For purposes of this contention, Advanced Reactor Design Criterion (ARDC) 16 (Containment) of RG 1.232, as modified for MHTGRs (and thus denoted as MHTGR-16) is relevant, as it discusses the functional containment demonstration that the LM-CPA must include:

> A reactor functional containment, consisting of multiple barriers internal and/or external to the reactor and its cooling system, shall be provided to control the release of radioactivity to the environment and to ensure that the functional containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.[41]

Importantly, staff's rationale for modifying PDC 16 for MHTGRs specifically cited the condition that "approval of the proposed approach to functional containment for the

[40] *See generally* RG 1.232, App. C.
[41] RG 1.232, App. C, p. C-8.

MHTGR concept, with its emphasis on passive safety features and radionuclide retention within the fuel over a broad spectrum of off-normal conditions, would necessitate that the required fuel particle performance capabilities be demonstrated with a high degree of certainty."[42]

By any reasonable standard, the LM-CPA does not demonstrate "the required fuel performance capabilities … with a high degree of certainty," as required. As explained in Dr. Lyman's Declaration, the reasons the LM-CPA does not satisfy this standard is that "an approved evaluation model and experimental information essential for determining fuel performance capabilities and developing mechanistic source terms are not available at the present time and will not be available until commercial-scale fuel produced under prototypical conditions has been fully tested over a sufficiently 'broad spectrum of off-normal conditions.'"[43] The development of sufficiently accurate mechanistic source terms is a fundamental step for evaluating the ability of the functional containment, in the LM-CPA, to meet regulatory requirements.[44] As Dr. Lyman explains, the essential information that is missing from the LM-CPA includes: "(1) demonstrated fuel fabrication defect rates and (2) radionuclide release fractions from as-manufactured fuel at the peak temperatures predicted in certain design basis events in the LM-CPA, which have not been

[42] *Id.*, p. C-9 (quoting from NRC staff's "Next Generation Nuclear Plant—Assessment of Key Licensing Issues").
[43] Exhibit E, p. 3 (quoting RG 1.232, p. C-9).
[44] *See* X Energy, LLC (X-energy) Xe-100 Licensing Topical Report Mechanistic Source Term Approach, Revision 3 (Mar. 14, 2025) (ML25073A094).

experimentally determined."[45] The inadequacy of the MSTs proposed by LME is discussed further below.

Because there is no approved evaluation model for mechanistic source term development at this stage, the only option for LME to evaluate the adequacy of its proposed functional containment would be to use a deterministic source term based upon a "major accident," as required by 10 C.F.R. § 50.34(a)(1)(ii)(D). However, the LM-CPA contains no such evaluation.

Therefore, in the absence of such an evaluation, to meet the letter and the intent of RG 1.232, Appendix C, Criterion 16, the Xe-100 design referenced in the LM-CPA would have to include a conventional, essentially leak-tight containment structure to ensure compliance with 10 C.F.R. § 50.34. This is consistent with the recommendation made by NRC staff, in its 1995 draft MHGTR preapplication safety review, wherein staff stated that a prototype MHTGR with a low-leakage containment should be considered if the "necessary design and quality of the fuel to meet the performance objectives" has not been demonstrated.[46] But the Xe-100 design in the LM-CPA does not include a physical, leak-tight containment structure.

Accordingly, the LM-CPA fails to demonstrate with reasonable assurance that its proposed containment design will control the release of radioactivity to the environment under all "postulated accident conditions" sufficiently to fulfill the safety design objective

[45] Exhibit E, p. 3.
[46] *See* Draft Copy of Preapplication-Safety Evaluation Report (PSER) on the Modular High-Temperature Gas-Cooled Reactor (MHTGR) (Mar. 26, 1996) (ML052780519).

of meeting "10 CFR 50.34 offsite dose requirements at the plant's exclusion area boundary (EAB) with margins."[47]

3. The mechanistic source terms in the LM-CPA's functional containment demonstration fail to meet the minimum criteria for adequacy.

The adequacy of the functional containment depends on the adequacy of the MST determination. But as explained by Dr. Lyman in his Declaration and as summarized below, the MSTs fail to satisfy the minimum criteria for adequacy.[48]

(a) The computer code used in the LM-CPA to determine the mechanistic source terms critical for demonstrating the acceptability of the functional containment approach has not been approved by the NRC. Indeed, it has not even been submitted yet for review. (This is discussed in more detail in Dr. Lyman's Declaration.)

(b) The LM-CPA provides no manufacturing defect data obtained from sampling industrial-scale, representative fuel to justify the assumptions made about TRISO pebble performance under normal and accident conditions. Thus, it cannot demonstrate that those assumptions are conservative when evaluating the adequacy of the functional containment to meet regulatory requirements. (This is discussed in more detail in Dr. Lyman's Declaration.)

(c) The LM-CPA analysis of the "extreme case" "depressurized loss of forced circulation" (DLOFC) event, which occurs during a number of the design basis accidents (DBAs) evaluated, results in maximum fuel temperatures approaching 2000°C for nearly two days, and sustains peak temperatures of over 1800°C for a period of several days after that. This is well outside of the bounds established by the LM TRISO fuel qualification Topical Report (TR) from the experimental database for TRISO UCO fuel. Thus, any assumptions made in the LM-CPA about the performance of its fuel under such conditions that support the development of MSTs have not been validated. And the LM-CPA analyses of DBAs including DLOFCs supporting the adequacy of the functional containment to meet regulatory requirements are invalid. Accordingly, there is considerable uncertainty and the possibility that the MST

[47] RG. 1.232, p. C-8 (Criterion 16).
[48] *See generally* DANU-ISG-2022-01, Appendix C.

and radiological consequences for the Seismic DBA are significantly underestimated. (This is discussed in more detail in Dr. Lyman's Declaration.)

(d) The methodology used in the LM-CPA for calculation of the core radionuclide inventory has large uncertainties and possibly even errors that have resulted in an underestimate of the total radionuclide inventory and hence the MSTs used to justify the adequacy of the functional containment. (This is discussed in more detail in Dr. Lyman's Declaration.)

(e) There are limited to no experimental measurements of iodine or tellurium releases from TRISO fuel in temperature transients. As these are significant contributors to offsite dose, this lack of data introduces significant uncertainty into the MST calculations supporting the adequacy of functional containment.

(f) The Advanced Gas Reactor (AGR) program test data for UCO fuel is only available for compacts rather than the pebble fuel forms that the Xe-100 will use. This has been noted as a significant limitation in the use of AGR data for assessing the effectiveness of the Xe-100 fuel matrix as a component of the functional containment.[49]

(g) There has been no testing of sufficiently representative fuel manufactured at a commercial scale. X-Energy's plan to conduct such testing at Idaho National Laboratory is highly unlikely to yield results in time to inform the NRC's decision on the LM-CPA's proposed functional containment.

(h) There is no experimental data available on steam ingress and its effect on the Xe-100 core. This phenomenon could have a significant impact on the MST used to assess the adequacy of functional containment. The Department of Energy is constructing a furnace to conduct such tests, but the schedule is uncertain, and again, it is unclear when useful data will be available for incorporation into the MST model.

Taken together, the above deficiencies indicate that the MSTs relied on in the LM-CPA for the functional containment demonstration are not reliable and do not comply with DANU-ISG-2022-01.[50]

[49] X Energy—Safety Evaluation of XE-100 Topical Report, "TRISO-X Pebble Fuel Qualification Methodology," Revision 3, p. 6 (Mar. 9, 2023) (ML22327A201).

[50] *See also* SECY-18-0096: Enclosure 2—Functional Containment Performance Criteria Technology-Inclusive, Risk-Informed, Performance-Based Approach (Sept. 28, 2018) (ML18115A367).

4. The LM-CPA does not conform to the limitations imposed by NRC staff in response to LME's Topical Report regarding the fuel qualification program and thus, does not provide an adequate demonstration that the proposed functional containment satisfies the requirements in 10 C.F.R. § 50.34.

The LM-CPA references the X-Energy Fuel Qualification Topical Report, Revision 3 (ML22216A179). The staff approved this report in March 2023 subject to three limitations and conditions (ML22327A201). They are as follows:

1. Applicants referencing the Technical Report (TR) should provide a justification for releases from defect particles, contamination in the fuel matrix, and diffusion of volatile radionuclides in addition to the intact particle failure fraction derived from the testing to be used in a future licensing application. In effect, this methodology forms a portion of the fuel qualification for the final reactor fuel form, but not the entirety of the fuel qualification process for the performance of the fuel (e.g., cover the aspects cited above or the more comprehensive list of fuel qualification areas in NUREG-2246).

2. This approval is limited to the plan to test TRISO fuel and the operational envelope (temperature, burnup, and environmental conditions) outlined in the TR. Applicants referencing the TR should provide a set of fuel specifications and demonstrate how fuel to be used in the reactor will meet these specifications. Future licensing submittals will be needed to qualify the fuel for the totality of the operational regime, including but not limited to transient accident conditions and mechanical effects to the extent that these are not incorporated within the scope of the TR.

3. An applicant referencing the TR is subject to the limitations and conditions associated with the approved EPRI TRISO TR.

The LM-CPA does not conform to these limitations. X-Energy's plan to address this problem is through a testing program. As explained by Dr. Lyman in his Declaration, X-Energy publicly disclosed that it was planning to conduct such testing at Idaho National Laboratory, including irradiation and transient testing.[51] However, no schedule for the

[51] Exhibit E, p. 12.

testing was presented publicly, and given the current unavailability of as-manufactured fuel from the yet-to-be-built TRISO-X facility, as well as the length of time such tests have taken historically to yield data, it is unlikely that useful results from such testing will be available by the time the NRC has committed to make a licensing decision on the LM-CPA.

5. LME's proposal to conduct fuel testing in the future does not comply with the requirements of 10 C.F.R. § 50.34(a)(4) and (a)(8).

10 C.F.R. § 50.34(a)(4) requires that the preliminary safety analysis report include:

> A preliminary analysis and evaluation of the design and performance of structures, systems, and components of the facility with the objective of assessing the risk to public health and safety resulting from operation of the facility and including determination of the margins of safety during normal operations and transient conditions anticipated during the life of the facility, and the adequacy of structures, systems, and components provided for the prevention of accidents and the mitigation of the consequences of accidents.

And 10 C.F.R. § 50.34(a)(8) requires the preliminary safety analysis report to include:

> An identification of those structures, systems, or components of the facility, if any, which require research and development to confirm the adequacy of their design; and identification and description of the research and development program which will be conducted to resolve any safety questions associated with such structures, systems or components; and a schedule of the research and development program showing that such safety questions will be resolved at or before the latest date stated in the application for completion of construction of the facility.

The LM-CPA fails to satisfy these requirements. This is because the latest date for completion of construction cited in the LM-CPA is 2033.[52] As explained above, and in Dr.

[52] LM-CPA Part I-1 (pdf p. 2).

Lyman's Declaration, X-Energy is unlikely to be able to conduct the necessary testing and obtain all results by then; LME has not demonstrated otherwise.

6. The LM-CPA fails to include an evaluation using a deterministic source term based upon a "major accident," and does not qualify for an exemption from this requirement.

Because the MST model is not acceptable for demonstrating the adequacy of the functional containment, the LM-CPA must include an evaluation and analysis of the postulated fission product release based on a "major accident" resulting in a "substantial meltdown of the core with subsequent release into the containment of appreciable quantities of fission products."[53] The LM-CPA is requesting a partial exemption from this requirement based, in part, on the claim that "core meltdown is not credible at the temperatures experienced in this non-metallic core."[54] But as discussed above, and as explained in Dr. Lyman's Declaration, it is reasonable to assume that "appreciable quantities of fission products" can be released at the temperatures greater than 1800°C that result from the DLOFC due to fuel damage. Thus, whether this constitutes a "meltdown," is a distinction without a difference—particularly when considering the radiological consequences of such an event. Even a partial exemption would present an undue risk to public health and safety and contravene the purpose of the PSAR rules.[55]

[53] 10 C.F.R. § 50.34(a)(1)(ii)(D) & n.3.
[54] LM-CPA 3.2-4 (pdf p. 1094).
[55] *See* 10 C.F.R. § 50.12.

C. This Contention Is Within the Scope of This Proceeding

This Contention is within the scope of the LME licensing proceeding because it seeks compliance with 10 C.F.R. § 50.34, which applies to construction permit applications.

D. This Contention Is Material to the Findings the NRC Must Make to Grant the LM-CPA

The failure to include a physical, leak-tight containment structure in the Xe-100 design at the construction permit application stage is a major omission that will have significant implications, not only for the LM-CPA decision-making process, but also for the operating license review. If NRC were to approve the LM-CPA, and if analysis results and experimental data obtained after such approval and the start of construction fail to support the assumptions in the LM-CPA regarding the adequacy of the functional containment, then the applicant will have to redesign the reactor to include a physical containment, and it will have to do so before obtaining an operating license. However, if LME has not undertaken all necessary actions at this CPA stage to ensure that it can install a physical containment in the event of this contingency, then the NRC will have no assurance that the company will have the financial and technical means to do so.

In sum, this contention must be addressed during this CPA licensing process.

E. Facts or Expert Opinion Supporting the Contention, Along with Appropriate Citations to Supporting Scientific or Factual Materials

The facts, expert opinions, and scientific materials that support this contention are included in Dr. Lyman's Declaration (Exhibit E) and in the discussion of the "Basis" for the contention, above.

CONTENTION 2: LME's functional containment fails to include beyond-design basis events (BDBEs) in the functional containment evaluation.

A. Statement of Contention

The LM-CPA does not comply with 10 C.F.R. § 50.34 and MHTGR-16 because it does not include beyond-design basis events (BDBEs) in the spectrum of accidents considered in the functional containment evaluation. This is inconsistent with the historical defense-in-depth function of the containment in mitigating the consequences of beyond-design-basis accidents, as demonstrated during the Fukushima Daiichi disaster and as explained by Dr. Lyman in his Declaration.

B. Basis

The role of the containment in mitigating both design-basis and beyond-design-basis accidents (also known as severe accidents) has been fully established by historical examples, as well as NRC guidance and regulations. Dr. Lyman discusses three historical examples in his Declaration: Three Mile Island, Chernobyl, and Fukushima.[56]

In policy and guidance, the defense-in-depth role of the containment is similarly established. In SRM-SECY-10-0121, the Commission reaffirmed "that the existing safety goals, safety performance expectations, subsidiary risk goals and associated risk guidance (such as the Commission's 2008 Advanced Reactor Policy Statement and Regulatory Guide 1.174), key principles and quantitative metrics for implementing risk-informed decision making, are sufficient for new plants."[57] Those performance expectations and

[56] Exhibit E, p. 13.
[57] SRM-SECY-10-0121 – Modifying the Risk-Informed Regulatory Guidance for New Reactors, p. 1 (Mar. 2011) (ML110610166).

subsidiary risk goals are defined in the Final Standard Review Plan (NUREG-0800), Chapter 19, "Probabilistic Risk Assessment and Severe Accident Evaluation for New Reactors" (2015) (ML15089A068), which provides acceptance criteria that apply to the probable risk assessment (PRA) and to severe accidents in general for new reactors.

These include determining "whether the applicant has adequately demonstrated that the risk associated with the design compares favorably against the Commission's goals of less than 1 x 10 -4 per year (/yr) for CDF [core damage frequency] and less than 1 x 10 -6/yr for LRF [large release frequency],"[58] as well as "whether the design compares favorably with the Commission's approved use of a CPG [containment performance goal], which includes (1) a deterministic goal that containment integrity be maintained for approximately 24 hours following the onset of core damage for the more likely severe accident challenges and (2) a probabilistic goal that the conditional containment failure probability be less than 0.1 for the composite of all core-damage sequences assessed in the PRA."[59] Additional criteria include, "whether the applicant has adequately demonstrated that the design properly balances preventive and mitigative features and represents a reduction in risk when compared to existing operating plants."[60]

Finally, the role of the containment as a defense-in-depth feature for beyond-design-basis accidents is established in numerous regulations, including 10 C.F.R. § 50.155, "Mitigation of beyond-design-basis events." This rule includes provision (b)(1)(i)

[58] NUREG-0800, p. 19.0-11.
[59] *Id.*
[60] *Id.*

requiring applicants and licensees to develop strategies and guidelines for "maintaining or restoring core cooling, containment, and spent fuel pool cooling capabilities" during a "beyond-design basis external event."[61]

Thus, due to the failure of the LM-CPA to evaluate the performance of its claimed "functional containment" for beyond-design-basis event sequences, it does not ensure compliance with the containment performance acceptance criteria that the NRC has established for all new reactors.

C. This Contention Is Within the Scope of This Proceeding

This Contention is within the scope of the LME licensing proceeding because it addresses LM-CPA's functional containment demonstration and its failure to comply with 10 C.F.R. § 50.34, which applies to construction permit applications.

D. This Contention Is Material to the Findings the NRC Must Make to Grant the LM-CPA

The NRC's establishment of containment performance goals for all "new reactors" during severe accidents makes clear that the NRC expects the proposed containment to play a significant role in severe accident mitigation, which must be addressed during this construction permit phase.

E. Facts or Expert Opinion Supporting the Contention, Along with Appropriate Citations to Supporting Scientific or Factual Materials

The facts supporting Waterkeeper's Contention are stated in the Contention itself, in Dr. Lyman's Declaration, and in the supporting materials cited in his Declaration and in the discussion of the "Basis" for this Contention.

[61] 10 C.F.R. § 50.155(b)(1)(i).

CONTENTION 3: LME has failed to demonstrate its financial qualifications to build and operate the LMGS.

A. Statement of Contention

NRC safety regulations for construction permits require a detailed demonstration that the applicant is financially qualified to build and operate the facility.[62] As LME acknowledges, the "underlying purpose" of these regulations "is to protect public health and safety by preventing safety lapses during construction from underfunded projects."[63] Instead of seeking to demonstrate fulfillment of 10 C.F.R. § 50.33(f) and Appendix C, however, LME seeks an exemption, requesting that it be held to the more lenient standard of 10 C.F.R. § 70.23(a)(5) of merely "appear[ing] to be financially qualified.[64] But LME has failed to satisfy the requirements for an exemption set forth in 10 C.F.R. § 50.12 or to meet the judicial standard of "extraordinary circumstances."[65] Its reliance on a disapproved draft proposed rule and an unrelated licensing proceeding are inapposite. And even if it were lawful to apply 10 C.F.R. § 70.23(a)(5), LME does not meet that standard because it has failed to make a sufficient demonstration of financial commitments to ensure the uninterrupted availability of sufficient finances to build and operate the project. In fact, LME's rationale rests on the premise that ARDP funding will cover 50% of its costs, but this is misleading and inaccurate, with ARDP funding more accurately covering at most 21%-26%.

[62] 10 C.F.R. § 50.33(f) and 10 C.F.R. Part 50, Appendix C.
[63] LM-CPA Part V at V-XVI (pdf. p. 18).
[64] *Id.* at V-X (pdf p. 11).
[65] *NRDC v. NRC*, 695 F.2d 623, 625 (D.C. Cir. 1982).

B. Basis

1. LME Fails to Demonstrate its Financial Qualifications Under 10 C.F.R. § 50.33(f) and Appendix C to Part 50.

Under 10 C.F.R. § 50.33(f) and 10 C.F.R. Part 50, Appendix C, a reactor construction permit applicant must provide:

> (1). . . information that demonstrates that the applicant possesses or has reasonable assurance of obtaining the funds necessary to cover estimated construction costs and related fuel cycle costs. The applicant shall submit estimates of the total construction costs of the facility and related fuel cycle costs, and shall indicate the source(s) of funds to cover these costs.
>
> . . . (4) Each application for a construction permit, operating license, or combined license submitted by a newly-formed entity organized for the primary purpose of constructing and/or operating a facility must also include information showing:
>
> > (i) The legal and financial relationships it has or proposes to have with its stockholders or owners;
> >
> > (ii) The stockholders' or owners' financial ability to meet any contractual obligation to the entity which they have incurred or proposed to incur; and
> >
> > (iii) Any other information considered necessary by the Commission to enable it to determine the applicant's financial qualification.
>
> (5) The Commission may request an established entity or newly-formed entity to submit additional or more detailed information respecting its financial arrangements and status of funds if the Commission considers this information appropriate. This may include information regarding a licensee's ability to continue the conduct of the activities authorized by the license and to decommission the facility.[66]

Appendix C further requires:

> "If the sources of funds relied upon include parent companies or other corporate affiliates, information to support the financial capability of each such company or affiliate to meet its commitments to the applicant should be set forth in the application. This information should be of the same kind and scope as would be required if the parent companies or affiliates were in fact the applicant. Ordinarily,

[66] 10 C.F.R. § 50.33(f).

it will be necessary that copies of agreements or contracts among the companies be submitted."

Furthermore, 10 C.F.R. § 50.33(f) and 10 C.F.R. Appendix C to Part 50 impose additional requirements on newly-formed entities to provide more detailed information about "the applicant's legal and financial relationships with its stockholders, corporate affiliates, or others (such as financial institutions) upon which the applicant is relying for financial assistance."[67]

LME completely fails to satisfy these requirements; in fact, LME doesn't even try.[68] Instead, LME argues 70.23(a)(5) applies, and provides a mere two-page appendix to Part I of the LM-CPA as its Financial Capacity Plan.[69] "Long Mott Energy, LLC, Financial Capacity Plan for Construction of the Long Mott Generating Station." This appendix includes only two statements of direct relevance to the LM-CPA, neither of which are sufficient to show LME is financially qualified to construct a nuclear facility; the remainder are merely about LME's parent company, the Dow Chemical Company ("TDCC"), which also has no evidenced experience constructing a nuclear facility, much less a first-of-its-kind reactor.[70]

LME also does not dispute that it is a "newly-formed entit[y] organized primarily for the purpose of engaging in the activity for which the permit is sought." It also states that it will rely on TDCC for financial support and Advanced Reactor Demonstration

[67] 10 C.F.R. Appendix C to Part 50.
[68] *See* LM-CPA Part I at I-III – I-IX (pdf pp. 4-10); *see also* Part V at V-X – V-XVII (pdf pp. 11-18) (applying only 10 C.F.R. § 70.23(a)(3)).
[69] *Id.* at I-VII – I-IX (pdf pp. 8-10).
[70] *Id.*

Program ("ARDP") funding. As such, and as LME's parent, TDCC is required under Appendix C to supply the same kind and scope of information as if it were the applicant itself. This would include at a minimum a statement of assets, liabilities, and capital structure, as well as TDCC's legal and financial relationships with those it is relying on for financial assistance.[71] Balance sheets and income statements for prior operations are also requested.[72] This information from TDCC is missing from the application.

Appendix C further states that "[t]he application should specifically identify the source or sources upon which the applicant relies for the funds necessary to pay the cost of constructing the facility, ***and the amount to be obtained from each***." LME does not specify the amount of funding that it will obtain from TDCC. Furthermore, LME asserts only that ARDP will provide 50% of the costs, but it does not identify the ***amount*** of ARDP funding. In fact, as described further below, its estimate that 50% of the costs are covered is likely inaccurate. These are two of the omissions that render the LM-CPA insufficient.

a) LME fails to submit sufficient information about itself and the ARDP grant to establish its financial qualifications.

LME asserts that: "An intercompany agreement is in place ensuring TDCC will provide financial support to LME for construction of LMGS."[73] Ordinarily, under 10 C.F.R. Part 50 Appendix C, "it will be necessary that copies of agreements or contracts

[71] 10 C.F.R. App. C(II)(A)(2).
[72] 10 C.F.R. App. C(II)(A)(2).
[73] LM-CPA Part I-IX (pdf. p. 10).

among the companies be submitted."[74] However, LME did not include a copy of its intercompany agreement as part of the LM-CPA, and thus the details of this purported agreement are unclear. Without the details of the agreement, it is unclear the amount of "financial support" TDCC may provide, conditions precedent to the provision of that support, and all other details that would be pertinent to establishing that LME has the requisite financial qualifications, whether under the applicable requirements of 10 C.F.R. § 50.33(f) or even the subjective standard of 10 C.F.R. § 70.23(a)(5). Nor does the LM-CPA provide any other information detailing how LME itself will navigate the complexities of the project's financing requirements.

LME then misleadingly asserts that half of LMGS's total construction costs—a total that has been redacted in the LM-CPA—will be paid by the U.S. Department of Energy (DOE) through a grant program, stating that:

> In May 2022, the Department of Energy announced the Advanced Reactor Demonstration Program (ARDP) to facilitate the transition of next generation nuclear reactors from concept to demonstration through cost-share partnerships. In October 2020, X-Energy, LLC, with its Xe-100 high-temperature gas-cooled reactor (HTGR), was selected to deliver a commercial first-of-a-kind advanced nuclear plant with partner Energy Northwest. In March 2023, the DOE agreed to make Dow a sub-awardee under the ARDP agreement, moving this funding from Energy Northwest. The ARDP provides a 50 percent DOE/private sector cost share on all projected costs to deliver LMGS.[75]

[74] 10 C.F.R. Part 50 Appendix C: "If the sources of funds relied upon include parent companies or other corporate affiliates, information to support the financial capability of each such company or affiliate to meet its commitments to the applicant should be set forth in the application. This information should be of the same kind and scope as would be required if the parent companies or affiliates were in fact the applicant. Ordinarily, it will be necessary that copies of agreements or contracts among the companies be submitted."

[75] LM-CPA Part I-IX (pdf. p. 10).

As an initial matter, problematically, LME does not attach the ARDP award contract to the LM-CPA to substantiate its claims as to what costs DOE will cover, and what conditions might limit reimbursement through the award. Moreover, LME's statement omits certain facts that would otherwise reveal that DOE's award is unlikely to cover 50 percent of LME's construction costs. Not only would this increase the costs that LME would have to finance on its own—rendering information about its own independent financial qualifications even that much more relevant—it also cuts against LME's arguments that the subjective standard of 10 C.F.R. § 70.23(a)(5) applies.

A more realistic picture of the likely amount of cost-sharing DOE will contribute becomes apparent when considering the following facts that LME omitted from the LM-CPA, and strongly suggests that only up to 21-26% of LME costs might be covered by DOE, not the 50% LME claims:

- **X-Energy's DOE Award is Limited.** In 2021, Congress authorized a one-time appropriation of $3.211 billion to DOE to fund the ARDP, including $2.5 billion for awards to two companies for construction of demonstration projects: X-Energy and Terrapower. In November 2021, X-Energy issued a statement that its share of the appropriation would be approximately $1.1 billion ("~$1.1B").[76] In 2023, X-Energy updated the total amount of DOE funding through the ARDP to be $1.23 billion, including a 2020 disbursement of $80 million.[77]

- **The Limited Award Will Be Split with a Second Project.** X-Energy's ARDP award is to be split between not one but two of its construction projects: this project

[76] Exhibit G, X-Energy, "Congress Appropriates ~$1.1B Dollars to X-Energy's ARDP Project with Historic Legislation Recognizing Clean Energy Supply as vital to US Infrastructure and Economic Health," November 15, 2021, see https://X-Energy.com/media/news-releases/congress-appropriates-1-billion-dollars-to-X-Energys-ardp-project, accessed August 5, 2025.

[77] Exhibit H, X-Energy, "X-energy and Ares Acquisition Corporation Announce Strategic Update to Business Combination Terms to Reinforce Long-Term Value Creation Opportunity and Alignment with Shareholders," June 12, 2023, see https://x-energy.com/media/news-releases/x-energy-ares-acquisition-corporation-announce-strategic-update-to-business-combination-terms, accessed August 5, 2025.

(the LMGS) and X-Energy's TRISO-X fuel fabrication plant, to be located in Tennessee.[78] DOE has stated that funding for the awards is subject to significant contingencies, including further Congressional appropriations and DOE's evaluation of the project's progress: "Funding beyond the near-term is contingent on additional future appropriations, evaluations of satisfactory progress and DOE approval of continuation applications."[79]

- **Costs for the Two Projects are at least $4.75 Billion.** In June 2023, X-Energy issued an updated cost projection for the two facilities: "The Company completed its most recent review of design processes and related costs on March 31, 2023. As a result, X-energy updated its cost estimates to complete the full ARDP scope to a total of between $4.75 and $5.75 billion. This scope includes the design and licensing of the Xe-100 standard plant, the design, licensing, and construction of the TRISO-X commercial fuel fabrication facility, and the construction of a four-unit Xe-100 facility at the Dow Inc. ("Dow") UCC Seadrift Operations site (the "Seadrift site") in Texas." No public information has been located as to the cost of either project alone.

In sum, only up to 21-26% of construction costs for the LME facility are currently likely to be eligible for ARDP reimbursement. [80] Thus, LME has no guarantee that 50% of the construction costs will be paid by DOE, increasing the share of the costs that it must finance to at least 74% to 79%.

In addition, despite X-Energy providing an updated cost projection in 2023, Congress has not acted to appropriate additional funds sufficient to cover 50% of those costs. Moreover, the ARDP award is structured as a reimbursement program, requiring

[78] Exhibit I, U.S. Department of Energy, "U.S. Department of Energy Announces $160 Million in First Awards under Advanced Reactor Demonstration Program," October 13, 2020, see https://www.energy.gov/ne/articles/us-department-energy-announces-160-million-first-awards-under-advanced-reactor, accessed August 5, 2025.
[79] *Id.*
[80] This assumes that ARDP funding will be split evenly between both of the X-Energy projects---a reasonable assumption to make given the fact LME has not provided the necessary information to determine the costs of each project individually nor the full details of the ARDP grant. In other words, total grant divided by total cost of the two projects: $1.23 B / ($ 5.75 B) * 100% = 21% and $1.23 B / ($ 4.75 B) * 100% = 26%.

LME to cover construction costs itself, and then apply to DOE for reimbursement of 50% of that amount.[81] Once X-Energy and LME have exhausted the available ARDP funding (in whatever amounts Congress has made available), LME will be liable to finance the remaining construction costs, with no guarantee of further DOE funding.

b) The information provided about LME's relationship with TDCC does not suffice to satisfy 10 C.F.R. § 50.33(f) and Appendix C.

LME's two-page disclosure also includes general statements asserting that TDCC, of which LME "is a wholly owned subsidiary," has the experience and financial capacity to manage large industrial construction projects; but notably, none of this experience is in the extremely specialized field of nuclear reactor construction. LME cites examples of two multi-billion-dollar petrochemical plant construction projects that TDCC has undertaken in recent years and reports that TDCC "has reported annual capital spending of $2.5 billion/year on average over the recent years since 2021," which it finances "through a combination of debt and equity sources, including cash flow from operations, bonds and the issuance of new debt." Even if this were relevant, which it is not, LME has only bare assertions that it could rely on its parent company's financial and project management capacity, having provided no details about the specific financial agreements between LME and TDCC for this project.

[81] Exhibit J, U.S. Government Accountability Office, NUCLEAR ENERGY PROJECTS: DOE Should Institutionalize Oversight Plans for Demonstrations of New Reactor Types, September 2022, see https://www.gao.gov/assets/gao-22-105394.pdf, accessed August 11, 2025.

2. LME Fails to Satisfy the Regulatory or Judicial Standards for an Exemption.

Even though 10 C.F.R. § 50.33 and Appendix C apply, LME seeks an exemption.[82] But for LME to be exempt from the requirements of 50.33 and Appendix C, LME must meet the standard for an exemption under 10 C.F.R. § 50.12. To be granted, an exemption must be (1) "[a]uthorized by law, . . . not present an undue risk to the public health and safety, and [be] consistent with the common defense and security" and (2) in response to "special circumstances."[83] LME fails to make these necessary showings.[84] And the District of Columbia Circuit has limited the granting of 50.12 exemptions to "extraordinary circumstances":

> Section 50.12 provides a mechanism for obtaining an exemption from the procedures incorporated in section 50.10, but one that may be invoked only in extraordinary circumstances. The Commission has made clear that section 50.12 is available "only in the presence of exigent circumstances, such as emergency situations in which time is of the essence and relief from the Licensing Board is impossible or highly unlikely." [citing *Washington Public Power Supply System*, 5 NRC 719, 723 (1977)].[85]

a) This exemption would present undue risk to public health and safety in violation of 10 C.F.R. § 50.12(a)(1).

First, LME relies on statements from a never-finalized, disapproved draft proposed rule to make its showing that the exemption would not present undue risk to public health and safety, stating that evolving oversight programs and processes reduce the need to rely

[82] LM-CPA Part I-III (pdf p. 4).
[83] 10 C.F.R. § 50.12(a)(2)(i)-(vi).
[84] Furthermore, a showing that these elements have been met does not bind the NRC to grant an exemption; it then "may" grant an exemption only after considering and balancing the factors in 10 C.F.R. § 50.12(b)(1)-(4).
[85] *NRDC v. NRC*, 695 F.2d 623, 625 (D.C. Cir. 1982).

on financial qualifications.[86] This rulemaking, described further below in this Section 2, was never finalized and is not binding. In fact, the Commission specifically disapproved this rulemaking. Furthermore, the novel nature of this reactor's design and its location adjacent to agricultural and residential land and commercial fisheries, as well as a large petrochemical industrial facility, poses a large and complex array of public health and safety risks.

Second, LME relies on other statements from this disapproved draft proposed rule to claim that its allegations of 50% cost coverage through ARDP is a sufficient demonstration of financial capacity.[87] However, as the above analysis in Section 1 of this Contention shows, LME has provided insufficient information to substantiate such a claim, because at best only approximately 21-26% of costs might be covered—though even those will be subject to a denial of reimbursement by DOE, leaving LME responsible for the non-covered costs.

Indeed, requiring compliance with 10 C.F.R. § 50.33(f) and 10 C.F.R. Part 50, Appendix C is the only way to make sure its underlying purpose—protection of public health and safety by preventing safety lapses during construction from underfunded projects—is achieved.

[86] LM-CPA Part V-XV (pdf p. 16).
[87] LM-CPA Part V-XV (pdf p. 16).

b) No special circumstances warrant an exemption.

LME argues that two special circumstances exist that would justify its exemption request, appealing to 10 C.F.R. § 50.12(2)(ii) and (vi),[88] but such relief is not warranted.

Specifically, LME's exemption request rests upon two arguments: a claim of precedent from a previous NRC licensing proceeding (which has limited relevance to the LM-CPA), and documents issued nearly a decade ago to support a proposed rule change to 10 C.F.R. § 50.33 that NRC has never adopted.

i. LME misrepresents the previous NRC licensing process that it seeks to rely on in support of its exemption request, and moreover it has limited relevance here.

LME incorrectly claims that an exemption to 50.33(f) that NRC granted to the applicant for a combined operating license ("COL") for South Texas Project ("STP") Units 3 and 4 in 2015 establishes a relevant precedent for its request for a similar exemption in the LM-CPA, which the NRC found constituted a special circumstance under 50.12(a)(2)(vi). A review of the 2015 safety evaluation report ("SER") that NRC issued for the STP COL application reveals that the applicant (NINA) both (1) provided much more detailed information regarding its sources of funding and corporate relationships than LME has included in the LM-CPA, and (2) proposed a set of conditions to be included in the COL to provide additional assurance of its financial qualifications, which LME has not proposed.

[88] LM-CPA Part V at 17-18.

For example, as detailed in the SER, NINA's FCP included much more detail about:

- its corporate affiliates' capacity and experience in financing nuclear reactor construction projects; (in contrast, LME and TDCC have no such experience)
- the involvement of an established financial consultant with relevant experience in utility infrastructure projects (Deloitte); (in contrast, LME has not disclosed hiring such an established financial consultant)
- the sources of financing for the project, including a negotiated term sheet with the DOE Office of Loan Programs; (which LME does not have) and,
- its parent affiliates' relationships with Japan Bank for International Cooperation ("JBIC") and Nippon Export and Insurance ("NEXI") for project finance and insurance, including letters of support for the STP 3&4 project from JBIC and NEXI. (in contrast, LME has provided no such letters or contracts establishing financial insurance or support).[89]

LME also does not propose analogous licensing conditions to those placed on the STP COL, nor does the LM-CPA include discussion of the NRC's rationale in approving the STP COL. Pertinently, the conditions required that NINA provide NRC notice 60 days before initiating construction, with the following documentation:[90]

> an updated cost estimate; documentation justifying any material variances from the original cost estimate in the COL application; and documentation demonstrating that NINA has secured financing to fund the updated cost estimate.

NRC found such a condition necessary, even in light of the extensive documentation provided by NINA, stating: "the license condition proposed by NINA and as revised by

[89] U.S. Nuclear Regulatory Commission, "Final Safety Evaluation Report (FSER) for the South Texas Project (STP), Units 3 and 4, Combined License Application," September 29, 2015, FSER Chapter 1 (ML15271A126).
[90] *Id.* at 1-39 – 1-40.

NRC staff, ensures that adequate construction funds will be available to NINA before it begins reactor construction of STP Units 3 and 4."[91]

The SER also discussed NRC's rationale for amending NINA's proposed condition and required NINA to not only "identify" material variances from the original cost estimate, but to "justify" them:

> Staff believes that justification of identified variances in the construction cost estimate provides additional supporting confirmation of the applicant's understanding of the costs and funding needs of the project, including changes in cost and financing requirements. The condition that the licensee not only identify variances, but also justify and explain them, provides further evidence of NINA's financial capacity, and ensures that any material cost variances are well understood and justified by the applicant prior to construction.[92]

LME proposes no such conditions to satisfy the financial qualifications standard it proposes, which were deemed essential by NRC in approving the referenced exemption in the STP COL.

As such, LME's failure to provide the same level of documentation as NINA and LME's omission of any similar conditions falls short of the standard NRC relied upon in approving an exemption from 50.33(f) in the STP COL; therefore, LME's reliance on the STP COL as precedent for its request fails to meet that standard.

ii. LME's reliance on a disapproved draft proposed rule is unavailing.

LME cites a 2016 regulatory basis document for a then-proposed change to the 10 C.F.R. § 50.33 financial qualifications requirements. NRC began developing this proposed rule change while the STP COL was under review, to address the circumstances non-utility

[91] *Id.* at 1-40.
[92] *Id.* at 1-39.

applicants may face in securing financing for reactor construction projects. Namely, those include the applicants' reliance on project financing and lenders' requirements that the borrower secure all required permits and approvals before a loan can be approved.

But LME describes no such obstacles in its FCP, stating merely that "An intercompany agreement is in place ensuring TDCC will provide financial support to LME for construction of LMGS" and "The ARDP provides a 50 percent DOE/private sector cost share on all projected costs to deliver LMGS." As detailed above, the latter statement omits significant details that undermine its value in demonstrating financial qualifications. The former statement is not substantiated by supporting documentation demonstrating the terms under which TDCC will provide adequate financial support to LME.

Further, LME admits that, after reviewing the proposed changes to 50.33(f):

> the Commission ***disapproved*** the proposed rule that would have amended these requirements and directed the staff to address financial qualifications during the development of 10 CFR 53.[93]

LME is aware that the NRC has not adopted any final rule amending the financial qualifications requirements, but obliquely characterizes them as "in a pendent state as it is being addressed as part of the ongoing 10 CFR 53 rulemaking effort per Commission direction."[94] In fact, not only did the Commission disapprove of the proposed rule change, the Staff Requirements Memorandum to which the LM-CPA cites indicates a great degree

[93] U.S. Nuclear Regulatory Commission, "Staff Requirements – SECY-18-0026 – Proposed Rule: Financial Qualifications Requirements for Reactor Licensing (RIN 3150-AJ43)," July 14, 2022 (ML22195A097) (emphasis added).
[94] LM-CPA Part V-XVII at 18.

of uncertainty regarding NRC's intentions, soliciting responses to questions that suggest a potential reevaluation of the rationale for amending 50.33(f), including:

> "Does this standard continue to pose challenges for merchant power plant applicants?"; and "Should Parts 50 and 52 have the same financial qualification requirements as Part 53? Why or why not?"[95]

In short, ten years after NRC authorized an exemption from 10 C.F.R. § 50.33(f) in the STP COL case, NRC disapproved an amendment to the rule in question, and it is not evident that one remains pending.

iii. As such, a special condition under (ii) does not exist.

10 C.F.R. § 50.12(ii) states that a special circumstance exists when:

> (ii) Application of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule;

As LME describes it, "The underlying purpose of the financial qualification requirements for construction in 10 CFR 50.33(f) and 10 CFR 50, Appendix C, is to protect public health and safety by preventing safety lapses during construction from underfunded projects."[96] This is exactly such a project that appears to be underfunded: LME's rationale rests on the premise that ARDP funding will cover 50% of its costs, but as Section I of this Contention shows, this is misleading and inaccurate, with ARDP funding more accurately at most 21%-26%. To the extent LME might rely on the disapproved draft proposed rule or the decision in STP,[97] these grounds are also unconvincing, as the above explains.

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[95] U.S. Nuclear Regulatory Commission, "Staff Requirements – SECY-18-0026 – Proposed Rule: Financial Qualifications Requirements for Reactor Licensing (RIN 3150-AJ43)," July 14, 2022 (ML22195A097).
[96] LM-CPA Part V-XVII at 18.
[97] LME's rationale for exemption (ii) only cites to its ARDP funding.

iv. A special condition under (vi) does not exist.

10 C.F.R. § 50.12(vi) states that a special circumstance exists when:

> There is present any other material circumstance not considered when the regulation was adopted for which it would be in the public interest to grant an exemption. If such condition is relied on exclusively for satisfying paragraph (a)(2) of this section, the exemption may not be granted until the Executive Director for Operations has consulted with the Commission.

LME's rationale with respect to (vi) is also unavailing. LME cites a regulatory basis analysis issued in support of a proposed rule change to 50.33(f) and to the exemption granted in the STP COL. But as described above, the LM-CPA does not provide a similar level of detail or assurances to those NRC relied upon in approving the STP COL.

Therefore, LME has not demonstrated that an exemption is justified and that it meets any of the special circumstances required by 10 C.F.R. § 50.12(a)(2).

3. Even assuming for purposes of argument that an exemption is justified, LME Fails to Demonstrate Its Financial Qualifications under 10 C.F.R. § 70.23(a)(5).

Even assuming that an exemption is justified (which it is not), LME fails to demonstrate its financial qualifications under even the more lenient standard of 10 C.F.R. § 70.23(a)(5). This rule prohibits NRC from issuing a license unless "the applicant appears to be financially qualified to engage in the proposed activities."

The information provided in the LM-CPA is insufficient to meet even this subjective standard. As detailed above in Section 1 of this Contention, based on the LM-CPA's assertions and publicly available information, the ARDP award that LME relies on will not suffice to cover 50% of construction costs, but it will only likely cover at most 21%-26% of presently projected costs. Furthermore, the inaccurate characterization of the ARDP

award and the failure to disclose the interaction of the two ARDP-funded X-Energy projects (the LMGS and TRISO-X construction projects) with respect to that award raise additional questions about the reliability of LME's financial qualifications and its Financial Capacity Plan.

In addition, the LM-CPA's omission of documents that could substantiate the commitments of LME's parent company and the managerial and financing relationships between LME and TDCC further obscures the sufficiency of LME's statements. Even without the language of the agreements between LME, TDCC, and DOE, the information provided in Part I of the LM-CPA does not support the conclusion that there is reasonable assurance that adequate funds will be available. Moreover, as detailed in Section I, neither company has experience in constructing, operating, or financing nuclear reactors and cannot rely on past experience in the industry.

And even when NRC has applied 10 C.F.R. § 70.23(a)(5) and found an applicant financially qualified, it has done so by incorporating the commitments made by the applicant into licensing conditions. In contrast, here, LME has not proposed any license conditions to ensure its financial qualifications are adequately established. To be sufficient, the conditions must be detailed and straightforward to apply, requiring ministerial review only. Conditions that require resolution of legal or factual questions are inappropriate.

For example in *Private Fuel Storage ("PFS")*, the applicant was a limited liability company formed by eight members, all of which were nuclear power generating utilities.[98]

[98] Private Fuel Storage, L.L.C. (Independent Spent Fuel Storage Installation), CLI-00-13, 52 N.R.C. 23, 26 (2000).

It sought a nonreactor license and the NRC found that Part 50 financial requirements did not apply.[99] However, the Commission held that a license applicant's additional commitments should be expressly incorporated into the license to eliminate any question about what the commitments are and about whether they are enforceable.[100]

Likewise, in *Louisiana Energy Services ("LES")*, even though the NRC found the applicant to have sufficiently demonstrated its financial qualifications, it required that license conditions be included to incorporate commitments made in the pleading and in front of the NRC.[101] In deciding to review the application under the more lenient standard of "appears to be financially qualified," it relied on the fact that the application was for uranium enrichment, which have less health and safety risks than nuclear reactors.[102]

Here, LME has proposed no licensing conditions that would incorporate its reliance on TDCC's financial support or otherwise commit to making up for costs not covered by the ARDP grant. Furthermore, neither TDCC nor LME have the same experience in nuclear power that PFS's financial backers and member companies did. It is also proposing to build nuclear reactors, unlike the uranium enrichment operations that the Commission found would be inherently more safe in *LES*.

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[99] *Id.* at 30-31.
[100] *Id.* at 32.
[101] Louisiana Energy Services, L.P. (Claiborne Enrichment Center), CLI-97-15, 46 N.R.C. 294, 308 (1997).
[102] *Id.* at 306.

C. This Contention Is Within the Scope of This Proceeding

This contention is within the scope of the LME licensing proceeding because it seeks compliance with the NRC's rules regarding financial qualifications, a necessary element that must be established before a license may be issued.

D. This Contention Is Material to the Findings the NRC Must Make to Grant the LM-CPA

This contention is material to the findings NRC must make to issue this license because it challenges LME's assertion that 10 C.F.R. § 70.23(a)(5) applies, when in fact it has not met the standard for an exemption under 10 C.F.R. § 50.12, and therefore LME should be held to the financial qualification standard in 10 C.F.R. § 50.33(f) and Appendix C to Part 50.

E. Facts or Expert Opinion Supporting the Contention, Along with Appropriate Citations to Supporting Scientific or Factual Materials

The facts supporting Waterkeeper's Contention are stated in the Contention itself, which includes references to the LM-CPA.

CONTENTION 4: The Environmental Report erroneously minimizes the adverse environmental impacts of the proposed LMGS.

A. Statement of Contention

LME asserts that the adverse environmental impacts of building and operating the LGMS will range from MODERATE to none (during construction) and SMALL to none (during operation).[103] But these claims are based on a seriously deficient environmental analysis, which is in turn based on a seriously deficient safety analysis. A detailed list of

[103] ER Table 4.6-1 (construction), Table 5.12-1 (operation); *see also* Table 10.2-1.

the deficiencies in LME's environmental analysis is provided in the basis statement below. If these issues are evaluated adequately, the proposed action is likely to have reasonably foreseeable and significant adverse effects on the quality of the human environment.

B. Basis

As a major federal action, LME's proposed facility must undergo a NEPA review, which must assess the direct, indirect, and cumulative effects of the proposed action. When such a proposed action will have a reasonably foreseeable significant effect on the quality of the human environment an environmental impact statement is required. 42 U.S.C. § 4336(b)(1).[104] Here, there is a reasonably foreseeable and potentially significant effect on the quality of the human environment at least due to the risk of accidents. As drafted, the PSAR and ER obscure the actual risk of accidents because of erroneous assumptions and omissions in these documents, including the failure to adequately address climate change impacts. The ER is also deficient because it treats seismic risks as not credible with insufficient explanation to support this determination. In sum, the ER and PSAR do not provide sufficient information and analyses to support LME's conclusions as to the magnitude of impacts.

[104] 10 C.F.R. § 51.20(b)(1) also independently requires that an EIS be prepared for an application to construct a nuclear reactor, which the LM-CPA seeks here. LME would need to be granted an exemption from 10 C.F.R. § 51.20(b) to avoid violating this requirement and proceed with an EA. In its transmittal letter, LME suggested that it be exempt from this requirement, and the NRC appears to intend to proceed first with an EA. *See* Long Mott Transmittal Letter (Mar. 31, 2025) (ML25090A058) at 4; Long Mott Generating Station Construction Permit Application Review Schedule and Resource Estimate (June 10, 2025) (ML25155B841) (Environmental Review Milestones: Environmental Assessment Issuance and Finding of No Significant Impact (FONSI); Estimated Completion: June 2026)). However, even if LME is found to be exempt from 51.20(b), an EIS would still be required because reasonably foreseeable significant impacts would be expected.

The Declarations from Dr. Lyman and Mr. Mitman set forth in detail flaws in the PSAR and ER:

As Dr. Lyman explains, the LM-CPA's proposed functional containment fails to satisfy the minimum criteria for adequacy as required by the applicable regulations, including those in 10 C.F.R. § 50.34.[105] This is due to the fact that:

- No manufacturing defect data is presented that would justify the assumptions made in the LM-CPA;[106]
- The assumptions underlying depressurized loss of forced circulation ("DLOFCs") are invalid;[107]
- The methodology for calculating the core radionuclide inventory is unreliable;[108]
- Other deficiencies exist that render the mechanistic source terms inadequate and unreliable;[109] and,
- The LM-CPA does not address the limitations regarding the Fuel Qualification Topical Report.[110]

As such, Dr. Lyman concludes that the LM-CPA does not demonstrate that the proposed Xe-100 functional containment will provide adequate protection of public health and safety.[111]

Furthermore, Dr. Lyman points out that an additional defect exists related to the functional containment evaluation, as the LM-CPA does not include beyond-design basis events (BDBEs) in the spectrum of accidents considered in the functional containment evaluation.[112]

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[105] Exhibit E, ¶¶ 6-13, 37-38.
[106] *Id.*, ¶¶ 16-18.
[107] *Id.*, ¶¶ 19-23.
[108] *Id.*, ¶¶ 24-30.
[109] *Id.*, ¶¶ 31-34.
[110] *Id.*, ¶¶ 35-37.
[111] *Id.*, ¶ 38.
[112] *Id.*, ¶¶ 39-44.

Mr. Mitman describes further flaws in the PSAR that demonstrate there is insufficient support for LME's conclusions. As he explains and as is detailed in his Declaration:

- The PSAR is flawed because with the exception of a single input into the hurricane analysis (sea level rise), the PSAR contains no discussion of the effects of climate change on the safety of the proposed LMGS, even though it is reasonably foreseeable that the LMGS site would be vulnerable to impacts from climate change, including flooding and hurricanes;[113]

- The PSAR's conclusion as to maximum flood elevations of nearby waterbodies is based on only historic data and incomplete analyses, with no consideration of climate change;[114]

- The application indicates that safety structures were consolidated and moved, and that analyses in the PSAR are thus based on outdated information;[115]

- It appears that even the historical data that is provided by the PSAR is inadequate (or even inapplicable) to suffice for a climate change analysis with respect to flooding. Indeed, LME admits that "[a]dditional site-specific analyses and associated information that includes the postulated coincidental wind setup and wave setup" is still lacking from the ER. Furthermore, the methodologies used to calculate probable maximum precipitation ("PMP") and local intense precipitation ("LIP")—inputs into accident risk analyses—do not consider very recent intense storms that could affect the models;[116]

- The PSAR's dam failure analysis fails to consider the reasonably foreseeable adverse effects of climate change;[117]

- The PSAR's assumptions on operating basin failure possibilities are unjustified;[118]

[113] Exhibit F, ¶¶ 8-15.
[114] *Id.*, ¶¶ 16-18.
[115] *Id.*, ¶ 19.
[116] *Id.*, ¶¶ 20-21.
[117] *Id.*, ¶¶ 22-24.
[118] *Id.*, ¶¶ 23-24.

- LME's probable maximum surge predictions rely on a questionable assumption for sea level rise and otherwise do not consider the reasonably foreseeable impacts from climate change;[119]

- LME does not appear to indicate how it plans to protect the safety-related SSCs from surge and seiche flooding;[120] and,

- LME omits the analysis of a reasonably foreseeable accident hazard: a climate-change exacerbated storm event that could cause uncontemplated safety impacts and risks to the LMGS and the surrounding environment.[121]

These flaws propagate into the Environmental Report because it relies on the analysis conducted in the PSAR and does not remediate the aforementioned issues, nor address climate change's risks to the facility and subsequently the surrounding environment.[122] The ER is further flawed, as Mr. Mitman points out, because it treats seismic risk as not credible, without sufficient explanation to support this determination.[123] And the LM-CPA's assertion that the total calculated dose risk is less than other reactors studied in the literature is misleading because the LM-CPA does not analyze the external event scenarios.[124] Taken together, the deficiencies show that the PSAR and ER are inadequate.[125]

In other words, Dr. Lyman's Declaration shows multiple fundamental flaws in LME's conclusion that the functional containment system will be adequate. Mr. Mitman also describes additional flaws in the PSAR data and analyses. Yet the PSAR incorporates

[119] *Id.,* ¶¶ 25-27.
[120] *Id.,* ¶ 28.
[121] *Id.,* ¶¶ 29-32.
[122] *Id.*, ¶ 33.
[123] *Id.*, ¶¶ 34-36.
[124] *Id.*, ¶ 37.
[125] *Id.*, ¶¶ 38-39.

all of these flawed assumptions when assessing the risks to the facility from the natural phenomenon threats that Mr. Mitman's Declaration describes. And when assessing these risks, LME both ignores relevant historical data and fails to take into account how climate change exacerbates risk for the plant and the human environment around it.

Furthermore, Mr. Mitman identifies a specific accident risk, i.e., climate-change exacerbated dam failure that could send an excess of water into the LMGS site. Yet the Environmental Report gives no signs of incorporating these sorts of reasonably foreseeable environmental impacts from climate change on the facility that would increase the risk to the plant and the human environment around it.

LME's discussion regarding storage of spent nuclear fuel also fails to comply with applicable regulations—which further undermines LME's conclusions regarding safety, and creates a risk of reasonably foreseeable environmental impacts, which must be evaluated. LME's Environmental Report, discussing continued at-reactor storage of spent nuclear fuel, references and relies on NUREG-2157 and 10 C.F.R. § 51.23 for purposes of demonstrating compliance with the required assessment of the impacts of continued storage beyond the licensed lifetime of the reactor.[126] However, 10 C.F.R. § 51.23 and NUREG-2157 (General Environmental Impact Statement for Continue Storage of Spent Nuclear Fuel) apply only to light-water reactors, not non-light-water reactors, such as the one proposed here.[127] Thus, LME was required to conduct an assessment of the impacts of

[126] LM-CPA Environmental Report, p. 5.7-13 (pdf p. 799).

[127] The NRC has proposed a rule adopting a Generic Environmental Impact Statement for advanced, or non-light-water reactors, which if and when adopted, would allow non-light water reactors to rely on NUREG-215 and 10 C.F.R. § 51.23—with the condition that the spent fuel "is

continued storage of spent nuclear fuel beyond the licensed lifetime of the reactor. Alternatively, LME was required to seek an exemption from this requirement, which it did not do.

Not only are these material flaws in their own right, a NEPA violation is threatened when these errors are incorporated into the Environmental Report without being addressed because the NEPA analysis will be built off of the information in the ER. And even where the NRC purports to have resolved safety issues through its Atomic Energy Act-based regulatory process, it must nevertheless comply with NEPA's procedural obligations for addressing those issues in its decision-making processes.[128]

Specifically, NEPA requires consideration of "reasonably foreseeable environmental effects of [a] proposed agency action."[129] Reasonably foreseeable environmental impacts include the effects of climate change.[130] An agency may avoid discussing an environmental risk only if the probability of an environmental effect is "so

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stored in a manner that meets the regulatory requirements for spent fuel storage cask approval and fabrication in accordance waste casks that comply with 10 C.F.R. Part 72 (TN4884), Subpart L – "Approval of Spent Fuel Storage Casks." NUREG-2249, Generic Environmental Impact Statement for Licensing of New Nuclear Reactors, Draft Report for Comment (Sept. 2024), (ML24176A220), p. 1-7. But this rule has not yet been finalized or adopted. And so, it does not yet apply here.

[128] *Limerick Ecology Action*, 869 F.2d 719, 729-31 (3d Cir. 1989). *See also State of New York v. NRC*, 681 F.3d 471, 478 (D.C. Cir. 2012) ("a finding that 'reasonable assurance exists that sufficient mined geologic repository capacity will be available when necessary' . . . does not describe a probability of failure so low as to dismiss the potential consequences of such a failure.").

[129] 42 U.S.C. § 4332(C)(i) (2023). *See also New York*, 681 F.3d at 476 (quoting 40 C.F.R. §§ 1508.8, 1508.18; *Dep't of Transp. v. Public Citizen*, 541 U.S. 752, 763 (2004) ("major federal actions" include "actions with '[i]ndirect effects, which are caused by the action and are later in time or farther removed in distance, but are reasonably foreseeable'")).

[130] *N.J. Conservation Found. v. FERC*, 111 F.4th 42, 54 (D.C. Cir. 2024).

low as to be 'remote and speculative,' or if the combination of probability and harm is sufficiently minimal."[131]

And as drafted, the ER and PSAR do not reflect a complete or adequately rigorous evaluation of all external hazards, do not consider uncertainties, and do not address the reasonably foreseeable effects of climate change on the risks of accidents at the LME facility.

C. This Contention Is Within the Scope of This Proceeding

This Contention is within the scope of the LME licensing proceeding because it seeks compliance by the NRC's environmental review with NEPA and the NRC's implementing regulations. The NRC's NEPA requirements are set forth in 10 C.F.R. Part 51. One of the requirements for a construction license is for the nuclear plant operator to submit an environmental report.[132] The ER typically incorporates the analyses from the PSAR, which is a required part of the application under 10 C.F.R. § 50.34(a). And the ER forms the basis for NRC's NEPA review.[133]

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[131] *New York*, 681 F.3d at 478-79 (*quoting City of New York v. Dep't of Transp.*, 715 F.2d 732, 738 (2d Cir. 1983*)). See also Standing Rock Sioux Tribe v. U.S. Army Corps. of Engineers*, 985 F.3d 1032, 1050 (D.C. Cir. 2021) (*quoting Sierra Club v. FERC*, 827 F.3d 36, 47 (D.C. Cir. 2016) (even where an environmental risk "may be low," NEPA requires consideration if "the risk is sufficient 'that a person of ordinary prudence would take it into account in reaching a decision.'")).
[132] 10 C.F.R. § 51.45(b).
[133] 10 C.F.R. § 51.45.

In addition, agencies must comply with NEPA "to the fullest extent, unless there is a clear conflict of statutory authority."[134] Defendants may not rely on the NRC's Atomic Energy Act-based safety review to preclude or avoid NEPA compliance.[135]

D. This Contention Is Material to the Findings the NRC Must Make to Grant the LM-CPA

This Contention argues that precursor analyses to ensure NEPA compliance are omitted from the application materials, namely from the PSAR and ER. These omissions are material because, had such evaluations been included in these reports and in any subsequent environmental document (EA or EIS), they reasonably could affect the NRC's proposed findings as to the magnitude of environmental impacts the LME facility will cause. Without addressing these flaws and omissions, it is likely that the resulting NEPA document will lack a reasonable basis for its conclusions. Moreover, the public-participation benefits of an EIS review will have been forfeited because an EA does not include the same level of outreach to the public and governments, including scoping.

E. Facts or Expert Opinion Supporting the Contention, Along with Appropriate Citations to Supporting Scientific or Factual Materials

The facts supporting Waterkeeper's Contention are stated in the Contention itself, in Dr. Lyman and Mr. Mitman's Declarations, and in the supporting materials cited in their Declarations and in the discussion of the "Basis" for this Contention.

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[134] *Calvert Cliffs' Coordinating Comm. v. U.S. Atomic Energy Comm.*, 449 F.2d 1109, 1115 (D.C. Cir. 1971); *see also Limerick Ecology Action v. NRC*, 869 F.2d 719, 729 (3rd Cir. 1989) (Atomic Energy Act does not preclude NEPA compliance).
[135] *Id.* at 729-30.

V. CONCLUSION

For the foregoing reasons, Waterkeeper's Petition to Intervene and Request for Hearing should be granted.

Date: August 11, 2025

Respectfully submitted,

Signed (electronically) by Marisa Perales
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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE COMMISSION

In the Matter of:	§	
	§	**Docket No. 50-614-CP**
Long Mott Energy, LLC	§	
	§	**August 11, 2025**
(Long Mott Generating Station)	§	
	§	

CERTIFICATE OF SERVICE

Pursuant to 10 C.F.R. § 2.305, I hereby certify that, on August 11, 2025, copies of the foregoing "San Antonio Bay Estuarine Waterkeeper's Petition to Intervene and Request for Hearing" were served upon the Electronic Information Exchange (the NRC's E-Filing System), in the above-captioned docket.

Signed (electronically) by Marisa Perales
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EXHIBIT A

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of	)
Long Mott Energy, LLC	)
Construction Permit Application for the	)
Long Mott Generating Station	)
Docket No. 50–614; NRC–2025–0079	)
	)

DECLARATION OF DIANE WILSON

I, Diane Wilson, hereby state as follows:

1. My name is Diane Wilson. I am over 18 years of age and competent to give this declaration. All information herein is based on my personal knowledge unless otherwise indicated. I give this declaration regarding the opportunity to request a hearing and petition for leave to intervene in the Long Mott Energy, LLC (LME) construction permit application for the proposed Long Mott Generating Station in Calhoun County, Texas.

2. I have lived in the Lavaca, Matagorda, and San Antonio Bays area for my entire life. I currently live at 600 Ramona Road, Seadrift, Texas 77983. My home lies within 15 miles of the proposed Long Mott Generating Station.

3. I am a retired fourth-generation shrimper with long-standing recreational and aesthetic interests in the Bays within at least 2.5 to 34 miles of the proposed reactors. My family has lived in the area for 120 years. I have a great love of the bays, estuaries, and fishing communities here. Seadrift is historically a fishing village, and it is the last authentic fishing village on the entire Gulf Coast.

4. I am the founder and director of the San Antonio Bay Estuarine Waterkeeper ("Waterkeeper"). Waterkeeper is an organization located in Calhoun County, founded in 2012 as

a project of the non-profit Calhoun County Research Watch. It is part of a national network of organizations in the Waterkeeper Alliance. Waterkeeper defines its mission as monitoring and proactively protecting Lavaca, Matagorda, and San Antonio Bays, in part by educating the public on the sources of pollution that impact Calhoun County, engaging in visits and community actions, and reporting concerning issues to the appropriate authorities when needed. Waterkeeper is committed to engaging volunteers, marine biologists, environmental advocates from both Calhoun Country Resource Watch and Texas Injured Workers, commercial fishermen, and other members of the community to identify violations of environmental laws and promote cleanup and recovery efforts for the regional waterways and bays.

5. Waterkeeper also promotes the preservation of local wetlands and waterways for commercial and sport fishing and other recreational uses, such as swimming and other watersports, to further appreciation of these beautiful natural resources. Specifically, Waterkeeper often works with shrimpers and oystermen who fish in the waterbodies near the Dow/Union Carbide facility and the site of the proposed Long Mott Generating Station. Waterkeeper is dedicated to advancing environmental justice in this region on behalf of Vietnamese and Latino/a crabbers, shrimpers, fishers, and oystermen who depend on a healthy and productive marine ecosystem. Through direct engagement and advocacy, Waterkeeper works directly with frontline and low-income communities to ensure their participation in environmental decision-making. The shrimpers and oystermen that Waterkeeper advocates on behalf of earn their livelihood fishing from these nearby waters and depend on a clean marine and estuarine environment to sustain it.

6. Waterkeeper has a long history of disseminating information related to the environmental health of these waters to the broader public through its outreach activities, including: supporting the growth of local fisher and shrimper groups; working to protect the lands

and waters of Green Lake, San Antonio Bay, Mission Bay, and Guadalupe Bay; and implementing the largest Clean Water Act settlement agreement in this nation's history with nearby Formosa Plastics. Waterkeeper communicates directly with its supporters through email alerts and an email newsletter. More broadly, Waterkeeper regularly issues press releases, gives interviews, engages in and hosts educational events, and communicates via public social media accounts with almost 1,000 direct followers.

7. Waterkeeper seeks to intervene and establish standing on behalf of its members before the Nuclear Regulatory Commission and to raise contentions and adjudicate issues bearing on the legal propriety as well as safety and environmental aspects of Long Mott's license request. Waterkeeper opposes granting the proposed license. Mr. Mauricio Blanco, Mr. Curtis Miller, Mr. John Daniel, and I are each members of Waterkeeper and are providing declarations in support of Waterkeeper's intervention.

8. I am deeply concerned about my safety living and recreating so close to the proposed facility and being exposed to contamination from the proposed nuclear reactors. I have been fighting industrial facility contamination for forty years in the Lavaca, Matagorda, and San Antonio Bays area. For years, I have conducted monitoring for plastic discharges from Dow/Union Carbide near its outfalls, including along the surrounding Bays and shoreline. Two of these outfalls, Outfalls 14 and 15, are less than a half mile from the LME site. Indeed, I understand that the reactor will be constructed in such a way that it will rely on Dow/Union Carbide's wastewater permit to discharge directly into the Victoria Barge Canal, through Outfalls 1 & 2, which I monitor regularly. I am concerned how the contaminants in Long Mott's wastewater stream will interact with Dow/Union Carbide's current discharge, which I have observed to regularly be contaminated with plastic pellets. Given that the plastic contamination spreads at least seven miles upstream and

downstream of the outfalls, I am worried about the spread of Long Mott's wastewater and the negative effects it will have on the health of the Bays, its ecosystems, and its people.

9. I am further concerned that the proposed nuclear modular reactors are untested and unsafe—and that one accident could wipe out my whole community. I am also worried about the integrity and security of the facility in the event of a hurricane, storm surge, flooding, terrorist attack, plane crash, or other disaster, especially as climate change makes natural disasters more frequent, severe, and deadly.

10. I am aware that in 1991, there was an explosion at Union Carbide Seadrift, which killed one person and injured several others. The Occupational Safety and Health Administration (OSHA) released documents showing that previous audits had warned of outstanding problems with the facility. I understand that LME relies heavily on Dow/Union Carbide's credentials in its application, but Dow/Union Carbide's inability to ensure safety and prevent the discharge of plastics into the Bays gives me little confidence that it has the technical expertise to manage a nuclear reactor safely, much less prevent an accident on its own plant from causing a disaster at the nuclear reactor. If it can't even stop regular discharges of visible plastics, how can it be trusted to stop emissions of invisible radiation and other pollutants from a nuclear facility, even during normal operations? I am uneasy about the construction of a nuclear reactor so close to a company with this kind of history. I have very little trust that LME and Dow/Union Carbide will do the right thing to ensure the safety of my community.

11. In December 2019, through my work with Waterkeeper we won a $50 million settlement in a case against Formosa Plastics for illegally dumping toxic plastic waste on Texas' Gulf Coast. Waterkeeper has allocated $10 million of that settlement to Calhoun County for a city park at Green Lake, the second largest body of freshwater in Texas and a source of drinking water

for Port Lavaca and Alamo Beach. Green Lake is located approximately 2.5 miles from the proposed facility. After all the work we have done to clean up the area around the proposed facility, I am worried about how it will further contaminate this freshwater lake and the Bays. I am also concerned about the integrity of known archaeological digs around the site of the proposed facility, as this area has great Native American historical significance. There are two sites on Hog Bayou by Green Lake that I think are especially important, where flint nodules and shell, flint fragments, deer bone, turtle, fish, gar, crab pinchers, and charcoal have been recovered.

12. The proposed Long Mott Generating Station threatens my aesthetic appreciation of the Bays and areas like the park at Green Lake. I love the water—and I frequently fish, boat, and observe wildlife in the Bays. I am concerned about endangered species like the whooping crane, which overwinters in the Bays within eight miles of the proposed facility.

13. I am also worried about the continued health of groups like the Matagorda Bay Fishing Cooperative, formed to bring back the seafood industry, and another initiative supported by my Formosa settlement. The fishing seasons no longer exist like they used to, and these marine and estuarine populations are already fragile. The proposed reactors would be located approximately three miles to nursery areas of embryonic shrimp, for example, which live in the Bays later in their lives. Any contamination or radiation could threaten to wipe out a whole season's crop.

14. I believe that this facility poses significant safety and environmental concerns and that my interests will not be adequately represented in this action without the opportunity of Waterkeeper to intervene as a party in the proceeding on my behalf.

15. Therefore, I have authorized Waterkeeper to represent my interests in this proceeding by opposing the issuance of a Construction Permit to LME for the Long Mott Generating Station.

I declare under the penalty of perjury under the laws of the United States that, to the best of my knowledge, the foregoing is true and correct.

Executed on August 11, 2025

Signed (electronically) by:

/s/ Diane Wilson
Diane Wilson, Declarant
600 Ramona Road, Seadrift TX 77983
wilsonalamobay@aol.com
(361) 218-2353
Executed in accordance with 10 C.F.R. § 2.304(d)

EXHIBIT B

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of	)
Long Mott Energy, LLC	)
Construction Permit Application for the	)
Long Mott Generating Station	)
Docket No. 50–614; NRC–2025–0079	)
	)

DECLARATION OF MAURICIO BLANCO

I, Mauricio Blanco, hereby state as follows:

1. My name is Mauricio Blanco. I am a member of San Antonio Bay Estuarine Waterkeeper ("Waterkeeper" or "Petitioner"). I am over 18 years of age and competent to give this declaration. All information herein is based on my personal knowledge unless otherwise indicated. I give this declaration regarding the opportunity to request a hearing and petition for leave to intervene in the Long Mott Energy, LLC (LME) construction permit application for the proposed Long Mott Generating Station in Calhoun County, Texas.

2. I live at 714 South San Antonio Street, Port Lavaca, Texas 77979. My home is approximately 10 miles from the site of the proposed Long Mott Generating Station.

3. I have been a full-time, commercial fisherman for about 38 years. Working on the water is how I survive and make my income. Over the years, I have fished throughout the Gulf of Mexico, including in Mississippi, Alabama, Louisiana, and Texas. I have fished in the San Antonio, Matagorda, and Lavaca Bays since 1989. Right now, I am working out of Matagorda Bay, catching live bait. Matagorda Bay is located approximately 15 miles from the site of the proposed Long Mott Generating Station. What I catch in a given month depends on what is seasonal. Around May 15, we start catching brown shrimp. By around July 15, we catch croakers,

perch and pink perch, mullet, and shrimp. Around August 15, we catch white shrimp, and from around November 1 to about the last day of April, we catch oysters. Some oyster farmers here work all year round. I also work in San Antonio Bay (approximately 8 miles from the proposed LME facility) and Guadalupe Bay (approximately 5 miles from the proposed LME facility), if and when there is seafood to catch there.

4. I own a fleet of about 11-12 boats, and I go out with them. We have around 28 visa workers for oyster season, and I am a captain on one of the boats. I am out working almost every day to support myself and my family. I typically go out in the mornings around 3 a.m., and I come home anywhere from late afternoon to 8-10 p.m. Wednesdays, Thursdays, Fridays, and the weekends can be especially busy. There is never an off season, just times when the work slows down.

5. I care deeply for the Bays and the communities here. In 2013, I created a union, the Union of Commercial Oystermen of Texas, which had at its peak approximately 6,000 members. I also helped Diane Wilson and Waterkeeper challenge the Formosa Plastics facility in Port Comfort, Texas for dumping plastic pellets into the Bays, and we won in court in 2019. The facility is still dumping pollution, but because of our settlement they have to make more efforts to stop it. It is still not 100% there yet.

6. Anything that affects the water affects myself and my family and my business. It is through my business that I am able to support and provide for my family, including my son, who is getting his education to be an engineer and wants to work at NASA one day. As such, I am very concerned about the contaminants that the facility may release into the water and how they may harm wildlife. I understand that the facility will use Dow/Union Carbide's wastewater outfalls to discharge into the Victoria Barge Canal, which feeds into San Antonio Bay. I worry how even

routine discharges generated by Long Mott will interact with the pollution generated by Dow/Union Carbide and other nearby industries, and how that will harm the fish, shrimp, and oyster populations I rely on. I have the same concerns about pollution washed into the Bays from Long Mott during storms or unexpected emergencies and accidents.

7. Air pollution, and the risk of radiation exposure, is another big concern, and because of that, I also have personal safety and health concerns about the design and operation of the proposed facility. I worry how routine and accidental radiation releases will impact my health, and that of my family, and also how it will harm the wildlife species fishermen like myself depend on. I am concerned that the proposed construction design, safety, and operation of the proposed facility are inadequate, especially as this is a new type of nuclear facility. I understand that the proposed facility is not designed to withstand the increased threats from climate change, even though climate change is increasing the frequency and severity of flooding, storm surges, and other natural disasters. An accident or emergency—caused by humans or nature—could cause irreparable damage to me, my family, and our property at work or at home.

8. I have significant concerns about the impact of the proposed Long Mott Generating Station on my livelihood as a commercial fisherman, in addition to my safety, health, and property interests. My interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf.

9. Therefore, I have authorized Waterkeeper to represent my interests in this proceeding by opposing the issuance of a Construction Permit to LME for the Long Mott Generating Station.

I declare under the penalty of perjury under the laws of the United States that, to the best of my knowledge, the foregoing is true and correct.

Executed on August _11__, 2025

Signed (electronically) by:

/s/ Mauricio Blanco

Mauricio Blanco, Declarant
714 South San Antonio Street, Port Lavaca, TX 77979
mauriciombpboats2@gmail.com
(361) 655-3606
Executed in accordance with 10 C.F.R. § 2.304(d)

EXHIBIT C

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of	)
Long Mott Energy, LLC	)
Construction Permit Application for the	)
Long Mott Generating Station	)
Docket No. 50–614; NRC–2025–0079	)
	)

DECLARATION OF CURTIS MILLER

I, Curtis Miller, hereby state as follows:

1. My name is Curtis Miller. I am over 18 years of age and competent to give this declaration. I am a member of San Antonio Bay Estuarine Waterkeeper ("Waterkeeper" or "Petitioner"). All information herein is based on my personal knowledge unless otherwise indicated. I give this declaration regarding the opportunity to request a hearing and petition for leave to intervene in the Long Mott Energy, LLC (LME) construction permit application for the proposed Long Mott Generating Station in Calhoun County, Texas.

2. I am a commercial fisherman and the owner of my family business, Miller's Seafood. Our processing plant and fresh seafood market are located at 1102 Broadway Street, Port Lavaca, Texas 77979, approximately 11 miles from the site of the proposed Long Mott Generating Station. Our commercial fishing boats and docks are located at 905 South Pine Street, Seadrift, Texas 77983, approximately 9 miles from the site of the proposed Long Mott Generating Station. I also have two buildings in Seadrift that are used as a dock office and for storage of equipment and supplies. I live at 102 Chisholm Trail, Victoria, Texas 77904, approximately 29 miles from the site of the proposed Long Mott Generating Station.

3. My uncle started Miller's Seafood in Seadrift in the mid-1960s, and my father ran it after that. I have been running Miller's Seafood since about 1989. My uncle started the business with a shrimp boat named Miss Cindy. He also had a van, which he used to load up shrimp and transport them to restaurants. He got a building in Seadrift on Highway 185, which is where the first Miller's Seafood was located. We were mostly selling wholesale at that point. We later built a retail market and processing area across the highway. For the first 20 years, our docks were in Seadrift. We later added docks in Port Lavaca. We have always had boats and docks in Seadrift, and we still do today.

4. I used to go out on the water with my uncle during the summers and weekends, starting when I was around 7-8 years old. I continue to enjoy fishing and recreating on the Bays when I can. I also worked on the Seadrift docks throughout the years. I lived in Seadrift after I got married, and I had two children. My children have worked at Miller's Seafood with me, too.

5. We catch, process, and sell fresh seafood from the Bays around Seadrift and Port Lavaca (both direct at our market and shipped for retail or for further processing), unloading our catch from our boats at our docks. Our main business is oysters, and we sell shrimp on a smaller scale as well. When it gets cold, shrimp migrate back into the Gulf to warmer and deeper waters. Oysters thrive year-round, but they do better when it is colder. They are in their prime around January and February. We sell whole, in the shell, or processed.

6. A big concern I have about the proposed Long Mott Generating Station is pollution into the Bays (e.g., San Antonio, Matagorda, and Lavaca Bays), where I make my living. I think of places like Long Island Sound in New York, a major area for commercial fishing and harvesting that has faced bans and closures because of environmental pollution. I would not like to see anything like that happen here; I have noticed significant stress on shrimp populations as is. There

has been an astounding decline in the last 10-15 years, and this and last year have been the worst shrimp seasons we have ever had. There are less shrimp boats on the water now than we had even 20 years ago.

7. My business is very close to ground zero regarding this proposed nuclear facility—in both Port Lavaca and Seadrift. I am concerned about air pollution or exposure to radiation, carcinogens, and other kinds of pollution. Anything that is radioactive or discharging into the water or into the Bays is a big concern. I am also concerned about accidents at the facility, and because I and the people involved in my family business would be in such close proximity, and at risk of injury or death. I am worried that this facility's design is inadequate because it is a new and untested technology. And, I am concerned that the design does not take into account the increasing frequency and intensity of hurricanes, floods, and other natural disasters in this area, which climate change will only make worse.

8. I believe that the proposed facility poses risks to my family business, the environment from which I earn my living, my recreational interests, and my health, and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf.

9. Therefore, I have authorized Waterkeeper to represent my interests in this proceeding by opposing the issuance of a Construction Permit to LME for the Long Mott Generating Station.

I declare under the penalty of perjury under the laws of the United States that, to the best of my knowledge, the foregoing is true and correct.

Executed on August _11__, 2025

Signed (electronically) by:

_/s/ Curtis Miller_____
Curtis Miller, Declarant
102 Chisholm Trail, Victoria, TX 77904
curtismillerseafood@gmail.com
(361) 552-6423
Executed in accordance with 10 C.F.R. § 2.304(d)

EXHIBIT D

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of	)
Long Mott Energy, LLC	)
Construction Permit Application for the	)
Long Mott Generating Station	)
Docket No. 50–614; NRC–2025–0079	)
	)

DECLARATION OF JOHN DANIEL

I, John Daniel, hereby state as follows:

1. My name is John Daniel. I am a member of San Antonio Bay Estuarine Waterkeeper ("Waterkeeper" or "Petitioner"). I am over 18 years of age and competent to give this declaration. All information herein is based on my personal knowledge unless otherwise indicated. I give this declaration regarding the opportunity to request a hearing and petition for leave to intervene in the Long Mott Energy, LLC (LME) construction permit application for the proposed Long Mott Generating Station in Calhoun County, Texas.

2. For years, I have owned and lived on and off property at 1714 FM2235 (the "1714 property"), leasing out the back acreage for farming and running cattle across it after harvests. I have also owned an adjacent property at 1462 FM2235 (the "1462 property"), where I currently raise cattle year-round. I run about 200 cattle on the land here in total. I recently transferred about 375 acres of the 1714 and 1462 properties to my son, who I have a lease with to continue raising cattle on this land. I still own and live on approximately four acres of the 1714 and 1462 properties, where I am currently remodeling a house. These properties and my home lie less than four miles northeast of the proposed Long Mott Generating Station. I am so close to the Dow/Union Carbide

plant that I can see it from my kitchen window and yard; the proposed nuclear reactor will be even closer to me.

3. I have lived throughout Calhoun County during my life. My father worked and retired at the UCC plant, and most of my family is still living locally in Calhoun County now, including Port Lavaca and Seadrift. I worked in chemical plants for 20 years and oil fields for 14 years. When I was working in the oil fields, I took care to make sure that we paid attention to doing cleanup right and to instill that value into my younger crew members. It is what I am most proud of from working in that industry.

4. I duck hunt locally, and I fish for the Texas trio: trout, flounder, and redfish. I strive to provide habitat for all creatures on our properties: from cottontail rabbits to rattlesnakes and wild hogs. I have put ponds on my property to bring quail and wildlife back. My favorite wildlife are ducks and geese, which I enjoy watching. The Bays near the proposed facility (e.g., San Antonio, Matagorda, and Guadalupe Bays) are a migration endpoint for redhead ducks, and they overwinter here. I have recreational and aesthetic interests in the health of the wildlife, waters, and land near the proposed facility, which I fear will damage these resources if proper environmental and safety protections are not implemented.

5. This proposed facility would put a nuclear reactor into my backyard. Further, it is not traditional, tried and true nuclear technology, but new technology. I have concerns about human health, including my own personal health, from explosions and radiation. Considering the increased storms and storm surges we get here on the coast, I am concerned that this facility is not designed with safety, climate change, and flooding in mind. I am also worried about the national security aspect of this plant's ability to withstand events like plane crashes and terrorist attacks.

6. I also have serious concerns about land and water contamination. Groundwater contamination and stormwater and wastewater discharge are especially concerning because we all have wells and use groundwater here. Around 140 acres of the properties I discussed above are under agricultural use right now. I am working to turn them into pastureland, which I consider to be less harmful than row crop farming. I am wary that a release onto my land and topsoil could destroy these improvements.

7. I am also concerned about the depreciation of the land's value if this proposed facility were built. I have put a lot of work into this land so it will appreciate over time. In fact, it took me a lifetime to put together, and I would like that accumulated value to pass down to my kids. I have paid to fence the land, adjusted the pH and nutrients to turn sterile land into fertile land, installed water troughs to run water for cattle to drink, and grow corn on the property for livestock to eat. But once I have nuclear reactors just miles from my fence line, I expect my property value to decrease. These properties are large, with hundreds of acres and six houses. I would not want to buy property of this size with a nuclear facility in the backyard, and I cannot imagine that others would want to take that environmental and safety risk either. There are too many other options that will not have a nuclear facility in the backyard.

8. I suspect that the proposed Long Mott Generating Station has already directly interfered with the economic use of this land. A few years ago, I had a large-scale battery project that I was trying to connect into the grid, and I obtained a five-year option contract for a project that would provide me a yearly payout for 50 years. This option contract expires next year. However, I understand that our local power company, Victoria Electric Cooperative, has frozen new battery projects that have not been realized, which includes mine. I suspect this is because of the Long Mott Generating Station, which will also send excess power to the grid. Battery storage projects

like mine are a break for small ranchers and farmers, but I am concerned that this proposed nuclear plant has blocked our ability to access this revenue stream.

9. I believe that the proposed facility poses serious harm to my property interests, in addition to my other recreational, aesthetic, environmental, and safety concerns. My interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf.

10. Therefore, I have authorized Waterkeeper to represent my interests in this proceeding by opposing the issuance of a Construction Permit to LME for the Long Mott Generating Station.

I declare under the penalty of perjury under the laws of the United States that, to the best of my knowledge, the foregoing is true and correct.

Executed on August _11__, 2025

Signed (electronically) by:

_/s/ John Daniel _____
John Daniel, Declarant
1714 FM2235, Port Lavaca, TX 77979
johndanielbr549@gmail.com
(979) 665-6699
Executed in accordance with 10 C.F.R. § 2.304(d)

EXHIBIT E

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of:	§	
	§	
Long Mott Energy, LLC	§	**Docket No. 50-614-CP**
	§	
(Long Mott Generating Station)	§	
	§	

DECLARATION OF EDWIN LYMAN, Ph.D. IN SUPPORT OF PETITION TO INTERVENE AND REQUEST FOR HEARING BY SAN ANTONIO BAY ESTUARINE WATERKEEPER

I, Dr. Edwin Lyman, declare as follows:

1. My name is Edwin Lyman. I am over eighteen (18) years of age and of sound mind, have never been convicted of a felony, and am otherwise capable of making this declaration. The information in this declaration is based on my personal experience and my review of publicly available information.

Background

2. I am the Director of Nuclear Power Safety at the Union of Concerned Scientists (UCS) in Washington, DC, and I have been employed at UCS since 2003. I earned a doctorate degree in physics from Cornell University in 1992. I have over three decades of experience in nuclear power safety and security, working as a postdoctoral research associate at Princeton University's Center for Energy and Environmental Studies (now the Science and Global Security Program) and serving as the president of the Nuclear Control Institute before I joined UCS. I have published articles and letters regarding those issues in journals and magazines including *Science, Nature, The Bulletin of the Atomic Scientists, Science and Global Security, Arms Control Today, Nuclear Engineering International, New Scientist* and *Energy and Environmental Science*. I am a co-author (with David Lochbaum and Susan Q. Stranahan) of the book *Fukushima: The Story of a Nuclear Disaster* (The New Press, 2014). I am a member of the Institute of Nuclear Materials Management and the American Nuclear Society, and I have

testified before Congress and the Nuclear Regulatory Commission and published articles in several journals and magazines about nuclear power. In 2018 I was awarded the Leo Szilard Lectureship Award from the American Physical Society for my work on nuclear safety and security. I have also served as a qualified expert witness for intervenors in several NRC adjudicatory proceedings. A copy of my curriculum vitae is attached as Exhibit E-1.

Review of Long Mott Energy, LLC's Application

3. I have been engaged as a technical consultant by San Antonio Bay Estuarine Waterkeeper ("Waterkeeper") for purposes of reviewing the Long Mott Generating Station's ("Long Mott") Construction Permit Application ("CPA" or "LM-CPA") and identifying issues of concern that may be relevant to Waterkeeper and its members.

4. To that end, I have reviewed Long Mott's CPA. I am familiar with and have reviewed applicable NRC regulations, policies, and guidance documents.

5. I assisted Waterkeeper with the preparation of their Contentions 1 and 2, which address the adequacy of LM-CPA's proposed functional containment.

Contention 1

6. Based on my professional judgment and my review of the LM-CPA and relevant NRC regulations and guidance documents, it is my opinion that the LM-CPA's proposed functional containment fails to satisfy the minimum criteria for adequacy as required by the applicable regulations, including 10 C.F.R. § 50.34. An explanation of the various bases for my opinion are detailed below.

7. The Xe-100 reactor design referenced in the LM-CPA fails to meet the Modular High-Temperature Gas-Cooled Reactor Design Criterion ("MHTGR-DC") 16, "Containment Design," as adapted by the NRC staff from the Advanced Reactor Design Criterion (ARDC) 16 in Regulatory Guide 1.232, Rev. 0, "Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors" (April 2018). In particular, the LM-CPA fails to establish that the Xe-100 reactor's so-called "functional" containment

consists of "multiple barriers internal and/or external to the reactor and its cooling system, that … control the release of radioactivity to the environment and … ensure that the functional containment design conditions important to safety are not exceeded for as long as postulated accident conditions require." *See* RG 1.232, App. C, p. C-8 (ML17325A611).

8. The NRC staff's rationale in RG 1.232 for modifying the Advanced Reactor Design Criterion (ARDC) 16 for MHTGRs specifically cited the condition that "approval of the proposed approach to functional containment for the MHTGR concept, with its emphasis on passive safety features and radionuclide retention within the fuel over a broad spectrum of off- normal conditions, would necessitate that the required fuel particle performance capabilities be demonstrated *with a high degree of certainty*." RG 1.232, App. C, p. C-9 (ML17325A611) (emphasis added).

9. By any reasonable standard, the LM-CPA does not demonstrate "the required fuel performance capabilities … with a high degree of certainty," as required. The plain reason is that an approved evaluation model and experimental information necessary for determining fuel performance capabilities and developing accurate mechanistic source terms, which are essential for evaluating the performance of the functional containment, are not available at the present time and will not be available until commercial-scale fuel produced under prototypical conditions has been fully tested over a sufficiently "broad spectrum of off-normal conditions." The necessary information that is absent includes (1) demonstrated fuel fabrication defect rates and (2) radionuclide release fractions from as-manufactured fuel at the peak temperatures predicted in certain licensing basis events (including certain design-basis accidents) in the LM-CPA, which have not been experimentally determined.

10. Thus, the LM-CPA fails to demonstrate with reasonable assurance that the proposed functional containment will control the release of radioactivity to the environment under all "postulated accident conditions" and thereby does not fulfill the safety design objective of meeting "10 CFR 50.34 … offsite dose requirements at the plant's

exclusion area boundary (EAB) with margins," as stated in RG. 1.232, Appendix C, MHTGR-DC 16.

11. Given that there is no approved evaluation model for mechanistic source term development at this stage, the applicant must instead utilize a deterministic source term based upon a "major accident," as required by 10 CFR 50.34(a)(1)(ii)(D), to evaluate the adequacy of its proposed functional containment. However, the LM-CPA contains no such evaluation.

12. Therefore, to meet the letter and the intent of MHTGR-DC 16, the Xe-100 design referenced in the LM-CPA must include a conventional, essentially leak-tight containment structure to ensure compliance with 10 CFR 50.34. This is consistent with the recommendation made by NRC staff in its 1995 draft MHGTR preapplication safety review that a prototype MHTGR with a low-leakage containment should be considered if the "necessary design and quality of the fuel to meet the performance objectives" has not been demonstrated. *See* Draft Copy of Preapplication-Safety Evaluation Report (PSER) on the Modular High-Temperature Gas-Cooled Reactor (MHTGR) (March 26, 1996) (ML052780519).

13. Below are the various reasons that, in my professional judgment, the mechanistic source terms in the LM-CPA's proposed functional containment demonstration fail to meet the minimum criteria for adequacy:

Computer code has not been approved by NRC

14. The LM-CPA utilizes a computer code known as XSTERM to develop the mechanistic source terms utilized in the modeling of the dose consequences of Xe-100 accidents. The code is referenced in the X-Energy Licensing Topical Report (MST TR) "Mechanistic Source Term Approach, Revision 3" (non-public version), which is incorporated by reference in the LM-CPA. However, in a draft Safety Evaluation (SE) of Revision 2 of the MST TR, the NRC staff state that although the MST TR "provides a reasonable plan for the development of the MST methodology," the staff "makes no

conclusions regarding the acceptability of the models in XSTERM for the MST analyses of the Xe-100 because … models within XSTERM are still under development" (Draft MST TR SE, May 6, 2025, ML25064A595). Moreover, the staff point out that they are unable at this time to assess the adequacy of the applicant's proposed plan for verification and validation (V&V) of the code. *Id.*

15. The LM-CPA states that a "separate licensing topical report for XSTERM will be submitted for NRC review and approval to support the OLA" (LM-CPA at 3.1-10). However, the NRC staff reported at the July 9, 2025 meeting of the Advisory Committee on Reactor Safeguards—which I attended remotely—that they had just started reviewing the underlying models in detail, although they were not submitted for review and approval in the LM-CPA. In any event, with the information that has been submitted on the record, the NRC staff has no technical basis to have sufficient confidence in the precision and accuracy of the results of the unverified and unvalidated XSTERM code, which are fundamental inputs into the calculations attempting to justify the adequacy of the functional containment. This is confirmed by the July 25, 2025 ACRS letter on the MST TR, which states that there are "several concerns and gaps that will need to be addressed" with implementation of the MST methodology and that "validation … will be challenging." ACRS Letter Re: X-Energy, LLC'S, XE-100 Licensing Topic Report Mechanistic Source Term Approach, Rev. 3 (July 25, 2025) (available at https://www.nrc.gov/docs/ML2520/ML25204A121.pdf) (hereinafter, "ACRS Letter").

No manufacturing defect data from fuel to justify assumptions

16. The ACRS letter on the X-Energy MST LR states: "The source term from TRISO fuel in a high temperature gas-cooled reactor is a strong function of the initial level of manufacturing defects (heavy metal contamination, SiC defects), the in-service failures under irradiation, and the incremental failures during postulated accidents. Because of the importance to the overall functional containment strategy, the initial fuel failure

fractions used in the X-energy safety analysis approach must bound actual manufacturing data." ACRS Letter at 4.

17. However, validation of the as-manufactured defect rate assumptions is currently impossible. The reason is that the facility where the TRISO pebbles for the LM project will be fabricated—the TRISO-X plant proposed for construction in Oak Ridge, TN—does not yet exist. The TRISO-X plant is not scheduled to receive a licensing decision from the NRC before the end of May 2026, which has been delayed due to a change in the chemical form of the initial enriched uranium feedstock to be supplied by the Department of Energy, which necessitated a major redesign of the facility. NRC Letter Re: Updated Review Schedule and Estimated Staff Costs for the TRISO-X, LLC License Application, (March 14, 2025) (available at https://www.nrc.gov/docs/ML2330/ML23305A193.pdf). Moreover, even if X-Energy's projection that it hopes to produce its first pebble in December 2027 (*see* https://www.exchangemonitor.com/wp-content/uploads/2025/06/bell-smrs.pdf) is realized, it is not likely that statistically meaningful data on production-scale defect rates would be available for several years after that—that is, long after the NRC is scheduled to complete its review of the LM-CPA and the functional containment approach.

18. Such data is crucial, though, because of evidence that the X-Energy MST model assumes particle defect rates "significantly lower" than what was ever achieved in fuel production campaigns in both Germany and the United States, according to ACRS member Dr. David Petti (ACRS X-Energy subcommittee transcript, June 3, 2025, pp. 247-249, ML25192A240). Thus, to justify the use of such low failure rates, LM has the burden of demonstrating them with the actual process that will be used to manufacture the fuel.

Assumptions underlying DLOFC are invalid

19. Moreover, assumptions made in the LM-CPA about the performance of its fuel in support of the development of MSTs have not been validated, based on the maximum

fuel temperatures and sustained peak temperatures that are achievable and even anticipated at the plant. Thus, the LM-CPA analyses of Design Basis Accidents ("DBAs") including depressurized loss of forced circulation ("DLOFC") supporting the adequacy of the functional containment to meet regulatory requirements are unverified and invalid, in my professional judgment.

20. The LM-CPA analysis of the "extreme case" "depressurized loss of forced circulation" event, or DLOFC, which occurs in the course of a number of the DBAs evaluated, results in maximum fuel temperatures approaching 2000°C for nearly two days, and sustains peak temperatures of over 1800°C for a period of several days after that. This is well outside of the bounds established by the LM TRISO fuel qualification TR from the experimental database for TRISO uranium oxycarbide (UCO) fuel. Thus, any assumptions made in the LM-CPA about the performance of its fuel under such conditions that support the development of MSTs have not been validated.

21. It is clear from the literature on TRISO fuel and MHTGR safety analyses that a peak temperature of 1600°C is typically set as the bounding condition for the outcome of the DLOFC, which is the most limiting design-basis accident for this class of reactors. This is because diffusion of most fission products through the multiple layers of the TRISO fuel is not expected to occur for intact particles held below this temperature for less than about 200 hours. *See* Petti, Hobbins, Lowry, and Gougar, *Representative Source Terms and the Influence of Reactor Attributes on Functional Containment in Modular High-Temperature Gas-Cooled Reactors*, Nuclear Technology, 184(2), 181–197 (available at: https://doi.org/10.13182/NT184-181).

22. However, as the temperature increases above 1600°C, TRISO particle failures steadily increase, and can increase by an order of magnitude or more at 1800°C, increasing some fission product release fractions by two orders of magnitude or greater. *High Temperature Gas Cooled Reactor Fuels and Materials,* IAEA TECDOC-1645, at 85-93 (2010). Above 1800°C, test data is sparse (and non-existent for the Xe-100 UCO TRISO fuel), but a 2022 US national laboratory study notes that "accident condition

failures are very sensitive to increases in temperature above 1800°C since the SiC [silicon carbide] layer chemically decomposes as it approaches and rises above 2000°C. Particles should be conservatively expected to eventually release all volatile and certain diffusive fission products somewhat above this sustained [1800°C] heat soak temperature." Coles et al., *Parametric Study of Factors that Affect Calculated Dose from TRISO Fueled Microreactor Transportation Accident*, Pacific Northwest National Laboratory/ Idaho National Laboratory, at 17 (Nov. 2022) (available at: https://www.osti.gov/servlets/purl/1922640).

23. Despite this lack of data for the fission product releases from X-Energy fuel at these extreme temperatures, the LM-CPA assumes a relatively low overall increase in failure fractions for DBAs involving DLOFCs. For example, by comparing the total activity released in the Seismic DBA (which is the most limiting DBA with less than a factor of 2 margin to the 25 rem regulatory limit), to the initial isotopic inventory for a radionuclide such as cesium-137, the increase in release fraction is about a factor of about 40, whereas the limited German data (which is for uranium dioxide; similar data does not exist for UCO) shows an increase of a factor of around 1000 at 1800°C compared to 1600°C (IAEA TECDOC-1645 at 92). Thus, there is considerable uncertainty and the possibility exists that the MST and radiological consequences for the Seismic DBA are significantly underestimated.

Methodology for calculation of the core radionuclide inventory is unreliable

24. Although the LM-CPA lacks sufficient detail to make a definitive conclusion, based on my review of the limited data contained therein, the methodology for calculation of the core radionuclide inventory appears to have large uncertainties and possibly even errors that may result in an underestimate of the total radionuclide inventory and hence the MSTs used to justify the adequacy of the functional containment.

25. The initial isotopic inventory in the LM-CPA that is used to develop the mechanistic source terms for DBA consequence analysis is presented in Table 3.3-2 of the LM-CPA PSAR (PSAR at 3.3-3). The column of values for DBAs, which are interpreted as the

fraction of the core inventory in the helium pressure boundary (which includes the buildup of plated out fission products over the 60 effective full power year core lifetime) incorporates a "maximum allowable" fuel failure fraction of $1x10^{-4}$. Because of the different components making up the reported inventory, it is not possible to extrapolate from these values to the total radionuclide inventory in the core without having access to proprietary details about the evaluation model.

26. Even so, some of the total core inventory values can be extracted, and from those, one can see that they are smaller than those provided in several other references describing very similar reactor designs at equilibrium. For example, iodine isotopes that leak out of defective particles are not believed to be retained in the graphite pebbles, and hence the iodine reported should be equivalent to the quantity reported in the helium pressure boundary (Petti et al. 2013). Thus, for example, the total core inventory of iodine-134 (I-134) would be $1x10^{4}$ times the inventory reported in the LM-CPA, or $7.75x10^{14}$ becquerels (Bq).

27. However, a recent study of the 250-MWt HTR-PM Chinese pebble-bed HTGR, using a new model for inventory calculations calculated an inventory of $6.1x10^{17}$ Bq of I-134 at equilibrium. Raza *et al*., *Development of radionuclide inventory and fission product release calculation model and its application to HTR-PM*, Annals of Nuclear Energy, Vol. 212 (March 2025) (available at: https://www.sciencedirect.com/science/article/pii/S0306454924007370). Since the core inventory of I-134, a short-lived fission product, is roughly proportional to power level, this would correspond to about $1.3x10^{17}$ Bq for the 200 MWt Xe-100—over one hundred times greater than the value in the LM-CPA. Given that several other sources that estimate the total equilibrium core inventory are consistent with the values in Raza *et al*., the LM-CPA appears to be an outlier.

28. Similar analyses for other fission product values reported in the LM-CPA also show that they are underestimated compared to other references. Even greater discrepancies occur for noble gas fission products. For example, Raza *et al*. calculates an inventory

of 2.9×10^{17} Bq for krypton-89 (Kr-89), another short-lived fission product that is not retained in graphite and should be proportional to power level. But the Xe-100 Kr-89 inventory is only 1.62×10^{13} Bq—four orders of magnitude too small. And discrepancies are also apparent for longer lived isotopes such as Cs-137. Raza *et al*. calculates a core inventory of 2×10^{16} Bq, which is 1.6×10^{16} Bq when scaled to 200 MWt. The Xe-100 Cs-137 core inventory should be greater than this, as the assumed maximum burnup of 168 GWd/MTU (MST LTR at 13) is nearly twice that assumed for the HTR-PM in Raza, *et al*. However, based on the attenuation factor of 5 cited for Cs-137 in Petti *et al*., this would imply an Xe-100 Cs-137 inventory less than 5.3×10^{15} Bq.

29. And there are also inexplicably missing isotopes in the LM-CPA list, most notably strontium-89 (Sr-89), which Raza *et al*. find has a higher activity than Sr-90 does.

30. Thus, in my professional judgment, these uncertainties and potential inaccuracies in the core inventory are cause for an additional lack of assurance that the MST calculations supporting the adequacy of the functional containment are conservative.

Other deficiencies

31. There are limited to no experimental measurements of iodine or tellurium releases in temperature transients (ACRS subcommittee transcript at 185). As these isotopes are significant contributors to offsite dose, this lack of data introduces significant uncertainty into the MST calculations supporting the adequacy of functional containment.

32. The AGR program test data for UCO fuel is only available for compacts rather than the pebble fuel forms that the Xe-100 will use. This has been noted as a significant limitation in the use of AGR data for assessing the effectiveness of the Xe-100 fuel matrix as a component of the functional containment. *See* X Energy, LLC – Safety Evaluation of XE-100 Topical Report, TRISO-X Pebble Fuel Qualification Methodology, Rev. 3, p. 6 (March 29, 2023).

33. There has been no testing of sufficiently representative fuel manufactured at a commercial scale. As discussed below, X-Energy's plan to conduct such testing at Idaho National Laboratory is highly unlikely to yield results in time to inform the NRC's decision on the LM-CPA's proposed functional containment.

34. There is no experimental data available on steam ingress and its effect on the Xe-100 core. This phenomenon could have a significant impact on the MST used to assess the adequacy of functional containment (ACRS letter at 5). The Department of Energy is constructing a furnace to conduct such tests, but the schedule is uncertain, and again, it is unclear when useful data will be available for incorporation into the MST model.

LM-CPA does not address limitations regarding Fuel Qualification Topical Report

35. The LM-CPA references the X-Energy Fuel Qualification Topical Report, Revision 3 (ML22216A179). The staff approved this Report in March 2023 *subject to* three limitations and conditions:

    1. Applicant's referencing the Technical Report (TR) should provide a justification for releases from defect particles, contamination in the fuel matrix, and diffusion of volatile radionuclides in addition to the intact particle failure fraction derived from the testing to be used in a future licensing application. In effect, this methodology forms a portion of the fuel qualification for the final reactor fuel form, but not the entirety of the fuel qualification process for the performance of the fuel (e.g., cover the aspects cited above or the more comprehensive list of fuel qualification areas in NUREG-2246)."

    2. This approval is limited to the plan to test TRISO fuel and the operational envelope (temperature, burnup, and environmental conditions) outlined in the TR. Applicant's referencing the TR should provide a set of fuel specifications and demonstrate how fuel to be used in the reactor will meet these specifications. Future licensing submittals will be needed to qualify the

fuel for the totality of the operational regime, including but not limited to transient accident conditions and mechanical effects to the extent that these are not incorporated within the scope of the TR.

3. An applicant referencing the TR is subject to the limitations and conditions associated with the approved EPRI TRISO TR.

36. For reasons including those discussed above, the LM-CPA does not conform to the staff's limitations. X-Energy's plan to address this problem is through a testing program. Although all details of this test program, including scope, schedule, and budget, are being withheld from the public, at the ACRS full committee meeting on July 9, 2025, (no transcript yet available), X-Energy publicly disclosed that it was planning to conduct such testing at Idaho National Laboratory ("INL"), including irradiation and transient testing. However, no schedule was presented publicly, and given the current unavailability of as-manufactured fuel from the yet-to-be-built TRISO-X facility, as well as the length of time such tests have taken historically to yield data, it is not clear that useful results from such testing will be available by the time the operating license application is submitted, much less by the time the NRC has committed to make a decision on the LM-CPA. By way of comparison, the Advanced Gas-cooled Reactor ("AGR") program at INL took more than 10 years from fabrication of the fuel through irradiation and post-irradiation examination. Demkowicz, *AGR Program TRISO Fuel Topical Report Dialog,* slide 7 (Feb. 2022) (available at: https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_57185.pdf).

37. In my professional judgment, the LM-CPA fails to comply with 10 C.F.R. § 50.34(a)(8). This is because the latest date for completion of construction cited in the LM-CPA is 2033 (LM-CPA, Part I-1). This would require a far more abbreviated schedule for irradiation, testing, and post-irradiation examination than the actual timetable of the AGR program, which is not reasonably achievable.

38. Similarly, based on the above discussion, in my professional judgment, the LM-CPA simply does not demonstrate that the proposed Xe-100 functional containment will

provide adequate protection of public health and safety and does not comply with the requirements of 10 C.F.R. § 50.34(a)(4). This is because the adequacy of the functional containment, which is dependent on the adequacy of the MST determination, has not been demonstrated. In the absence of such a determination, the reactor design must be modified to include a conventional, nearly leak-tight, physical containment structure.

Contention 2

39. The LM-CPA does not include beyond-design basis events (BDBEs) in the spectrum of accidents considered in the functional containment evaluation—although this is required by MHTGR-16. This is inconsistent with the historical defense-in-depth function of the containment in mitigating the consequences of beyond-design-basis accidents.

40. Although reactor containment structures are not generally designed for beyond-design-basis accident conditions, they in fact play a significant role in adequate protection of public health and safety from BDBAs. This was evident in practice in the three severe accidents that have afflicted power reactors around the world: Three Mile Island, Chernobyl, and Fukushima.

41. During the Three Mile Island accident, hydrogen accumulation and deflagration occurred in the containment, yet the large dry containment structure withstood the resulting overpressure and hence prevented a greater release of fission products from the damaged reactor core.

42. Similarly, although excessive leakage from the drywell containment structures is believed to have occurred at the three operating reactors at Fukushima Daiichi that experienced meltdowns, the containments largely held and restricted fission product releases to the environment to a few percent of the core-to-containment release fractions. Analyses of severe accidents at Mark I boiling water reactors (BWRs) with containment failure generally show greater releases.

43. In contrast to the above beyond-design basis accidents in light-water reactors with containments, the lack of a pressure-resisting containment in RBMK reactors has been widely cited as a major factor contributing to the large fission product release that occurred during the Chernobyl accident.

44. In my professional judgment, because of the failure of the LM-CPA to evaluate the performance of its proposed "functional containment" for beyond-design-basis event sequences, it does not ensure compliance with the containment performance acceptance criteria that the NRC has established for all new reactors.

Declaration Signature

45. My name is Edwin Lyman, my date of birth is June 21, 1964, and my address is 1825 K Street NW, Suite 800, Washington, District of Columbia, 20006, USA. I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Executed on the 11th day of August, 2025, in accordance with 10 C.F.R. § 2.304(d).

Signed (electronically) by Edwin Lyman

Edwin Lyman, Ph.D.
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EXHIBIT E-1

Edwin Stuart Lyman

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Education

Ph.D., Cornell University, Physics, August 1992.
M.S., Cornell University, Physics, January 1990.
A.B., *summa cum laude*, New York University, Physics, June 1986; Phi Beta Kappa.

Professional Experience

January 2020 – Present: Director of Nuclear Power Safety, Union of Concerned Scientists, Washington, D.C.

May 1, 2003 – January 2020: Senior Scientist, Global Security Program, Union of Concerned Scientists, Washington, D.C.

Spring 2015: Adjunct Professor, Elliott School of International Affairs, The George Washington University, Washington, DC. Taught Master's level course on nuclear energy.

June 2002 – April 2003: President, Nuclear Control Institute, Washington, D.C.

July 1995 – May 2002: Scientific Director, Nuclear Control Institute, Washington, D.C.

August 1992 – June 1995: Postdoctoral research associate, Center for Energy and Environmental Studies, Princeton University, Princeton, NJ.

Spring 1994: Lecturer, Woodrow Wilson School, Princeton University. Preceptor for "Science, Technology and Public Policy."

July 1988 – June 1992: Graduate research assistant, Newman Laboratory of Nuclear Studies, Cornell University, Ithaca, NY. Conducted thesis research on high-energy physics.

August 1986–June 1988: Andrew D. White Graduate Fellow, Physics, Cornell University.

Awards

2018 Leo Szilard Lectureship Award, American Physical Society.

Awarded annually to recognize outstanding accomplishments by physicists in promoting the use of physics for the benefit of society in such areas as the environment, arms control, and science policy.

Other

Maintains UCS Nuclear Safety Project "X" account: @NucSafetyUCS
Held Nuclear Regulatory Commission "L" clearance (administratively withdrawn in 2019)

Books and Book Chapters

National Academies of Sciences, Engineering, and Medicine. *Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors.* The National Academies, Washington D.C., 2023.

D. Lochbaum, E. Lyman and S.Q. Stranahan. *Fukushima: The Story of a Nuclear Disaster.* The New Press, New York, 2014.

E. Lyman," Nuclear Energy and Human Health," *Encyclopedia of Environmental Health*. Elsevier Science, 2011.

E. Lyman, "Can Nuclear Fuel Production in Iran and Elsewhere be Safeguarded Against Diversion?" in *Falling Behind: International Scrutiny of the Peaceful Atom* (H.D. Sokolski, ed.). Strategic Studies Institute, U.S. Army War College, 2008, 101-120.

E. Lyman and D. Lochbaum, "Protecting Vital Targets: Nuclear Power Plants," in *Homeland Security: Protecting America's Targets, Vol. III* (J. Forest, ed.). Praeger, Westport, CT, 2006, 157-173.

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Journal Articles and Letters

R. S. Kemp, E. S. Lyman, M. R. Deinert, R. L. Garwin, and F. N. von Hippel, "The Weapons Potential of High-Assay Low-Enriched Uranium." *Science* **384** (2024), 1071-1073.

E. Lyman, "Nuclear Power is Not Clean or Safe Enough," *The Environmental Forum*, March/April 2024, 59.

E. Lyman, "Aging Nuclear Plants, Industry Cost-Cutting, and Reduced Safety Oversight: A Dangerous Mix," *Bulletin of the Atomic Scientists online*, August 29, 2019.

E. Lyman, "The Pentagon Wants to Boldly Go Where No Nuclear Reactor Has Gone Before. It Won't Work," *Bulletin of the Atomic Scientists online*, February 2019.

E. Lyman, "Advanced Reactors: Proliferation and Terrorism Concerns," *Physics and Society*, American Physical Society, October 2018.

E. Lyman, M. Schoeppner, and F. von Hippel, "Nuclear Safety Regulation in the Post-Fukushima Era," *Science* **356** (2017), 808-809.

E. Lyman and F. von Hippel, “Nuclear Waste: Weapons Plutonium Riskier Above Ground” (letter), *Nature* **530** (2016), 281.

T. Clements, E. Lyman and F. von Hippel, “The Future of Plutonium Disposition,” *Arms Control Today*, June/July 2013.

J. Beyea, E. Lyman and F. von Hippel, “Accounting for Long-Term Doses in "Worldwide Health Effects of the Fukushima Daiichi Nuclear Accident’,” *Energy and Environmental Science* **6 (**2013), 1042-1045.

E. Lyman, “Rotblat’s Pursuit of Nuclear Peace,” *New Scientist*, January 25, 2012.

E. Lyman, Surviving the One-Two Nuclear Punch. *Bulletin of the Atomic Scientists online,* September 2011.

E. Lyman, “Security Since September 11th, “*Nuclear Engineering International*, May 20, 2010.

E. Lyman, “Thirty Years after TMI: Five Continuing Vulnerabilities,” *Bulletin of the Atomic Scientists*, March 23, 2009.

E. Lyman, “Making Domestically Produced Medical Isotopes a National Priority,” *Bulletin of the Atomic Scientists*, December 18, 2008.

E. Lyman, “Can Nuclear Plants be Safer?” *Bulletin of the Atomic Scientists*, September/October 2008, 34-37.

E. Lyman and F. von Hippel, “Reprocessing Revisited: The International Dimensions of the Global Nuclear Energy Partnership,” *Arms Control Today*, April 2008, 6-14.

J. Beyea, E. Lyman and F. von Hippel, “Damages from a Major Release of ^{137}Cs Into the Atmosphere of the United States,” *Science and Global Security* **12** (2004) 125-136.

G. Bunn, C. Braun, A. Glaser, E. Lyman and F. Steinhausler, "Research Reactor Vulnerability to Sabotage by Terrorists," *Science and Global Security* **11** (2003) 85-107.

D. Hirsch, D. Lochbaum and E. Lyman, “The NRC’s Dirty Little Secret,” *Bulletin of the Atomic Scientists* (May/June 2003).

R. Alvarez, J. Beyea, K. Janberg, J. Kang, E. Lyman, A. Macfarlane, G. Thompson and F. von Hippel, “Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States,” *Science and Global Security* **11** (2003) 1-51.

E. Lyman, "Revisiting Nuclear Power Plant Safety" (letter), *Science* 299 (2003), 202.

E. Lyman, "The Pebble-Bed Modular Reactor: Safety Issues," *Physics and Society*, American Physical Society, October 2001.

E. Lyman, "Public Health Risks of Substituting Mixed-Oxide for Uranium Fuel in Pressurized Water Reactors," *Science and Global Security* **9** (2001), 1.

E. Lyman and S. Dolley, "Accident Prone," *Bulletin of the Atomic Scientists*, March/April 2000, 42.

E. Lyman and H. Feiveson, "The Proliferation Risks of Plutonium Mines," *Science and Global Security* **7** (1998), 119.

E. Lyman and P. Leventhal, "Bury the Stuff [Weapons Plutonium]," *Bulletin of the Atomic Scientists*, March/April 1997, 45.

E. Lyman, "Weapons Plutonium: Just Can It," *Bulletin of the Atomic Scientists*, November/December 1996, 48.

F. von Hippel and E. Lyman, "Appendix: Probabilities of Different Yields," addendum to J. Mark, "Explosive Properties of Reactor-Grade Plutonium," *Science and Global Security* **4** (1993), 125.

F. Berkhout, A. Diakov, H. Feiveson, H. Hunt, E. Lyman, M. Miller, and F. von Hippel, "Disposition of Separated Plutonium," *Science and Global Security* **3** (1993), 161

E. Lyman, F. Berkhout and H. Feiveson, "Disposing of Weapons-Grade Plutonium," *Science* **261** (1993) 813.

P. Argyres, E. Lyman and S.H.-H. Tye, "Low-Lying States of the Six-Dimensional Fractional Superstring," *Phys. Rev.* D46 (1992) 4533.

S.-w. Chung, E. Lyman and S.H.-H. Tye, "Fractional Supersymmetry and Minimal Coset Models in Conformal Field Theory," *Int. J. Mod. Phys* A7 (1992) 3337.

Selected Reports

E. Lyman, "Preventing an American Fukushima," Union of Concerned Scientists, March 2016.

E. Lyman, "Excess Plutonium Disposition: The Failure of MOX and the Promise of Its Alternatives," Union of Concerned Scientists, December 2014.

E. Lyman, "Small Isn't Always Beautiful: Safety, Security and Cost Concerns About Small Modular Reactors," Union of Concerned Scientists, September 2013.

D. Lochbaum and E. Lyman, "U.S. Nuclear Power Safety One Year After Fukushima," Union of Concerned Scientists, March 2012.

L. Gronlund, D. Lochbaum and E. Lyman, "Nuclear Power in a Warming World," Union of Concerned Scientists, December 2007.

E. Lyman (with M. Schneider et al.), "Residual Risk: An Account of Events in Nuclear Power Plants Since the Chernobyl Accident in 2006," commissioned by the Greens of the European Parliament, May 2007.

E. Lyman, "Chernobyl on the Hudson? The Health and Environmental Impacts of a Terrorist Attack at the Indian Point Nuclear Power Plant," commissioned by Riverkeeper, Inc., September 2004.

E. Lyman, "Safety Issues in the Sea Shipment of Vitrified High-Level Radioactive Wastes to Japan," report sponsored by the Nuclear Control Institute, Greenpeace International and Citizens' Nuclear Information Center Tokyo, December 1994.

E. Lyman, "Interim Storage Matrices for Excess Plutonium: Approaching the 'Spent Fuel Standard' Without the Use of Reactors," PU/CEES Report No. 286, Center for Energy and Environmental Studies, Princeton University, August 1994.

E. Lyman, "The Solubility of Plutonium in Glass," PU/CEES Report No. 275, Center for Energy and Environmental Studies, Princeton University, April 1993.

Selected Invited Talks and Testimony

"Dry Cask Sabotage: Outlier Events," presentation at the San Onofre Community Engagement Panel meeting on Outlier Events and Response Strategies, May 28, 2020.

Testimony on U.S. commercial nuclear reactor safety and security before the Senate Committee on Environment and Public Works, November 13, 2019.

"UCS Perspectives on Accident Tolerant Fuel Technologies and Licensing Process," presentation at NRC Commission briefing, February 23, 2020.

"UCS Perspectives on Advanced Reactor Regulatory and Policy Issues," presentation at NRC Commission briefing, February 6, 2020.

"Law and Innovation: Nuclear Power Development," Boston Bar Association, panel discussion, May 8, 2019.

"UCS Views on the Reactor Oversight Process," presentation at the NRC Regulatory Information Conference, March 13, 2019.

"The Nuclear Regulatory Commission after Fukushima: Lessons Learned and Unlearned," CISAC Seminar, Center for International Security and Cooperation, Stanford University, December 4, 2018.

"Learning from the Hard Cases: Iran, North Korea, Japan, and the Future of Nuclear Nonproliferation," Physics Department colloquium, Duke University, November 14, 2018.

"Addressing the Impacts of HEMPs/GMDs on Nuclear Power Plants," presentation at the Electromagnetic Defense Task Force Summit, Potomac, MD, August 20, 2018.

Testimony on advanced nuclear reactor and fuel cycle legislation before the House Energy and Commerce Subcommittee on Energy, May 22, 2018.

"UCS Perspectives on Advanced Reactor Regulatory and Policy Issues," presentation at NRC Commission briefing, April 24, 2018.

"Recycling Nuclear Waste: Risks and Benefits," Leo Szilard Lectureship Award talk, American Physical Society April Meeting, Columbus, OH, April 14, 2018.

"UCS Perspectives on Accident-Tolerant Fuel," presentation at NRC Commission briefing, April 12, 2018.

"Dilute and Dispose: The Best Approach for Surplus Plutonium Disposition," presentation to the National Academy of Sciences Committee on Disposal of Surplus Plutonium in the Waste Isolation Pilot Plant, Washington, DC, November 29, 2017.

Testimony on the Nuclear Waste Policy Amendment Acts of 2017 before the House Energy and Commerce Subcommittee on Environment, April 26, 2017.

Testimony on the Nuclear Energy Innovation and Modernization Act before the Senate Committee on Environment and Public Works, March 8, 2017.

"The U.S. Surplus Plutonium Dilemma: Lessons for Japan," presentation at the Conference on the U.S.-Japan Nuclear Cooperation Agreement and Japan's Plutonium Policy, Tokyo, Japan, February 24, 2017.

"Physical Security of Nuclear Facilities in the Post-9/11 Era," Nuclear Science and Engineering Energy Seminar, Colorado School of Mines, October 2016.

"Perspectives on Security Issues," presentation at NRC Commission closed briefing, June 23, 2016.

Testimony on advanced nuclear reactors before the Senate Committee on Environment and Public Works, Subcommittee on Clean Air and Nuclear Safety, April 21, 2016.

"Alternatives to MOX," presentation to the Savannah River Site Citizens' Advisory Board, Augusta, GA, March 29, 2016 (with Frank von Hippel)

"NRC's Fukushima Response: Lessons Learned and Lessons Unheeded," presentation at the NRC Regulatory Information Conference, March 10, 2016.

"Fixing the NRC's Broken Framework for Reducing Severe Accident Risk," presentation to the NRC Advisory Committee on Reactor Safeguards, December 1, 2015.

"UCS Perspectives on NRC and Industry Actions in Response to Fukushima," presentation at NRC Commission briefing, April 30, 2015.

"Perception versus Reality: UCS Views on Nuclear and Radiological Terrorism Risks," presentation at the Institute of Nuclear Materials Management "Reducing the Risk" Workshop, Washington, DC, March 17, 2015.

"Fukushima and its Lessons for Nuclear Safety," seminar at The Library of Congress, February 19, 2015.

"Production of Mo-99 Without the Use of Highly Enriched Uranium: Perspectives of the Union of Concerned Scientists," presentation to the National Academy of Sciences Committee on Status of Mo-99 Production, February 12, 2015.

"Safety and Security of Spent Fuel Storage in the United States," presentation to the National Academy of Sciences Fukushima Lessons Learned Panel, January 29, 2015.

"UCS Views on the NRC's Human Reliability Program Activities and Analyses," presentation at NRC Commission briefing, May 29, 2014.

"Public Confidence and Force-on-Force Inspections," presentation at the NRC Regulatory Information Conference, March 13, 2014.

"Fukushima: The Story of a Nuclear Disaster," lecture at the Carter Presidential Library, Atlanta, GA, February 10, 2014.

"UCS Views on NTTF Recommendation 1 and the NRC Staff Proposal," presentation at NRC Commission briefing, January 10, 2014.

"UCS Perspective on Expedited Transfer of Spent Fuel to Dry Casks," presentation at NRC Commission briefing, January 6, 2014.

"Security Impacts of Emerging Nuclear Technologies," MITRE STEP Technical Exchange, McLean, VA, December 3, 2013.

"UCS Perspective on Considering Economic Consequences in the NRC's Regulatory Framework," presentation at NRC Commission briefing, September 11, 2012.

"Lessons from Fukushima for Improving Nuclear Safety," American Physical Society March Meeting, Boston, MA, March 1, 2012.

"Lessons from Fukushima for Improving Nuclear Safety," Physics Department Colloquium, University of Central Florida, February 24, 2012.

Testimony on the Blue Ribbon Commission Report before the House Committee on Energy and Commerce, Subcommittee on Environment and the Economy, February 1, 2012.

"UCS Perspective on the Prioritization of NTTF Recommendations," presentation at NRC Commission briefing, October 11, 2011.

"UCS Perspective on the Japan Task Force Report Short-Term Actions," presentation at NRC Commission briefing, September 14, 2011.

Testimony on small modular reactors before the Senate Committee on Appropriations, Energy and Water Subcommittee, July 14, 2011.

Testimony on nuclear power legislation before the Senate Energy and Natural Resources Committee, June 7, 2011.

Testimony on the U.S. government response to Fukushima before the House Energy and Commerce Committee, Subcommittee on Oversight and Investigations, April 6, 2011.

Testimony on nuclear safety and Fukushima before the Senate Committee on Environment and Public Works, March 16, 2011.

"UCS Perspective on Maintaining Enhanced Safety for New Reactors," presentation at NRC Commission briefing, October 14, 2010.

"Limiting Future Proliferation and Security Risks," presentation to the Blue Ribbon Commission on America's Nuclear Future, Reactor and Fuel Cycle Technology Subcommittee, October 12, 2010.

"Opportunities in Reactor and Fuel Cycle Technologies ," presentation to the Blue Ribbon Commission on America's Nuclear Future, Reactor and Fuel Cycle Technology Subcommittee, August 30, 2010.

"Proliferation and Terrorism Risks of the 'Nuclear Renaissance,'" New York State American Physical Society meeting, April 24, 2010.

"Reprocessing in the U.S.: Just Say No," presentation at the NRC Fuel Cycle Information Exchange, June 25, 2009.

"Nuclear Concerns: Safety, Security, Waste and Proliferation," presentation at the Nuclear Nonoperating Owners' Group Conference, Baltimore, MD, April 23, 2009.

"NRC Regulation of the Nuclear Fuel Cycle: Safety and Security Concerns," presentation at the NRC Regulatory Information Conference, March 11, 2009.

"UCS Views on Risk-Informed Regulation," presentation at NRC Commission briefing, February 4, 2009.

"Licensing Challenges for Fuel Cycle Facilities Under the Global Nuclear Energy Partnership," U.S. Nuclear Regulatory Fuel Cycle Information Exchange, Rockville, MD, June 12, 2007.

"The 'Nuclear Renaissance' and the Spread of Nuclear Weapons," American Physical Society Ohio Chapter Meeting, May 7, 2007.

"Recycling Nuclear Waste," American Physical Society Annual April Meeting, Jacksonville, FL, April 15, 2007.

"The Security Imperative of Eliminating Commercial Use of HEU," presentation to the Committee on Medical Isotope Production Without Highly Enriched Uranium, National Academy of Sciences, Washington, DC, February 15, 2007.

"Recycling Nuclear Waste," Peace Studies Seminar, Cornell University, November 29, 2006.

"Nuclear Power and Nuclear Proliferation," Citizens for Global Solutions conference, Washington, DC, November 13, 2006.

"Next-Generation Nuclear Plants: Safety and Security," presented at "Is Nuclear Power a Solution to Global Warming and Rising Energy Prices?," American Enterprise Institute conference, Washington, DC, October 6, 2006.

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EXHIBIT F

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of:	§	
	§	
Long Mott Energy, LLC	§	**Docket No. 50-614-CP**
	§	
(Long Mott Generating Station)	§	
	§	

DECLARATION OF JEFFREY T. MITMAN IN SUPPORT OF PETITION TO INTERVENE AND REQUEST FOR HEARING BY SAN ANTONIO BAY ESTUARINE WATERKEEPER

STATE OF MARYLAND	§
	§
COUNTY OF MONTGOMERY	§

Under penalty of perjury, I, Jeffrey T. Mitman declare:

1. My name is Jeffrey T. Mitman. I am over eighteen (18) years of age and of sound mind, have never been convicted of a felony, and am otherwise capable of making this declaration. The information in this declaration is based on my personal experience and my review of publicly available information.

2. I have been retained by San Antonio Bay Estuarine Waterkeeper ("Waterkeeper") to review Long Mott Energy, LLC's (LME) construction permit application (LM-CPA) to the U.S. Nuclear Regulatory Commission (NRC) for the Long Mott Generating Station Units 1 to 4 (LMGS). My review focuses on the consideration of climate change (or absence thereof) in the accident analysis in LME's Preliminary Safety Analysis Report (PSAR) (ML25090A061) and environment impacts of those accidents discussed in the and the Environmental Report (ER) (ML25090A063). As

noted in paragraphs 34-35 below, I have also found the ER is deficient because it treats seismic risk as not credible, without adequate justification.

Expert Qualifications and Relevant Experience

3. By education and experience, I am a nuclear engineer, with a significant level of expertise in nuclear power, risk analysis and the impact of external events on nuclear power plant risk.

4. As set forth in my attached Curriculum Vitae (Exhibit F-1), I have more than 40 years of experience in the nuclear industry and 16 years as a regulator with the U.S. Nuclear Regulatory Commission (NRC). My experience includes 16 years on the technical staff of the NRC as a Reliability and Risk Analyst. During my last 15 years at the NRC, I served as Senior Reliability and Risk Analyst, with significant responsibility for managing a number of risk analysis projects and teams.

5. During my employment in the nuclear industry and the NRC, I became very familiar with NRC regulations and guidance regarding nuclear power plant safety, and with the application of risk analysis to reactor safety analysis. I am also familiar with the NRC's requirements regarding Preliminary and Final Safety Analysis Reports.

6. As an NRC Staff member, I participated in NRC safety reviews and performed risk analysis on U.S. nuclear reactors. I also participated in reviews related to the risk to Oconee Nuclear Plant, Units 1, 2 and 3 (Oconee) posed by potential failure of the upstream Jocassee Dam. In addition, I coauthored a generic study by NRC of dam failure risk, with particular application to Oconee. I also worked on the NRC post-Fukushima analysis included preparing and reviewing flooding analysis methodologies and procedures.

7. In 2021, I retired from the NRC and became a private consultant. In that role, I have participated as an expert consultant to environmental organizations in the subsequent license renewal proceedings for the Oconee and North Anna reactors

and in the administrative proceeding for revisions to the License Renewal Generic Environmental Impact Statement.

Introduction and Background

8. Climate change is now recognized as the defining environmental threat of our times. Across the United States, "the impacts of climate change are already being felt." U.S. Global Change Research Program, *Fourth National Climate Assessment,* Vol. II at 25 (2018), (ML19008A414) ("*2018 Climate Assessment*").[1] In the future:

> More frequent and intense extreme weather and climate-related events, as well as changes in average climate conditions, are expected to continue to damage infrastructure, ecosystems, and social systems that provide essential benefits to communities.

Id. Concerning the U.S. energy sector, the *2018 Climate Assessment* found:

> The Nation's energy system is already affected by extreme weather events, and due to climate change, it is projected to be increasingly threatened by more frequent and longer-lasting power outages affecting critical energy infrastructure and creating fuel availability and demand imbalances. The reliability, security, and resilience of the energy system underpin virtually every sector of the U.S. economy. Cascading impacts on other critical sectors could affect economic and national security.

Id. at 179.

9. Climate change has two defining and interacting characteristics: increased frequency of weather events and increased intensity of those events. As a result, it is no longer adequate to prepare for future adverse weather events by identifying the worst historical event and designing against it. The U.S. Global Change Research Program report "Climate Science Special Report Fourth National Climate Assessment, Volume I," (2017), (ML19008A410) has 43 references to the increased

[1] The U.S. Global Change Research Program began as a Presidential Initiative in 1989 and was codified in the Global Change Research Act of 1990 (Pub. L 101-606).

"frequency and intensity" of weather events due to climate change. For example, at page 21:

> The frequency and intensity of heavy precipitation events in the United States are projected to continue to increase over the 21st century (*high confidence*). (emphasis in original).

10. Weather and climate around nuclear power plants have a substantial impact on nuclear power plant safety and the associated risk levels. These external events and the related safety impacts have been recognized since at least the 1970s when they were codified in design criteria for nuclear plants. *See, e.g.,* 10 Code of Federal Regulation (CFR) Part 50 Appendix A in the General Design Criteria (GDC) Criterion 2—Design bases for protection against natural phenomena.

11. Yet, to date, these design criteria have been based on historical weather phenomena and have failed to account for the increased frequency and intensity of weather events caused by climate change. For instance, GDC 2 states:

> Structures, systems, and components [SSC] important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the most severe of the **natural phenomena that have been historically reported for the site and surrounding area**, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed.

Id. (emphasis added). Because the LMGS is not a light-water reactor, GDC 2 is not directly applicable to the LMGS. However, the Principal Design Criteria (PDC) for Non-Light-Water Reactors contains "Design bases for protection against natural phenomena" for MHTGRs [modular high temperature gas cooled reactors] that are the "Same as GDC." *See* Table 1, Non-Light-Water-Reactor-Crosswalk, in

Regulatory Guide (RG) 1.232 "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors" at page 13 (Rev. 0, April 2018) (ML17325A611).[2]

12. To my knowledge, the NRC has no regulatory requirement to consider the safety and environmental effects of climate change in its licensing decisions for nuclear reactors. In my expert opinion, this is a significant deficiency because climate change effects on nuclear reactor safety are reasonably foreseeable and potentially significant.

13. I am not alone in raising concerns about the NRC's failure to address climate change effects on reactor safety in its licensing decisions. As recently stated by the U.S. Government Accountability Office (GAO):

> Climate change is expected to exacerbate natural hazards—including heat, drought, wildfires, flooding, hurricanes, and sea level rise. In addition, climate change may affect extreme cold weather events. Risks to nuclear power plants from these hazards include loss of offsite power, damage to systems and equipment, and diminished cooling capacity, potentially resulting in reduced operations or plant shutdowns.

GAO-24-106326, "NRC Should Take Actions to Fully Consider the Potential Effects of Climate Change" at global page 2 (April 2024) ("GAO Report"). And the

[2] The language of PDC 2 differs slightly from GDC 2, but is the same with respect to consideration of historical phenomena:

> Safety-significant structures, systems, and components shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the severity of **the natural phenomena that have been historically reported for the site and surrounding area**, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal, anticipated operational occurrence, design basis event, and design basis accident conditions with the effects of the natural phenomena, (3) the safety-significance of the functions to be performed (emphasis added).

Id. at C-3 (emphasis added).

GAO criticized the NRC for failing to justify its position that the "margin of safety" built into its regulatory scheme is adequate to account for climate change.

> NRC's actions to address risks from natural hazards do not fully consider potential climate change effects. For example, NRC primarily uses historical data in its licensing and oversight processes rather than climate projections data. NRC officials GAO interviewed said they believe their current processes provide an adequate margin of safety to address climate risks. However, NRC has not conducted an assessment to demonstrate that this is the case.

Id. at page 2.

Comments on the PSAR

14. With the exception of a single input into the hurricane analysis,[3] the PSAR contains no discussion of the effects of climate change on the safety of the proposed LMGS. This is a serious deficiency, because the LMGS site is vulnerable to multiple climate change effects, including flooding and hurricanes. These effects may operate independently or in tandem to pose a serious threat to the safety of the proposed plant and the human and natural environment around it. For instance, the increased frequency of severe storms may result in circumstances where flood levels are already high, and the ground is already saturated when the next severe storm arrives. Hurricane Harvey in 2017, a slow-moving hurricane or tropical cyclone, is an example of this phenomenon. *See* paragraphs 29-32, below.

15. The only analysis in the PSAR of the LMGS's vulnerability to weather events is for historic events. Data from historical data is relevant and useful for a climate change analysis; and as discussed below, it demonstrates the site's vulnerability to climate change. But unfortunately, the data provided in the LMGS are incomplete and deficient.

16. Based on the information that has been submitted by LME, the PSAR contains information indicating that the proposed plant is vulnerable to climate-induced

[3] This single input is sea level rise ("SLR"), which I discuss in more detail below.

flooding. For instance, the PSAR gives a "final value" for the "Maximum Still Water Flood Elevation" of Coloma Creek as 33 feet, even without considering impacts of climate change. *See* Table 2.0-1 (Sheet 3 of 3) at page 2.0-4. The same table gives a site grade elevation of 31 feet. Given that safety related (SR) structures, systems and components (SSC) are located at grade elevation, their location two feet below the maximum flood level appears to have an influence on SR SSC.

17. It is important to note that the maximum flood level is based on historic data. If LME were to consider the increasing intensity of climate change, it is reasonable to anticipate that maximum climate-induced flood level already exceeds 33 feet and will continue to rise over the operating life of the LMGS, resulting in an even more serious threat to safety equipment.

18. Table 2.0-1 also indicates that LME's analysis of the maximum still water flood level is incomplete. In footnote 3 to Table 2.0-1, LME states: "Additional site-specific analyses will be provided by the end of 2025." Elsewhere in the same table, the "Combined Effects Maximum Flood Elevation (Coloma Creek)" is also modified by same Note 2. It is reasonable to infer that the missing information includes data as well as analyses. The lack of complete or accurate data and analysis of historic flood levels on Coloma Creek makes it impossible to conduct a thorough, complete and accurate safety evaluation without all this final input information. But more to the point, the application lacks any data or analysis of how climate change could exacerbate these flood levels.

19. Similarly, the application indicates that safety structures were moved, and that the PSAR is based on outdated information. For instance, the PSAR states:

> As a result of the relocation of the plant structures on the subject site, the data presented in Section 2.5.4.3 is based on available data from the prior locations of the structures.

Id. at page 2.5-219. Similarly, the PSAR states:

> Due to a revised layout of the LMGS site, the data presented in this section is based on information from a previous location. The **updated plant layout involves consolidating the safety-related structures** and their relocation approximately 750 ft (228.6 m) in a westward direction.

Id. at page 2.5-245 (emphasis added). Moving the SR structure's location potentially impacts those SR SSCs and their ability to adequately cope with weather-related external events (a discussion of those events is below). And because the LM-CPA lacks any description of how the plant design changed during the "consolidat[ion of] the safety-related structures" I am unable to fully understand what LME is currently planning to construct. These deficiencies bring into question the adequacy of the safety analysis, the associated risk analysis, and consequentially the environmental analysis.

20. While historical data alone are not sufficient to project climate change impacts into the future, they are essential inputs to any climate change analysis. Therefore, I am concerned that even the historical data that *is* provided by the PSAR is inadequate –or even inapplicable—for a climate change analysis with respect to flooding. For example, the PSAR's analysis of flooding on nearby streams and rivers is based on a study completed as part of an early site permit application to the NRC for the Victoria County Station in 2007. *See* PSAR at page 2.4-74. But the Victoria County Station site is more than 20 miles away, and thus not sufficiently comparable for a flooding analysis. Apparently recognizing this, LME states: "Additional site-specific analyses and associated information that includes the postulated coincidental wind setup and wave setup will be provided by the end of 2025." *Id.* Once again, the PSAR does not give enough information for a reasonable analysis.

21. The PSAR also lacks sufficient data to support a climate-change analysis because it does not consider recent very intense storms that could affect climate change projections. For instance, the PSAR's discussion of probable maximum precipitation (PMP) and local intense precipitation (LIP) is based on methodologies outlined in the U.S. National Weather Service Hydrometeorological Reports No. 51

and 52 (HMR 51 and HMR 52) (NOAA, 1978 and NOAA, 1982). *See* PSAR at page 2.4-51. The age of these reports shows that recent, unusually severe storms such as Hurricane Harvey in 2017 and Hurricane Beryl in 2024 are not considered. In addition, the methodologies outlined in HMR 51 and HMR 52 are insufficient to address climate change because they reflect only historical knowledge at the time they were written and do not attempt to evaluate how the frequency and intensity of severe storms will increase due to climate change.

Dam Failures

22. The PSAR's dam failure analysis is troubling for its failure to consider the reasonably foreseeable adverse effects of climate change. Based on the 2007 Victoria County Station early site permit application, the PSAR states that "dam failures induced by hydrologic causes such as a PMF (probable maximum flood) is not controlling[.]" PSAR at page 2.4-160. The PSAR purports to justify this conclusion on the ground that the dams "were designed to accommodate and sustain the respective PMFs[.]" *Id*. It is reasonable to infer that the PMF analysis supporting the dam design was conducted using the standard HMR 51 and 52 methods discussed above, which are driven by historical data and do not take into consideration climate change.

23. LME also makes unreasonable assumptions about the integrity of rolled-earth embankments at two water control/storage structures in the vicinity of the LMGS nuclear island. According to the PSAR, these embankments, with an average height of 10 feet (*id.* at page 2.4-160), were analyzed for "[p]ostulated failure mechanisms," including:

> [E]xcessive seepage from piping through the foundations of the embankment, seismic activity leading to potential liquefaction of the foundation soils, and erosion of the embankment as the result of overtopping from flood or wind-wave events.

Id. at 2.4-160. But LME concludes that: "Failure of the operating basins embankments as the result of any of these mechanisms is not . . . a credible event." *Id.* at page 2.4-161. No justification for this conclusion is provided. This argument is indefensible because earthen embanks fail all the time from the identified failure mechanisms.[4] As with previous discussion, some of the failure mechanisms are impacted by weather, *e.g.,* overtopping and wind-wave events and thus they also are impacted by climate change.

24. Thus, LME's failure to consider the potential for climate-induced dam failures and failure of impoundment embankments is unreasonable and potentially quite dangerous.

Probable Maximum Surge

25. In its discussion of probable maximum surge and seiche flooding states, the PSAR states: "The effect of long-term climate variability on hurricane intensity is an area of active research." *Id.* at page 2.4-196. Given the proximity of the proposed facility to the Gulf coast, the PSAR's failure to provide any data or analysis regarding this issue is a gross defect.

26. The one topic on which LME considers the relevance of climate change to reactor safety is a single input into its discussion of sea level rise (SLR) connected with a hurricane-caused storm surge. And yet its SLR estimate is low in comparison with estimates reported by the GAO and the Army Corps of Engineers. The PSAR estimates SLR at 1.2 feet and uses this as input to its storm surge calculation, *i.e.,* the AWL (antecedent water level). *Id.* at page 2.4-200.[5]

[4] *See* Exhibit F-2, U.S. Army Corps of Engineers HEC-RAS Hydraulic Reference Manual ("Causes and Types of Dam Failures") https://www.hec.usace.army.mil/confluence/rasdocs/ras1dtechref/6.5/performing-a-dam-break-study-with-hec-ras/estimating-dam-breach-parameters/causes-and-types-of-dam-failures.

[5] As stated in the PSAR, this comes from NRC "Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment, Interim Staff Guidance," Rev. 0, JLD-ISG-2012-06, January 4, 2013

27. But this assumption of 1.2 ft for SLR is questionable, in my judgment. For example, the GAO reports that an SLR of 1.9 feet is expected in the Western Gulf by 2050, long before the end of the proposed operating license.[6] The Galveston District Office for the U.S. Army Corps of Engineers, which will be responsible for granting any Clean Water Act Section 404 permits needed for this project, predicts even more drastic sea level rise, up to 6 feet in the next 50 years.[7]

Flooding Protection Requirements

28. It is also not apparent that the safety-related structures systems and components will be protected from all of the inundation scenarios analyzed in the PSAR. PSAR Section 2.4.10 "discusses the need for protection of safety-related structures systems and components (SSC) from design bases flood events." PSAR at page 2.4-314. In its discussion on breaching of on-site Basins #5 and #31, LME states that the maximum predicted water level may submerge the base of SR SSC by 1 foot. It then asserts that "Drainage systems for the plant location will be designed so that the flood waters from the breaching of the embankments is directed away from safety-related SSCs at the site." *Id.* at page 2.4-315. But in its subsequent discussion of inundation height from surge and seiche flooding, it predicts a maximum water level at the nuclear island of 10.47 feet above ground elevation. *Id.* at page 2.4-315. This flood depth is over nine feet deeper than the flood height predicted from breaching of the on-site basins, yet the PSAR makes no assertion that it intends to protect the SR SSC from this more severe inundation. This fails to meet the requirements found in PDC 2 which requires SSCs "shall be designed to withstand the effects of natural

(ML12314A412) https://www.nrc.gov/docs/ML1231/ML12314A412.pdf." To my knowledge, this is the only guidance that NRC has issued concerning climate change.

[6] Exhibit F-3, GAO Report Figure 8 at Page 24.

[7] Exhibit F-4, "Coastal Texas Protection and Restoration Feasibility Study Final Report," (August 2021) page 14 ("Current forecasts indicate that relative sea levels could rise by 1 to 6 feet over the next 50 years.").

phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions." *Id.* at page 5.3-2.

Omitted Reasonably Foreseeable Accident Hazard

29. As discussed above in paragraphs 22-24, the PSAR excludes any analysis of a hydrologic event (i.e., PMP/PMF) causing a dam failure. The justification offered by LME is that the dams were designed and built to pass the PMP/PMF. But LME has not considered a reasonably foreseeable scenario involving a large slow-moving hurricane (e.g., the 2017 Hurricane Harvey) after an antecedent storm. In this scenario, the antecedent storm fills the surrounding watershed, including but not limited to, lakes, rivers, creeks and canals (e.g. Green Lake, the Guadalupe and San Antonio Rivers, Coleto Creeks) to or beyond their capacities. The now-saturated soils would leave the watershed without the capability to store any additional water. In the next phase, the hurricane would move inland on top of the watershed above one of the large dams (e.g., Canyon or Coleto Creek Dams), unleashing a PMP onto that dam's watershed.

30. Such a storm is not unheard of—Hurricane Harvey took a similar slow and deadly progression across the Texas coast, leading to saturation of the watershed and massive flooding.

31. Under the historical considerations of PDC 2 and GDC 2 PMP/PMF analysis of the dam might suffice. However, climate change alters the dynamics. The analysis of watershed and its storage capacity never considered climate change. Nor has the PMP/PMF analyses of the large dams considered climate change. Instead, the PMP/PMF analysis assumes a sunny-day failure, with a minimal amount of water stored behind the dam.

32. But under this reasonably foreseeable scenario that takes into consideration climate change, it is quite possible that the dam could overtop given a larger PMP on the dam. Overtopping would send more water into the watershed than is contemplated

under a sunny-day failure. Then, when the dam failure is routed down the watershed to the LMGS vicinity it is possible that the SR SSC, not having been designed to withstand this event, would fail. This climate change driven scenario poses uncontemplated safety impacts and risks to LMGS and should be considered, but it appears nowhere in the LM-CPA.

Comments on Environmental Report

33. Like the PSAR, the Environmental Report (ER) contains no discussion of the effects of climate change on the safety or environmental impacts of the proposed LMGS: not in Sections 5.13 (Environmental Impacts of Postulated Accidents Involving Radioactive Materials (starting at Page 5.13-1)), nor in Section 7.2.11 (Postulated Accidents (starting at Page 7.2-25)). Instead, the environmental impacts of design basis and severe accidents completely rely on the underlying risk analysis which in turn rests on the foundation of the safety analysis. Thus, if the safety analysis foundation is inadequate, then the environmental report that relies on it is also inadequate. And as discussed above, the PSAR suffers from serious deficiencies as it does not adequately address the impacts of climate change on the safety analysis. And as illustrated above, the LMGS site is vulnerable to multiple climate change-exacerbated effects, including flooding and hurricanes. Because the safety analysis foundation is inadequate to address climate change, the environmental analysis therefore is also inadequate.

Design Basis Accidents and Seismic

34. On a separate topic, the ER is deficient because it treats seismic risk as not credible, with insufficient explanation to support this determination.

35. Environmental Report Table 5.13.1-1: Design Basis Accidents (Page 5.13-14) identifies the design basis events evaluated. The last event identified is a seismic event. The associated remark states:

> As discussed in PSAR Section 2.5, a seismic event is not a credible initiating event for the LMGS site.

ER at Page 5.13-14. PSAR Section 2.5 (Geology) does discusses the seismology of the LMGS, but I found no basis for excluding seismic events in the PSAR or ER. Without providing a basis for excluding seismic events, this appears to conflict with the nuclear industry's well understood knowledge that seismic risk can be a significant contributor to total risk in nuclear power plants, as is illustrated by the, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants-Final Report (NUREG-1437, Rev. 2)," 2024.08, Vol. 3 (ML24086A528) documents.

36. NUREG-1437, Rev. 2 Appendix E Table E.3-11 "Seismic (Full Power) Core Damage Frequency Comparison" shows that some plants have relatively large earthquake risk compared to other plants. For example, while the mean seismic PRA (probabilistic risk assessment) SCDF (seismic core damage frequency) for the identified plants was 3.0E-05 per year, one plant, the Robinson Unit 2 plant, has a SCDF value of 1.3E-04 per year approximately four times higher than the mean. In addition, the relative hazard of earthquakes can be a significant contributor to the total hazards. NUREG-1437 Vol. 3, Table E.3 12 "Pressurized Water Reactor and Boiling Water Reactor All Hazards (Full Power) Core Damage Frequency Comparison" (Page E 36) shows a mean all-hazards (i.e., total) CDF value for LAR (license amendment request) plants to be 6.1E-05 per year. Thus, the mean SCDF is approximately 50% (= 3.0E-05 / 6.1E-05) of the all-hazard CDF. While the LMGS is different than the light water reactors characterized in NUREG-1437, the NUREG-1437 analysis illustrates how seismic risk can be a significant contributor to total risk in nuclear power plants. The LMGS application supplies no justification for not considering seismic in the required environmental analysis.

Severe Accidents Comparison

37. Section 5.13.2.8 Conclusions states in part:

> The total calculated dose risk to the 50 mi (80 km) population from the LD-DBA is 3.76E-02 person-rem (3.76E-04 person-Sv) per plant year. This value is less than the dose risk from the five reactors analyzed in NUREG-1150.

Id. Page 5.13-7. While this may be true, the NUREG-1150 plants results include at least some external events such as earthquakes, floods and fires. Which external events were included in the NUREG-1150 analysis varied by plant. Thus, LME's comparison between the LMGS and the NUREG-1150 plants is not an apples-to-apples comparison as adding in external events would increase the total LMGS risk potentially exceeding the values in NUREG-1150.

Conclusion

38. In my professional opinion, the LMGS PSAR and ER is deficient for several reasons. The PSAR and ER are deficient because they do not address the reasonably foreseeable and potentially significant impacts of climate change on safety, risk and the environment. The effects of climate change on accident risk are potentially significant and must be addressed before the LM-CPA can be deemed to constitute an adequately complete and rigorous environmental analysis. Taken together, these deficiencies show a level of inadequacy that is unacceptable.

39. In addition, I conclude that the ER is deficient because it treats seismic risk as not credible, without adequate justification.

Declaration Signature

40. My name is Jeffrey T. Mitman, my date of birth is January 7, 1957, and my address is 18407 Jerusalem Church Road, Poolesville, Maryland 20837, USA. I declare under penalty of perjury that the foregoing is true and correct.

Executed in the County of Montgomery, State of Maryland, on the 11th day of August, 2025, in accordance with 10 C.F.R. § 2.304(d).

Signed (electronically) by Jeffrey T. Mitman
Jeffrey T. Mitman
18407 Jerusalem Church Road

Pollesville, Maryland 20837, USA
301-633-7525
jmitman@gmail.com

EXHIBIT F-1

CURRICULUM VITAE FOR JEFFREY T. MITMAN

Poolesville, MD
August 2025

QUALIFICATIONS

Reliability and risk analyst with more than 45 years' experience in the nuclear industry. Skills include evaluation of probabilistic risk analyses (PRA) and management of PRA projects and teams. Highly experienced in low power and shutdown (LPSD) risk modeling issues. Solid record of bringing projects in on schedule and budget.

MAJOR ACCOMPLISHMENTS

- Transitioned NRC to detailed PRA models for LPSD significance determinations process evaluations.
- Guided development of and managed industry's first configuration risk management software tool.
- Obtained regulatory approval of EPRI's risk informed in-service inspection (RI-ISI) methodology.
- Managed first PRA of bolted spent fuel storage cask.

EXPERIENCE

PRIVATE CONSULTANT (Poolesville, MD)

Nuclear Risk Analyst 2021-Present

- Reviewed North Anna Subsequent License Renewal application and prepared technical report on adequacy of environmental and safety analyses.
- Reviewed Oconee Subsequent License Renewal application and prepared technical report on adequacy of environmental and safety analyses to address flooding risks.
- Reviewed and submitted comments on NRC's draft (2023) Generic Environmental Impact Statement (NUREG-1437 Revision 2).

US NUCLEAR REGULATORY COMMISSION (Rockville, MD) 2005 - 2021

Senior Reliability and Risk Analyst (NRC Office of Nuclear Reactor Regulation)

- Conducted Significance Determination Process (SDP) evaluations of reactor events including development and/or modification of required risk models.
- Served as lead analyst for low power and shutdown event issues and concerns.
- Guided development of shutdown Standardized Plant Analysis Risk (SPAR) models.
- Conducted extensive Human Reliability Analysis (HRA).
- Evaluated external event risk from dam failures.
- Served on NRC's "Japan Team" (part of USAID disaster assistance response team for Fukushima Daiichi accident), providing technical advice and support through the U.S. Ambassador to Japanese government.
- Participated in post NRC's Fukushima Near Term Task Force (NTTF) flooding guidance development.
- Developed NRC's guidance on crediting FLEX in risk-informed regulatory applications.
- Advised NRC National Fire Protection Association (NFPA) 805 team on issues related to shutdown fire risk.
- Performed evaluations of risk informed license applications.

Reliability and Risk Analyst (NRC Office of Nuclear Regulatory Research)

- Project Manager for the development of shutdown SPAR models

ERIN ENGINEERING AND RESEARCH, INC. (Walnut Creek, CA) 2004 - 2005

Lead Senior Engineer

- Prepared configuration risk management evaluation of at-power fire risk.
- Prepared configuration risk management evaluation of loss of offsite power.

ABE STAFFING SERVICES (Palo Alto, CA) 2003 - 2005

Consultant to EPRI

- Brought project and team to closure involving Dry Cask Storage PRA involving Transnuclear bolted cask containing PWR fuel.

EPRI (Palo Alto, CA) 1998 - 2003
Project Manager

- **Outage Risk Assessment and Management** (ORAM-Sentinel)

- Grew first of a kind software application for performing configuration risk management in nuclear power plants.
  - Conducted research in low power and shutdown risk; shutdown initiating event and event frequency derivation.
  - Delivered multiple versions (including alpha, beta & production), testing and full documentation.
  - Administered utility user group, marketing, contract preparation, technology transfer, technical report publication and training.
  - Actively managed both development and application contracts with multiple suppliers and customers. Managed annual $1M budget.

- **Dry Cask Storage PRA**: Initiated innovative analysis of Transnuclear cask containing PWR fuel.
  - Managed unique team with diverse experience in both cask design and PRA backgrounds.
- **Risk Informed In-service Inspections** Project (RI-ISI): Lead team in obtaining regulatory approval of methodology to safely reduce piping weld inspection requirements using combination of probabilistic and degradation analysis.
  - Responsible for methodology finalization and acceptance by industry and U.S. NRC.
  - Conducted marketing, sales, contract preparation, technology transfer, training and technical report publication.
  - Actively managed both development and application contracts with both suppliers and customers. Managed annual $1M budget.
- **Human Reliability Analysis Project**: Managed project to bring consistency on industry use of HRA methods.
  - Responsible for EPRI HRA area, including development of HRA Calculator software and establishment of associated users group.

ERIN ENGINEERING AND RESEARCH, INC. (Palo Alto, CA) 1992 - 1998
Lead Senior Engineer
Collaborated with EPRI ORAM-SENTINEL Project Manager in project development and administration, user group administration, contract preparation, technology transfer workshops, technical report generation and editing. Performed ORAM analysis of the Diablo Canyon plant. Performed ORAM Probabilistic Analysis of Perry spent fuel pool. Drafted and edited ORAM V2.0 User's Manual. Assisted in ORAM-SENTINEL software design, performed software debugging. Principle researcher and author of BWR outage contingency report. Prepared marketing and training, materials.

ABB IMPELL CORPORATION (King of Prussia, PA) 1990 - 1992
Lead Senior Engineer

- **Design Basis Documentation**: directed team of three engineers to review PECO Feedwater System Design. Wrote Design Basis Documentation reports for Limerick and Peach Bottom power plants, identifying licensing and design concerns by reviewing the system design as documented in drawings, calculations, vendor manuals, Technical Specifications, UFSAR, SER, SRP, 10CFR50.59 safety evaluations etc. and by interfacing with utility engineering personnel. Prepared Engineering Change Requests as necessary.
- **Shift Outages**: during Limerick Nuclear Power Plant refueling / maintenance outage. Coordinated all shift maintenance work and testing. Collaborated with all groups in power plant, allocating resources as needed to maintain schedule and reporting to senior plant outage management. Performed system reviews prior to placing them back in service. Conducted shift outage meetings. Tracked work group performance against schedule. Advised utility management on techniques for schedule and outage organizational improvements.

GENERAL ELECTRIC COMPANY (San Jose, CA) Experience Prior to 1990
Startup-Test Engineer

- **Shift Startup Engineer:** During power ascension phase coordinated all system testing on shift and startup interface with operations. During preoperational phase, acted as operations shift supervisor responsible for coordinating all system testing and flushing on shift from main control room. Updated senior utility management daily on testing status.
- **Additional positions:** Shift Technical Advisor, Test Engineer, Lead QC / Welding Inspector.

EDUCATION / PROFESSIONAL DEVELOPMENT

- BSE, Nuclear Engineering, University of Michigan, Ann Arbor, MI.
- Introductory VBA class, University of California, Berkeley, CA.
- Misc. business courses at various colleges and universities.
- Senior Reactor Operator Certified.
- GE Station Nuclear Engineering.
- Effective Utilization of PSA, ERIN Engineering & Research, Walnut Creek, CA.

PROFESSIONAL ASSOCIATIONS

- American Nuclear Society (ANS) member since 1978.
- ANS Nuclear elected member of Installation Safety Division Executive Committee 2015 to 2021.
- ANS Risk Informed Standards Committee (RISC).
- ANS/ASME Risk Informed Standards Writing Group on Shutdown PRA Standard.
- ASME Section XI, Working Group on Implementation of Risk Based Examination.
- MIT Professional Summer Programs Guest Lecturer at Risk-Informed Operational Decision Management Course.

PAPERS

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3. Uncertainty Analysis for Large Dam Failure Frequencies Based on Historical Data, PSAM11 2012. Co-author.
4. An Assessment of Large Dam Failure Frequencies Based on US Historical Data, PSA 2011. Co-author.
5. Development of PRA Model for BWR Shutdown Modes 4 and 5 Integrated in SPAR Model, to be presented at PSAM10 2010. Co-author.
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15. Control of Reactor Vessel Temperature/Pressure during Shutdown, GE SIL 357. June 1981. Co-author

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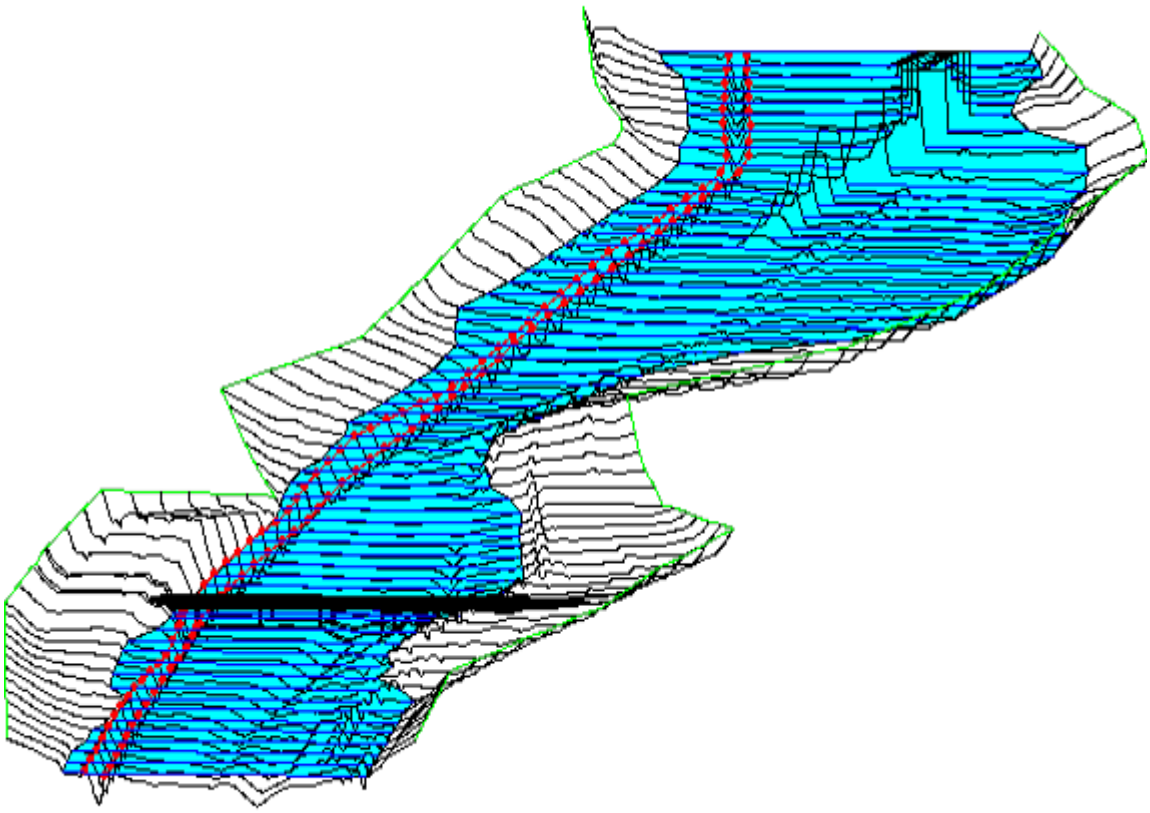
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5. "Guidance for Incorporating Organizational Factors into Nuclear Power Plant Risk Assessments: Phase 1 Workshop." EPRI and U.S. DOE 2002. 1003322. PM.
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EXHIBIT F-2

US Army Corps of Engineers®
Hydrologic Engineering Center

HEC-RAS

River Analysis System



Causes And Types Of Dam Failures

Version 6.5
Exported - August 2025

Approved for Public Release. Distribution Unlimited.

Table of Contents

No headings included in this document

Historically, all types of dams have experienced failures due to one or more types of event/ loading. However, by far the majority of dam failures that have occurred have been earthen dams, caused by some level of flood. The types of dams that are commonly built and found in the field are:

- Earthen embankment/rockfill
- Concrete arch and multi arch
- Concrete gravity
- Buttress (combination of concrete gravity and arch dam)
- Steel, timber, and composite materials

There are many mechanisms that can be the driving force of a dam failure. The following is a list of mechanisms that can cause dam failures:

- Flood event
- Piping/seepage (internal and underneath the dam)
- Land slide
- Earthquake
- Foundation failure
- Equipment failure/malfunction (gates, etc…)
- Structural failure
- Upstream dam failure
- Rapid drawdown of pool
- Sabotage
- Planned removal

Given the different mechanisms that cause dam failures, there can be several possible ways a dam may fail for a given driving force/mechanism. Table 14-1 shows a list of dam types versus possible modes of failure (Costa, 1985, and Atallah, 2002).

Table 13-1. Possible failure modes for various dam types.

Failure Mode	Earthen/ Embankment	Concrete Gravity	Concrete Arch	Concrete Buttress	Concrete Multi-Arch
Overtopping	X	X	X	X	X
Piping/Seepage	X	X	X	X	X
Foundation Defects	X	X	X	X	X
Sliding	X	X		X	
Overturning		X	X		
Cracking	X	X	X	X	X
Equipment failure	X	X	X	X	X

Costa (1985) reports that of all dam failures as of 1985, 34% were caused by overtopping, 30% due to foundation defects, 28% from piping and seepage, and 8% from other modes of failure. Costa (1985) also reports that for earth/embankment dams only, 35% have failed due to overtopping, 38% from piping and seepage, 21% from foundation defects; and 6% from other failure modes.

EXHIBIT F-3

United States Government Accountability Office



Report to Congressional Requesters

April 2024

NUCLEAR POWER PLANTS

NRC Should Take Actions to Fully Consider the Potential Effects of Climate Change

GAO-24-106326

GAO Highlights

Highlights of GAO-24-106326, a report to congressional requesters

April 2024

NUCLEAR POWER PLANTS

NRC Should Take Actions to Fully Consider the Potential Effects of Climate Change

Why GAO Did This Study

NRC licenses and regulates the use of nuclear energy to provide reasonable assurance of adequate protection of public health and safety, to promote the common defense and security, and to protect the environment. Like all energy infrastructure, nuclear power plants can be affected by disruptions from natural hazards, some of which are likely to be exacerbated by climate change. Most commercial nuclear plants in the United States were built in the 1960s and 1970s, and weather patterns and climate-related risks to these plants have changed since their construction.

GAO was asked to review the climate resilience of energy infrastructure. This report examines (1) how climate change is expected to affect nuclear power plants and (2) NRC actions to address risks to nuclear power plants from climate change. GAO analyzed available federal data and reviewed regulations, agency documents, and relevant literature. GAO interviewed officials from federal agencies, including NRC, the Department of Energy, and the National Oceanic and Atmospheric Administration, and knowledgeable stakeholders from industry, academia, and nongovernmental organizations. GAO also conducted site visits to two plants.

What GAO Recommends

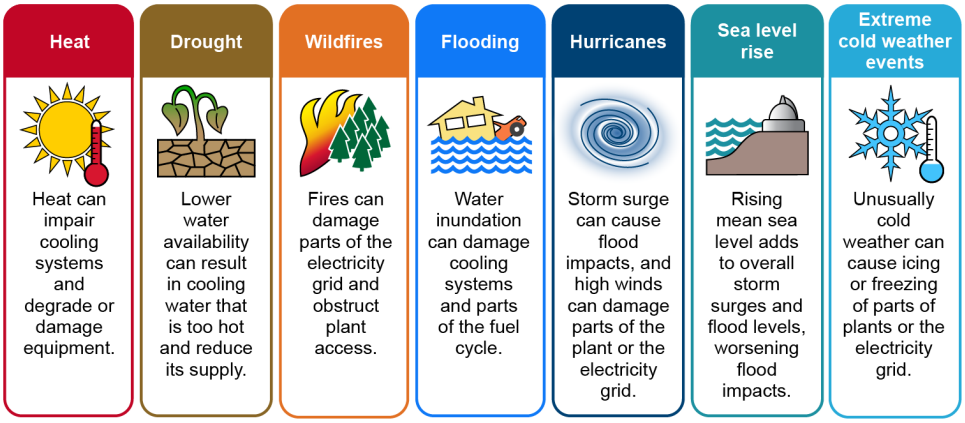
GAO is making three recommendations, including that NRC assess whether its existing processes adequately address climate risks and develop and implement a plan to address any gaps identified. NRC said the recommendations are consistent with actions that are either underway or under development.

View GAO-24-106326. For more information, contact Frank Rusco at (202) 512-3841 or ruscof@gao.gov.

What GAO Found

Climate change is expected to exacerbate natural hazards—including heat, drought, wildfires, flooding, hurricanes, and sea level rise. In addition, climate change may affect extreme cold weather events. Risks to nuclear power plants from these hazards include loss of offsite power, damage to systems and equipment, and diminished cooling capacity, potentially resulting in reduced operations or plant shutdowns.

Examples of Natural Hazards that May Pose Risks to Nuclear Power Plants



Sources: Nuclear Regulatory Commission documents; summary of literature; GAO (icons). | GAO-24-106326

The Nuclear Regulatory Commission (NRC) addresses risks to the safety of nuclear power plants, including risks from natural hazards, in its licensing and oversight processes. Following the tsunami that led to the 2011 accident at Japan's Fukushima Dai-ichi nuclear power plant, NRC took additional actions to address risks from natural hazards. These include requiring safety margins in reactor designs, measures to prevent radioactive releases should a natural hazard event exceed what a plant was designed to withstand, and maintenance of backup equipment related to safety functions.

However, NRC's actions to address risks from natural hazards do not fully consider potential climate change effects. For example, NRC primarily uses historical data in its licensing and oversight processes rather than climate projections data. NRC officials GAO interviewed said they believe their current processes provide an adequate margin of safety to address climate risks. However, NRC has not conducted an assessment to demonstrate that this is the case. Assessing its processes to determine whether they adequately address the potential for increased risks from climate change would help ensure NRC fully considers risks to existing and proposed plants. Specifically, identifying any gaps in its processes and developing a plan to address them, including by using climate projections data, would help ensure that NRC adopts a more comprehensive approach for assessing risks and is better able to fulfill its mission to protect public health and safety.

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Abbreviations

FLEX	Diverse and Flexible Coping Strategies
NCA	National Climate Assessment
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
POANHI	Process for the Ongoing Assessment of Natural Hazard Information
SAFER	Strategic Alliance for FLEX Emergency Response

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U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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April 2, 2024

The Honorable Joe Manchin III
Chairman
Committee on Energy and Natural Resources
United States Senate

The Honorable Tom Carper
Chairman
Committee on Environment and Public Works
United States Senate

Since 1990, nuclear energy has accounted for about 20 percent of the electricity generated in the United States. In 2022, nuclear energy provided nearly half of our nation's carbon-free electricity, making it the largest domestic source of carbon-free energy. Nuclear power plants emit no carbon dioxide during operations and, unlike many sources of renewable energy, typically operate around the clock, producing on average above 90 percent of their generating capacity.

However, nuclear power plants can be affected by natural hazards—including heat, drought, wildfires, flooding, hurricanes, sea level rise, and extreme cold weather events—some of which are expected to be exacerbated by climate change, with effects varying by region. Most commercial nuclear power plants in the United States were licensed and built in the 1960s and 1970s, and the risks to plants' safety and operations from natural hazards have changed since their construction.

The Nuclear Regulatory Commission (NRC) is responsible for regulating the civilian use of radioactive materials to promote the nation's common defense and security, provide reasonable assurance of adequate protection of public health and safety, and protect the environment. As electricity demand in the United States is expected to continue to grow over the coming decades, Congress and others are turning to nuclear power as one means of meeting the increased demand while reducing carbon emissions. For example, in recent years, Congress has provided incentives for the continued operation of existing nuclear power plants

and for the construction of new plants, which, if licensed, could operate into the next century.[1]

You asked us to review the climate resilience of energy infrastructure. This report focuses on nuclear power plants' resilience to climate change and examines (1) how climate change is expected to affect nuclear power plants and (2) what actions NRC has taken to address the risks to nuclear power plants from climate change.

To address both objectives, we interviewed officials from NRC headquarters and its four regional offices, NRC resident inspectors, and officials from the Department of Energy—including the Office of Nuclear Energy and the Idaho National Laboratory—the Federal Energy Regulatory Commission, the Federal Emergency Management Agency, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Forest Service. In addition, we interviewed a nongeneralizable sample of nine stakeholders knowledgeable about nuclear power plant operations and safety, climate change, and resilience measures. We also visited two selected nuclear power plants—Palo Verde Nuclear Generating Station in Buckeye, Arizona, and Turkey Point Nuclear Generating Station in Homestead, Florida—and interviewed plant staff and NRC resident inspectors at these plants. We selected these plants because of their exposure to a variety of natural hazards that may be exacerbated by climate change and regional diversity. Findings from selected stakeholder interviews and site visits are not generalizable to all stakeholders and sites.

To examine how climate change is expected to affect nuclear power plants, we conducted a literature review of articles and reports related to the effects of climate change on nuclear power plants. On the basis of this method, we identified and used 36 articles to support the findings in our report. We also reviewed the fourth and fifth U.S. Global Change

[1]NRC has efforts underway to support the licensing of advanced nuclear reactors—nuclear fission reactors that may offer significant improvements over the most recent generation of nuclear fission reactors and may involve first-of-a-kind designs—which, according to NRC officials, contribute to climate resilience by supporting an alternative to fossil-fuel-based power plants. For more information on NRC's licensing of advanced nuclear reactors, see GAO, *Nuclear Power: NRC Needs to Take Additional Actions to Prepare to License Advanced Reactors,* GAO-23-105997 (Washington, D.C.: July 27, 2023).

Research Program's National Climate Assessments (NCA),[2] federal data on natural hazards, and prior GAO reports.

Additionally, we identified and obtained national-level data sets from relevant federal agencies for six of the seven natural hazards identified by the NCA and our literature review as likely to be exacerbated by climate change: extreme heat, extreme cold, wildfires, flooding, storm surge from hurricanes, and sea level rise.[3] For heat, cold, and sea level rise, we used data that are based on climate scenarios. For heat and cold, we analyzed the projected exposure of nuclear power plants to those hazards.[4] For wildfires, hurricane storm surge, and flooding, we used data that are based on current and past conditions.[5] We assessed the reliability of the data sources used and found the data to be sufficiently reliable for the purposes of our reporting objectives. For more detailed information on our scope and methodology, and the steps we took to assess the reliability of the data used in this report, see appendix I. For more detail on data sources used in this report, see appendix II.

In addition, we obtained NRC data on the location of all 54 operating U.S. nuclear power plants as well as on the 21 shutdown nuclear power plants

[2]U.S. Global Change Research Program, *Fifth National Climate Assessment*, (Washington, D.C.: 2023); U.S. Global Change Research Program, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, vol. II (Washington, D.C.: 2018).

[3]To identify and select national-level data sets, we used information from the NCA. The fifth NCA was released on November 14, 2023, after we had obtained and analyzed the hazard data sets. We reviewed relevant sections from the fifth NCA and did not identify major differences in the predicted or projected trends for the selected natural hazards. We did not analyze drought data because we were unable to identify national-level geospatial data that was both relevant to nuclear power plants and sufficiently reliable for our purposes.

[4]To analyze projected exposure to heat and cold hazards, we used data from the fourth NCA on the projected exposure to maximum and minimum temperatures by the midcentury (i.e., 2036–2065). We selected data using the projected change by the midcentury time frame under both a low- and high-emission scenario to show the range of potential projected change to selected natural hazards. The midcentury time frame was selected because it captures potential hazard effects during the period in which most U.S. nuclear power plants are likely to remain operational.

[5]To analyze exposure to floods, we used 2023 data from the Federal Emergency Management Agency that categorize flood exposure as a high, moderate, minimal, other, or unknown flood hazard. To analyze exposure to hurricane storm surge, we used NOAA data on storm surge exposure from Category 1 hurricanes (the lowest possible category) and Category 4 or 5 hurricanes (the highest possible categories) to show a range of potential climate change effects. To analyze exposure to wildfires, we used 2023 data from the U.S. Forest Service on wildfire hazard potential.

that have spent nuclear fuel stored onsite in spent fuel pools or in dry cask storage.[6] We analyzed these data using mapping software to identify nuclear power plants located in areas that may be affected by selected natural hazards. We determined that the data were sufficiently reliable for the purposes of our reporting objectives.

To examine NRC's actions to address risks to nuclear power plants from climate change, we reviewed relevant laws and regulations; agency guidance and documents, including NRC's 2022–2026 Strategic Plan; NRC office instructions; and the NRC inspection manual on adverse weather protection.[7] We also reviewed GAO's *Standards for Internal Control in the Federal Government*.[8]

We conducted this performance audit from November 2022 to April 2024 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[6]When a company decides to shut down a nuclear power plant permanently, the facility must be decommissioned by safely removing it from service and reducing residual radioactivity to a level that permits release of the property and termination of the operating license. NRC regulates the decommissioning a nuclear power plant and any spent nuclear fuel that will remain on site. See 10 C.F.R. pt. 20, subpt. E; 10 C.F.R. §§ 50.75, 50.82, 51.53, 51.95. For the purposes of this report, we use the term "shutdown" to refer to plants at various stages of decommissioning, including those in the process of decommissioning and those already decommissioned, with spent nuclear fuel stored onsite. Spent nuclear fuel is the fuel that has been removed from commercial nuclear power reactors after it has been used to produce electricity. Spent nuclear fuel is initially stored immersed in pools of water designed to cool and isolate it from the environment. Water circulates in the pools to remove the heat generated from the radioactive decay. Industry practice has been to store the spent nuclear fuel in these pools for at least 5 years or until the fuel has cooled enough to be transferred to dry cask storage. Dry cask storage consists of a steel canister that holds the fuel assemblies, protected by an outer cask made of steel and concrete designed to cool the fuel and provide shielding from its radiation. We also obtained data on the location of the two Strategic Alliance for FLEX Emergency Response (SAFER) centers that maintain emergency equipment that can be provided to plants as a backup to the plants' onsite primary backup equipment.

[7]NRC, *Strategic Plan Fiscal Years 2022-2026,* NUREG-1614, Vol. 8 (Washington, D.C.: April 2022). See also, NRC, *Inspection Manual: Adverse Weather Protection,* Inspection Procedure 71111, Attachment 01 (Washington, D.C.: Jan. 1, 2018).

[8]GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: Sept. 10, 2014).

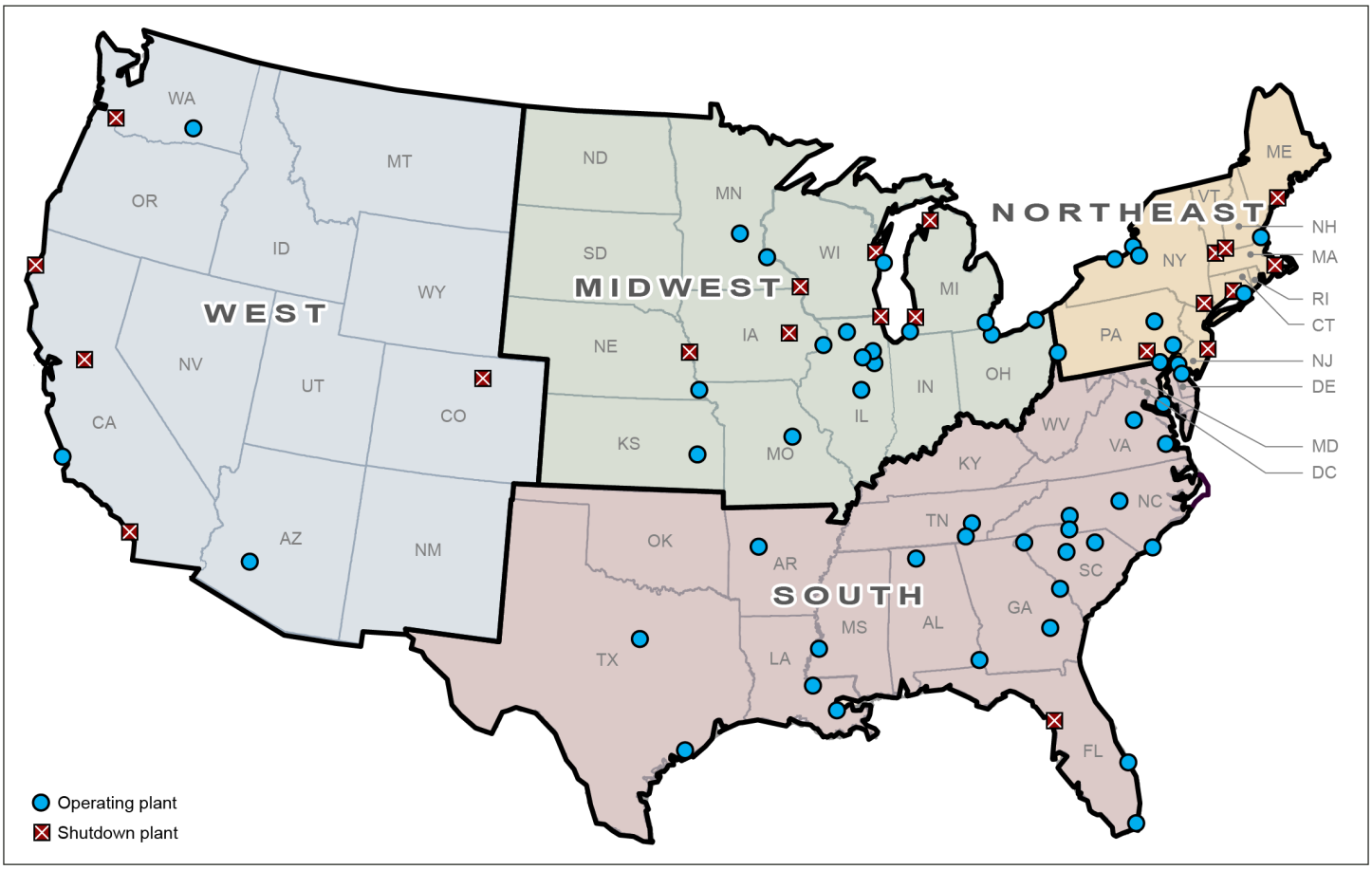
Background

The Nuclear Power Industry and U.S. Plant Operations

Private companies own nearly all nuclear power plants in the United States. As of August 2023, the United States had 93 operating commercial nuclear reactors with an average age of about 42 years old, according to the U.S. Energy Information Administration. These reactors are located at 54 nuclear power plants in 28 states.[9] In addition, as of July 2023, there were 21 shutdown plants that have spent nuclear fuel stored onsite in spent fuel pools or in dry casks. See figure 1 for the locations and regions of operating and shutdown nuclear power plants by U.S. Census region.

[9]According to the U.S. Energy Information Administration, nuclear reactors are machines that contain and control nuclear chain reactions while releasing heat at a controlled rate. A nuclear power plant uses the heat that a nuclear reactor produces to turn water into steam, which then drives turbine generators that generate electricity.

Figure 1: Map of Operating and Shutdown Nuclear Power Plants by U.S. Census Region



Sources: GAO analysis of U.S. Census Bureau and Nuclear Regulatory Commission data; U.S. Census Bureau (map). | GAO-24-106326

Note: This map includes 75 U.S. nuclear power plants—54 operating plants and 21 shutdown plants with spent nuclear fuel onsite.

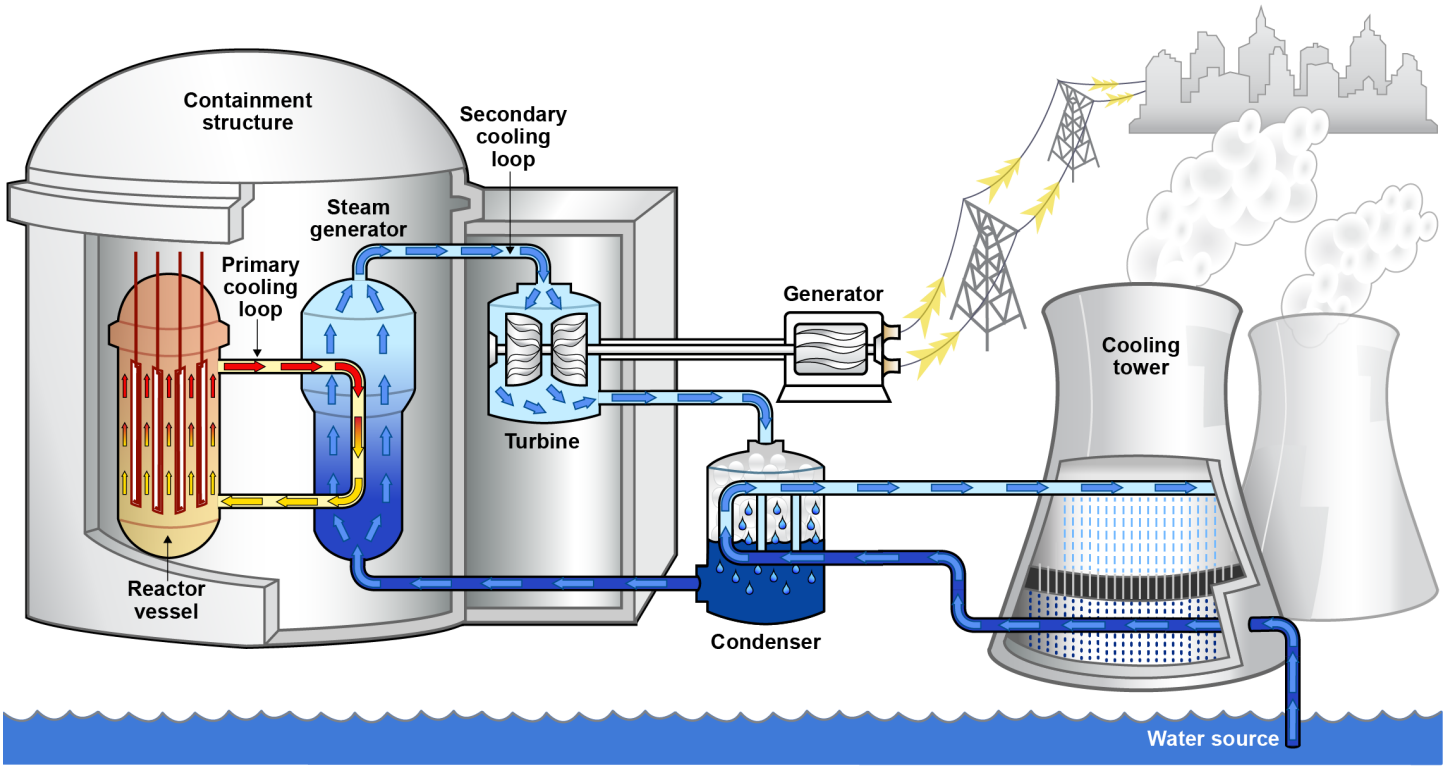
Nuclear reactors rely on technologies to initiate and control chain reactions that produce heat through a physical process called fission—whereby atoms are split to release energy. All commercial nuclear power reactors in the United States use uranium as fuel and are light water reactors, which means they use water as both a coolant and moderator to

serve critical safety and operations functions.[10] Nuclear power plants use water during normal operations to absorb the heat that is left over after making electricity and to cool the equipment and buildings used in generating that electricity. In the event of an accident, nuclear power plants also need water to remove the heat produced by the reactor core, even when it is temporarily shut down. Water is also used to cool spent fuel once it is removed from the reactor core. Because light water reactors rely on water for key safety and operational functions, nuclear power plants are typically located next to lakes, rivers, or oceans.

There are two types of light water reactors in the United States—pressurized water reactors and boiling water reactors. Pressurized water reactors, the predominant type of light water reactor in the United States, use steam generators to transfer the heat created by fission from the primary coolant loop to the secondary coolant loop, creating steam in the secondary loop that spins a turbine and generates electricity. Boiling water reactors, which constitute a third of the operating reactors in the United States, do not use steam generators or have secondary loops. Instead, the steam is generated directly inside the reactor vessel. See figure 2 for an overview of a nuclear power plant's components for a pressurized water reactor.

[10]The commercial nuclear power reactors currently operational in the United States are known as "light water reactors," meaning reactors that use ordinary water to cool and moderate the reactor, as opposed to heavy water, which contains deuterium, an isotope of hydrogen.

Figure 2: Nuclear Power Plant Components and Operations for a Pressurized Water Reactor



Sources: GAO illustration and analysis of Department of Energy and Nuclear Regulatory Commission documentation. | GAO-24-106326

Note: This illustration depicts a pressurized water reactor, the predominant reactor type in the United States. Boiling water reactors, which constitute a third of the operating reactors in the United States, do not use steam generators or have secondary loops. Boiling water reactors boil water directly inside the reactor vessel to produce steam.

To operate the cooling pumps and other systems that manage the water that reactors rely on for key safety and operational functions, nuclear plants need a reliable source of power. Nuclear power plants typically rely on the electricity grid to which the plant is connected for offsite power.[11]

[11]As we reported in 2021, climate change is expected to affect every aspect of the electricity grid—from generation, transmission, and distribution, to demand for electricity. We found that power outages can have significant cascading effects on critical sectors and electric service disruptions can significantly affect the reliability of other parts of the energy sector. These losses are of special concern because outages caused by climate effects can be widespread and affect large geographic areas all at once, according to the Department of Energy. GAO, *Electricity Grid Resilience: Climate Change Is Expected to Have Far-Reaching Effects and DOE and FERC Should Take Actions,* GAO-21-346 (Washington, D.C.: March 5, 2021).

However, if a plant loses access to offsite power, it must rely on backup power sources, such as diesel generators, to power cooling pumps. The loss of power and ability to pump cooling water can have a significant adverse impact on a plant's ability to safely shut down and maintain safe shutdown conditions. This could result in damage to a reactor's core and potentially release radiological material into the environment.

NRC's Role

NRC is an independent federal agency, headed by five commissioners, responsible for permitting the construction and licensing of commercial nuclear power reactors and regulating and overseeing their security and safe operation.[12] NRC can issue a license to operate a nuclear power reactor for up to 40 years and can renew a license for up to 20 additional years. A renewed license may be subsequently renewed for up to another 20 years, allowing a reactor to operate for up to a total of 80 years. As of December 2023, NRC had issued subsequent license renewals for six reactors at three nuclear power plants in the United States.[13] Spent nuclear fuel may remain onsite long after a plant shuts down.[14]

As part of NRC's process for issuing construction permits and licenses for nuclear power plants, agency staff conduct safety and environmental reviews. As part of the safety review, NRC reviews a plant's design to ensure it meets the technical specifications required for the safe operation of the plant. Specifically, NRC's reactor design criteria require that important safety systems, structures, and components are designed to withstand the effects of natural hazards, including climate-related hazards

[12]NRC's mission is to regulate the civilian use of radioactive materials, to provide reasonable assurance of adequate protection of public health and safety, to promote the common defense and security, and to protect the environment. As such, any new requirements that the agency imposes on commercial nuclear plants must meet this standard, according to NRC officials.

[13]NRC issued subsequent license renewals to Turkey Point Units 3 and 4 in December 2019; Peach Bottom Units 2 and 3 in March 2020; and Surry Units 1 and 2 in May 2021.

[14]The United States does not have a consolidated storage facility or repository where plants can send their spent fuel during operations or after a plant shuts down. GAO, *Commercial Spent Nuclear Fuel: Congressional Action Needed to Break Impasse and Develop a Permanent Disposal Solution,* GAO-21-603 (Washington, D.C.: Sept. 23, 2021).

such as hurricanes and floods, without losing the ability to perform their safety functions.[15]

License applicants are responsible for ensuring their plants are protected against natural hazards by assessing the hazards that may affect their plants and designing the plants to withstand those hazards. NRC is responsible for reviewing plant and reactor designs and comparing the design limits for natural hazards with those found in applicants' hazard assessments, which consider the characteristics of the plant's geographic location. Once a nuclear power plant is licensed and operational, NRC conducts regular inspections of the plant's systems and ensures that the licensee is operating in accordance with its license. If a plant experiences external conditions that exceed the limiting conditions for operation, the licensee is required to either shut the reactor down, take remedial actions as permitted in its license, or request a license amendment or enforcement discretion from NRC to continue operations.[16]

NRC also regulates the decommissioning of nuclear power plants, which means safely removing nuclear power plants from service by reducing residual radioactivity to a level that permits the release of the property and termination of the license.[17]

NRC's Regulatory Approach

NRC uses conservatism, safety margins, and defense-in-depth to implement regulatory requirements for the design, construction, maintenance, operation, and decommissioning of nuclear power plants to prevent and mitigate accidents that could release radiation or hazardous

[15]10 C.F.R. Part 50, Appendix A, General Design for Nuclear Power Plants, Criterion 2—*Design Bases for Protection Against Natural Phenomena*. According to an NRC document, all currently operating reactors were licensed to meet the intent of the General Design Criteria, which include General Design Criterion 2. See also 10 C.F.R. §§ 50.34, 52.79 (detailing safety analysis and design requirements for a license application).

[16]Limiting conditions for operation are the lowest functional capability or performance levels of equipment required for safe operation of the plant. 10 C.F.R. § 50.36(c)(2)(i). If the limiting conditions are exceeded by an extreme weather event, licensees can request the following from NRC: a temporary enforcement discretion for a brief period to allow them to continue operating despite the exceedance; a temporary license amendment to revise the limiting conditions for a specified period (e.g., 1–3 months); or a permanent license amendment to change the technical specifications.

[17]The NRC ensures that safety requirements are being met throughout the decommissioning process by reviewing decommissioning or license termination plans, conducting inspections, monitoring to ensure that radioactive contamination is reduced or stabilized, and issuing permits for spent nuclear fuel that will remain on site after license termination. See 10 C.F.R. pt. 20, subpt. E; 10 C.F.R. §§ 50.75, 50.82, 51.53, 51.95.

materials. According to agency documents and NRC officials we interviewed, the approach can be described as follows:

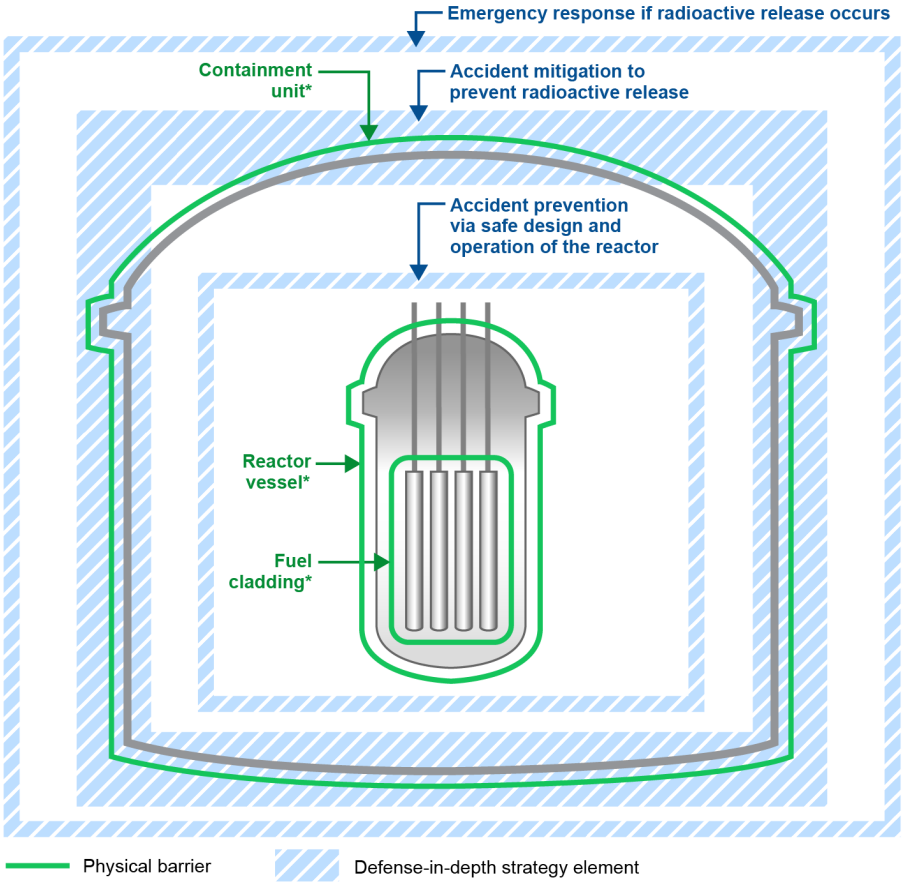
- Conservatism, for example, includes the consideration of the most severe natural phenomena that have been historically reported for a nuclear power plant site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.[18]
- Safety margins are the extra capacity factored into the design of a structure, system, or component so that it can cope with conditions beyond what is expected as a way to compensate for uncertainty.[19]
- Defense-in-depth includes multiple independent and redundant layers of defense to compensate for potential human and mechanical failures so that no single layer, no matter how robust, is exclusively relied upon. Defense-in-depth includes the use of access controls, physical barriers, redundant and diverse key safety functions, and emergency response measures (see fig. 3).[20]

[18]10 C.F.R. Part 50, Appendix A, General Design Criterion 2, *Design Bases for Protection Against Natural Phenomena*. See also, NRC, *Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decision-Making*, NUREG-1855 (Washington, D.C.: March 2017).

[19]NRC, *Glossary of Risk-Related Terms in Support of Risk-Informed Decision-Making,* NUREG-2122 (Washington, D.C.: Nov. 2013).

[20]For more information on defense-in-depth, see NRC, *Historical Review and Observations of Defense-in-Depth*, NUREG/KM-0009 (Washington, D.C.: April 2016).

Figure 3: Measures Consistent with the Nuclear Regulatory Commission's (NRC) Defense-in-Depth Approach



***Containment unit** – airtight enclosure around the nuclear reactor to confine radiation that otherwise might be released to the atmosphere in the event of an accident

***Reactor vessel** – forms a reactor coolant pressure boundary that provides a barrier against the release of radioactivity generated within the reactor

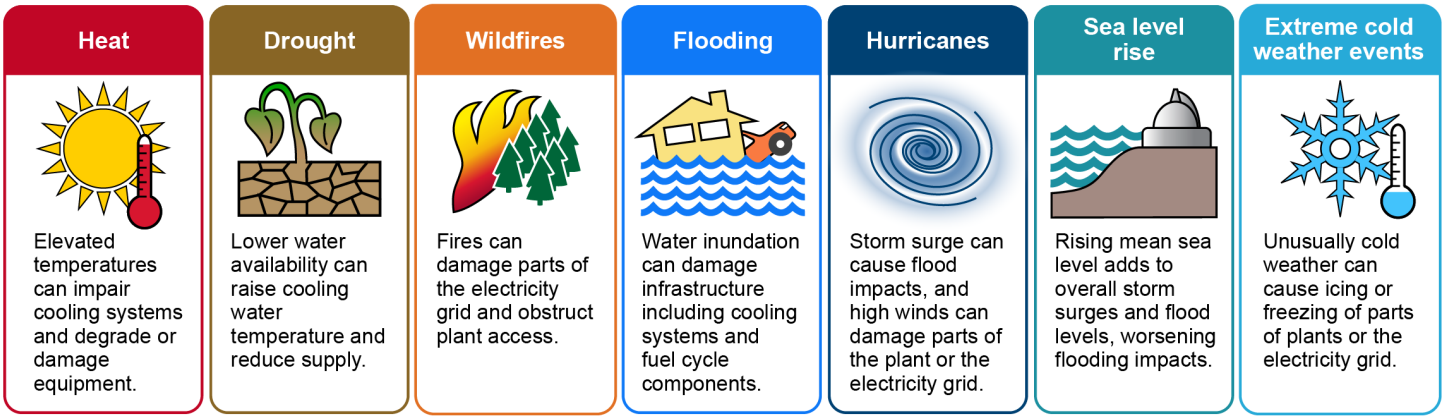
***Fuel cladding** – the thin-walled metal tube that forms the outer jacket of a nuclear fuel rod

Source: GAO and NRC documentation. | GAO-24-106326

Climate Change Is Expected to Exacerbate Natural Hazards That Pose Risks to Nuclear Power Plants

Climate change is expected to exacerbate natural hazards—including heat, drought, wildfires, flooding, hurricanes, and sea level rise. In addition, climate change may affect extreme cold weather events.[21] These natural hazards pose risks to nuclear power plants (see fig. 4).

Figure 4: Examples of Natural Hazards that May Pose Risks to Nuclear Power Plants



Sources: Nuclear Regulatory Commission documents; summary of literature; GAO (icons). | GAO-24-106326

Note: The potential risks to nuclear power plants from these hazards include a loss of offsite power, diminished cooling capacity, flood damage, and reduced operations or temporary plant shutdowns. The loss of offsite power is a complete loss of electrical power from the grid to a nuclear power plant. The loss can decrease a plant's ability to maintain safe shutdown conditions. Diminished cooling capacity refers to any impact which reduces a plant's ability to cool reactor or fuel cycle components and can result in a temporary plant shutdown.

[21]According to the NCA, climate change has driven increases in the frequency and severity of some extreme weather events. For example, climate change caused Hurricane Harvey's rainfall to be an estimated 15 and 20 percent heavier than it would have been without human-caused warming. However, researchers disagree about some climate impacts. For example, whereas emerging research suggests that the frequency of cold-weather events and heavy snowfall may be increasing because of warming Arctic temperatures, there is some disagreement in the research community regarding this projection.

Heat, Drought, and Wildfires Pose Risks to Nuclear Power Plants, and Climate Change Is Expected to Exacerbate These Hazards, Particularly in the South and Southwest

According to our analysis of NCA and U.S. Forest Service data, all 75 operating and shutdown U.S. nuclear power plants are located in areas where climate change is expected to exacerbate heat, drought, wildfires, or all three.

Heat and drought. Heat and drought pose risks to nuclear power plants because they can affect the water used for cooling. Specifically, higher-than-usual ambient air temperatures may increase the temperature of water used for cooling. Drought can also reduce the supply of cooling water. If a plant has an insufficient supply of cooling water or its cooling water approaches or exceeds the maximum allowable temperature for cooling certain reactor components, a licensee may need to temporarily limit or stop operations to ensure plant safety. Higher temperatures in the bodies of water into which nuclear power plants discharge cooling water may also require a plant to limit or temporarily stop operations to comply with laws designed to protect aquatic ecosystems and wildlife.[22] In addition, high temperatures can also degrade the performance or cause failure of pumps and other equipment, reduce the lifetime of plant components, and reduce the overall efficiency of power plants. Warmer temperatures may also increase levels of certain algae or other biological material which can block cooling water systems and lead to reduced production or a temporary plant shutdown.

[22]Some plants that discharge cooling water into rivers or lakes are subject to environmental requirements. These requirements could force a power plant to shut down or reduce power generation. For example, in 2007, 2010, and 2011, the Tennessee Valley Authority had to reduce power output from its Browns Ferry Nuclear Power Plant in Alabama because river temperatures were too high to receive discharge water from the plant without posing ecological risks.

Heat and Drought at Turkey Point Nuclear Generating Station

According to the Nuclear Regulatory Commission (NRC) and Turkey Point Nuclear Generating Station officials, in 2014, extended drought conditions and high algae content caused the cooling water for the Turkey Point Generating Station to exceed its maximum allowable temperature in its license. NRC approved the licensee's requests to not enforce the temperature requirement for the plant's cooling water for a limited period. Later, NRC granted the licensee a permanent license amendment that raised the maximum allowable cooling water temperature for the plant from 100 degrees to 104 degrees Fahrenheit.

High temperatures and drought conditions at Turkey Point Nuclear Generating Station potentially created risks to local drinking water sources when decreased water levels and increased evaporation rates led to higher salinity in the cooling canals. Higher salinity levels made the water denser, causing it to sink below the canals that contain it. This could have led to intrusion of higher salinity water into the areas of the Biscayne Aquifer, a source of drinking water for the Miami-Dade area.

To mitigate these risks, the licensee constructed a series of wells to decrease the water salinity in the cooling canals.



Well used to adjust salinity in the Turkey Point Nuclear Generating Station's cooling canals

Sources: Interviews with plant personnel at the Turkey Point Nuclear Generating Station, and review of NRC documents; GAO (photo). | GAO-24-106326

All operating and shutdown nuclear power plants are located in areas where climate change is projected to increase measures of heat, including daily and average maximum temperature, according to our analysis of NCA and NRC data. The effects of climate change on maximum temperatures are projected to be most severe in the South, where one-third of the plants are located.[23] The plants in the South are projected to experience an annual average of from 21 to 31 days with higher maximum temperatures than historical high temperatures. In addition, according to the NCA, climate change is expected to increase drought intensity in some regions, specifically in the Southwest, where two operating and four shutdown nuclear power plants are located.

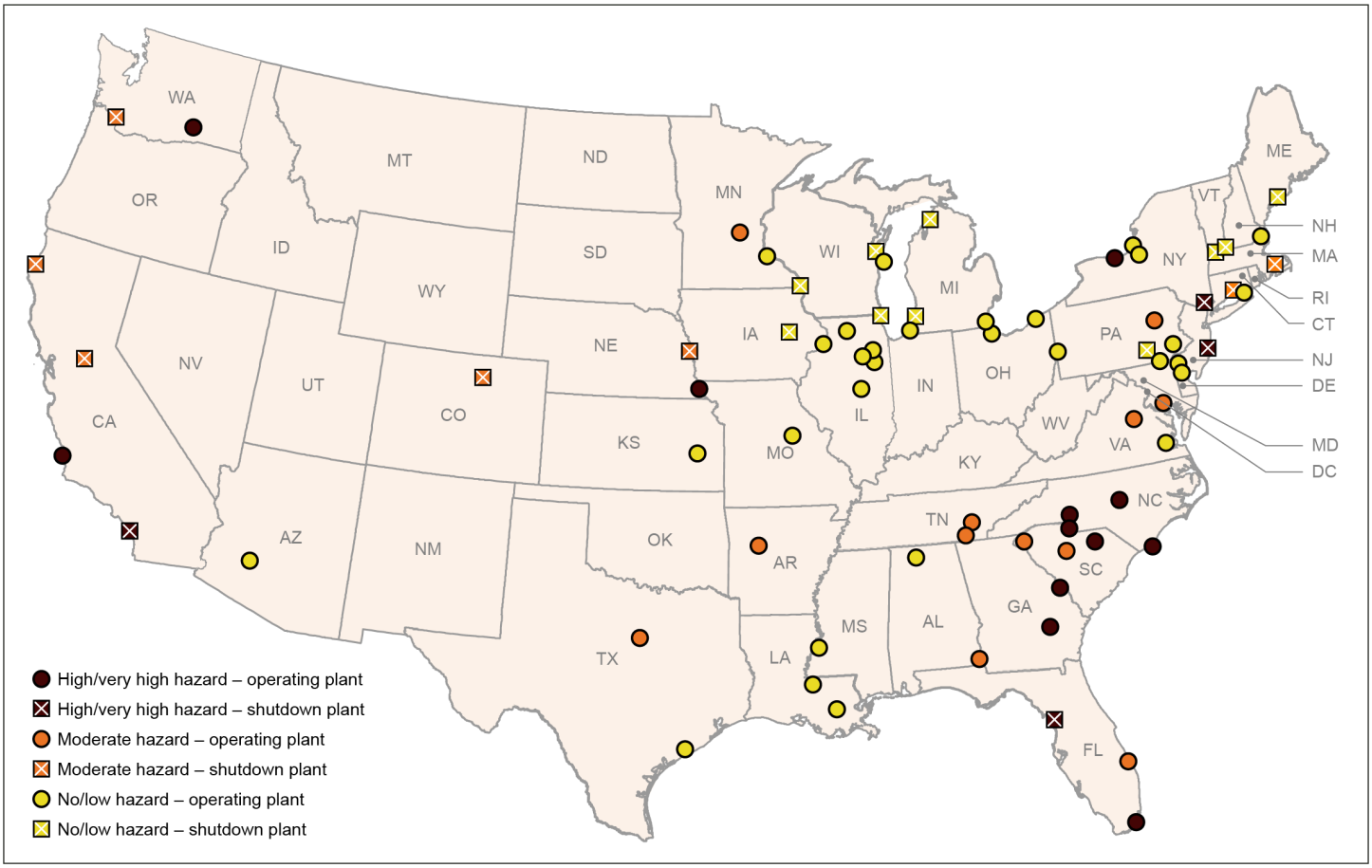
[23]Of the 25 plants in the South, 24 are operational and one is shutdown.

Wildfire. According to the NCA, increased heat and drought contribute to increases in wildfire frequency, and climate change has contributed to unprecedented wildfire events in the Southwest. The NCA projects increased heatwaves, drought risk, and more frequent and larger wildfires. Wildfires pose several risks to nuclear power plants, including increasing the potential for onsite fires that could damage plant infrastructure, damaging transmission lines that deliver electricity to plants, and causing a loss of power that could require plants to shut down. Wildfires and the smoke they produce could also hinder or prevent nuclear power plant personnel and supplies from getting to a plant.

According to our analysis of U.S. Forest Service and NRC data, about 20 percent of nuclear power plants (16 of 75) are located in areas with a high or very high potential for wildfire.[24] More specifically, more than one-third of nuclear power plants in the South (nine of 25) and West (three of eight) are located in areas with a high or very high potential for wildfire (see fig. 5).

[24]The U.S. Forest Service maps wildfire hazard potential based on landscape conditions and other observations. These maps include an index of wildfire hazard potential for the United States, based on, among other factors, annual burn probabilities and the potential intensity of large fires. The wildfire potential index is a relative ranking. The U.S. Forest Service categorizes the wildfire hazard potential index into five classes: very low, low, moderate, high, and very high. The U.S. Forest Service designates as “high” those areas with wildfire hazard potential index from the 85th to the 95th percentile, and as “very high” those areas above the 95th percentile. For this analysis, we combined the high and very high wildfire hazard potential categories; we did not identify the number of facilities in each of these categories separately. Of the 16 plants with high or very high potential for wildfire, 12 are operating and four are shutdown.

Figure 5: Nuclear Power Plants Located in Areas with Exposure to No/Low, Moderate, and High/Very High Wildfire Hazard Potential



Sources: U.S. Forest Service and Nuclear Regulatory Commission data; U.S. Census Bureau (map). | GAO-24-106326

Note: To determine if a plant is located in an area with wildfire hazard potential, we identified overlap between a 0.5-mile radius around nuclear power plant coordinates provided by the Nuclear Regulatory Commission and wildfire hazard potential data. Overlap indicates that a facility is located in an area that may be affected by the selected hazard. We used the U.S. Forest Service Wildfire Hazard Potential Map to show exposure to wildfire hazard potential. The U.S. Forest Service categorizes the wildfire hazard potential index into five classes of very low, low, moderate, high, and very high. We analyzed the moderate, high, and very high wildfire potential layers, and combined results for the high/very high layers. No/low refers to plants that are not located in an area with wildfire potential of moderate, high, or very high, based on the U.S. Forest Service Wildfire Hazard Potential Map. See appendix I for more details on our data analysis. We previously reported that the primary intended use of the wildfire hazard potential map is to identify priority areas for hazardous fuels treatments from a broad, national- to regional-scale perspective. This analysis does not account for any protective measures plants may have taken to mitigate the risk of selected natural hazards.

Appendix III provides additional details of exposure to heat and wildfire hazard potential in areas where nuclear power plants are located.

Flooding, Hurricanes, and Sea Level Rise Pose Risks to Nuclear Plants, and Climate Change Is Expected to Exacerbate These Hazards, Particularly in Coastal Regions

According to our analysis of NOAA and NRC data, about 63 percent of nuclear power plants (47 of 75) are located in areas with exposure to either Category 4 or 5 hurricane storm surge or high flood hazard, and nine are located on a coastline, where NOAA projects a range of sea level increases.[25] In addition, 20 percent of nuclear power plants (15 of 75) are located in areas with exposure to both Category 4 or Category 5 hurricane storm surge and high flood hazard. The NCA predicts that climate change will exacerbate all three hazards.

[25]To identify coastal plant locations, we used nuclear power plant coordinates from NRC and added a 0.5-mile radius around NRC's plant coordinates as a proxy for an average size nuclear power plant. Coastal plants were those with a radius that intersected with or beyond the coastline.

Flood Protection

To mitigate the impacts of flooding, licensees have implemented various measures, including the elevation of spent fuel pools and use of flood barriers.



Flood barrier protecting part of the Turkey Point Nuclear Generating Station

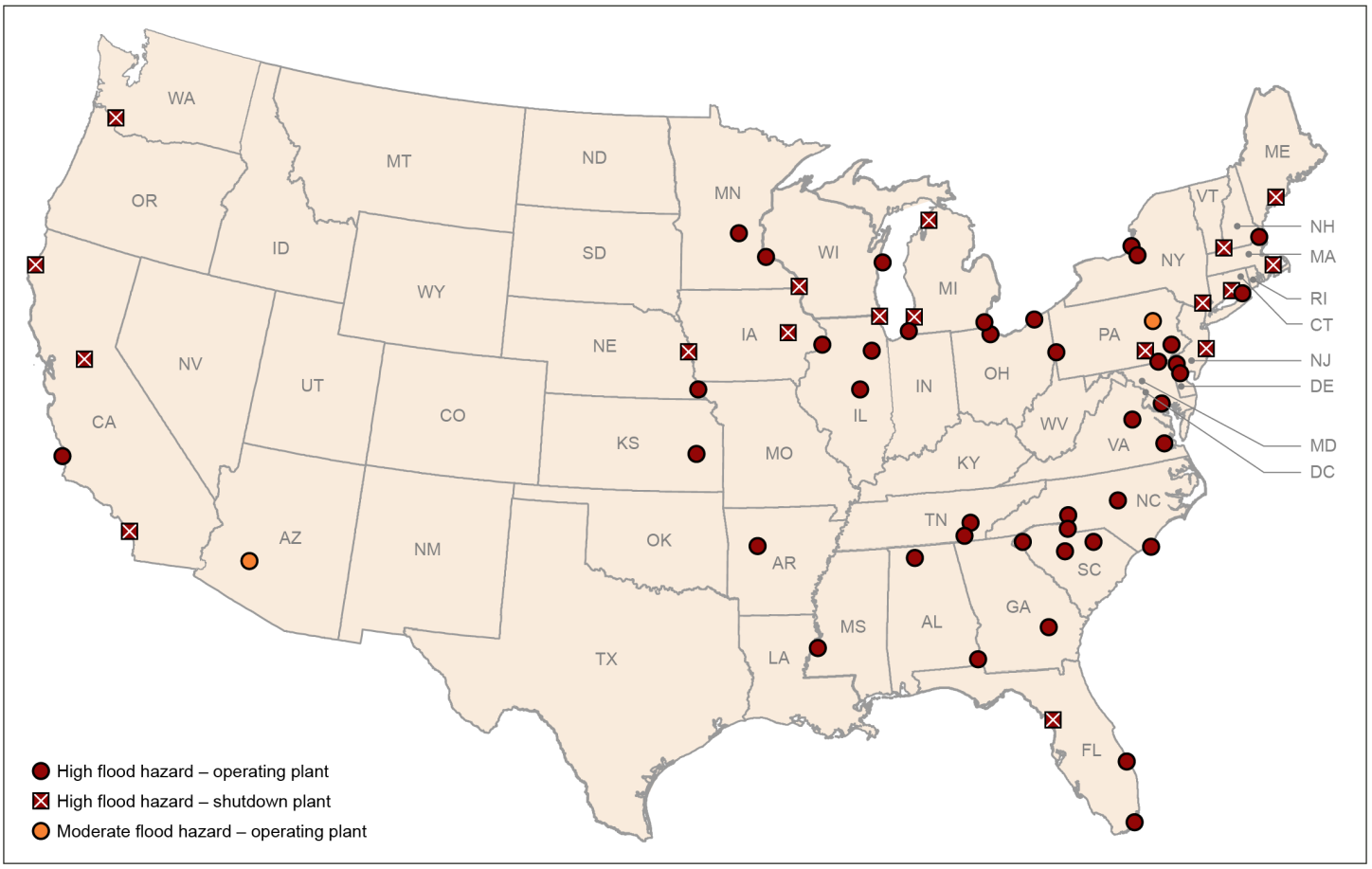
Sources: GAO site visit and interviews with plant personnel at the Turkey Point Nuclear Generating Station; GAO (photo). | GAO-24-106326

Flooding. Flooding could pose risks to nuclear power plants by, among other things, diminishing a plant's cooling capacity. Flooded roads could prevent personnel, equipment, and supplies from reaching a plant. Flooding could also cause damage to buildings, equipment, and electrical systems that could require a plant to curtail operations or shut down. In addition, flood waters could interfere with heat removal from spent fuel pools by blocking ventilation ports with water. Prolonged exposure to salt water from coastal flooding could also degrade or corrode a cask's exterior, potentially posing risks to the environment and human health.

Our analysis of Federal Emergency Management Agency data found that 60 of the 75 nuclear power plants in the United States are located in areas with high flood hazard and two are in areas with moderate flood hazard.[26] Just over one-third of the plants (21 of 60) located in areas with high flood hazard are in the South (see fig. 6). According to the NCA, heavy rainfall and flooding are expected to become more frequent and severe across the United States. The NCA predicts that climate change will continue to exacerbate hurricane storm surge, rainfall, and flood events in U.S. coastal areas.

[26]We analyzed Federal Emergency Management Agency data from 2023. For our analysis, high flood hazard corresponds to areas in 100-year floodplains (areas with a 1 percent or higher annual chance of flooding), moderate flood hazard corresponds to areas in 500-year floodplains (areas with a 0.2 percent or higher annual chance of flooding), and no/low corresponds to areas with minimal, unknown, or other flood hazards, including areas with reduced risk because of levees as well as areas with flood hazard based on future conditions, such as the future implementation of land-use plans. Of the 60 plants located in areas with high flood hazard, 42 are operating and 18 are shutdown. Both of the plants located in areas with moderate flood hazard are operating.

Figure 6: Nuclear Power Plants Located in Areas with High and Moderate Flood Hazard



Sources: Federal Emergency Management Agency and Nuclear Regulatory Commission data; U.S. Census Bureau (map). | GAO-24-106326

Note: To determine if a plant is located in an area with exposure to moderate or high flood hazard, we identified overlap between a 0.5-mile radius around nuclear power plant coordinates provided by the Nuclear Regulatory Commission and the flood hazard data. Overlap indicates that a facility is located in an area that may be affected by the selected hazard. See appendix I for more details on our data analysis. To show exposure to flooding, we use the Federal Emergency Management Agency's National Flood Hazard Layer, which estimates several levels of flood hazard, including high flood hazard (areas with a 1 percent or higher annual chance of flooding), and moderate flood hazard (areas with a 0.2 percent or higher annual chance of flooding). This analysis does not account for any protective measures plants may have taken to mitigate the risk of selected natural hazards.

Hurricanes. High winds from hurricanes can generate projectiles capable of damaging parts of nuclear power plants and electricity transmission lines that provide nuclear power plants with power. In addition, storm surge from hurricanes can cause flooding, which could diminish a plant's cooling capacity and damage buildings, equipment, and electrical

systems. About 23 percent of nuclear power plants (17 of 75) are located in areas that may be inundated by storm surge from Category 4 or Category 5 hurricanes,[27] according to our analysis of NOAA and NRC data.[28] All 17 of these plants are in the East and South, and the six plants with exposure to Category 5 hurricanes are located in the South (see fig. 7).[29] According to the NCA, climate change is expected to heighten hurricane storm surges, wind speeds, and rainfall rates.[30]

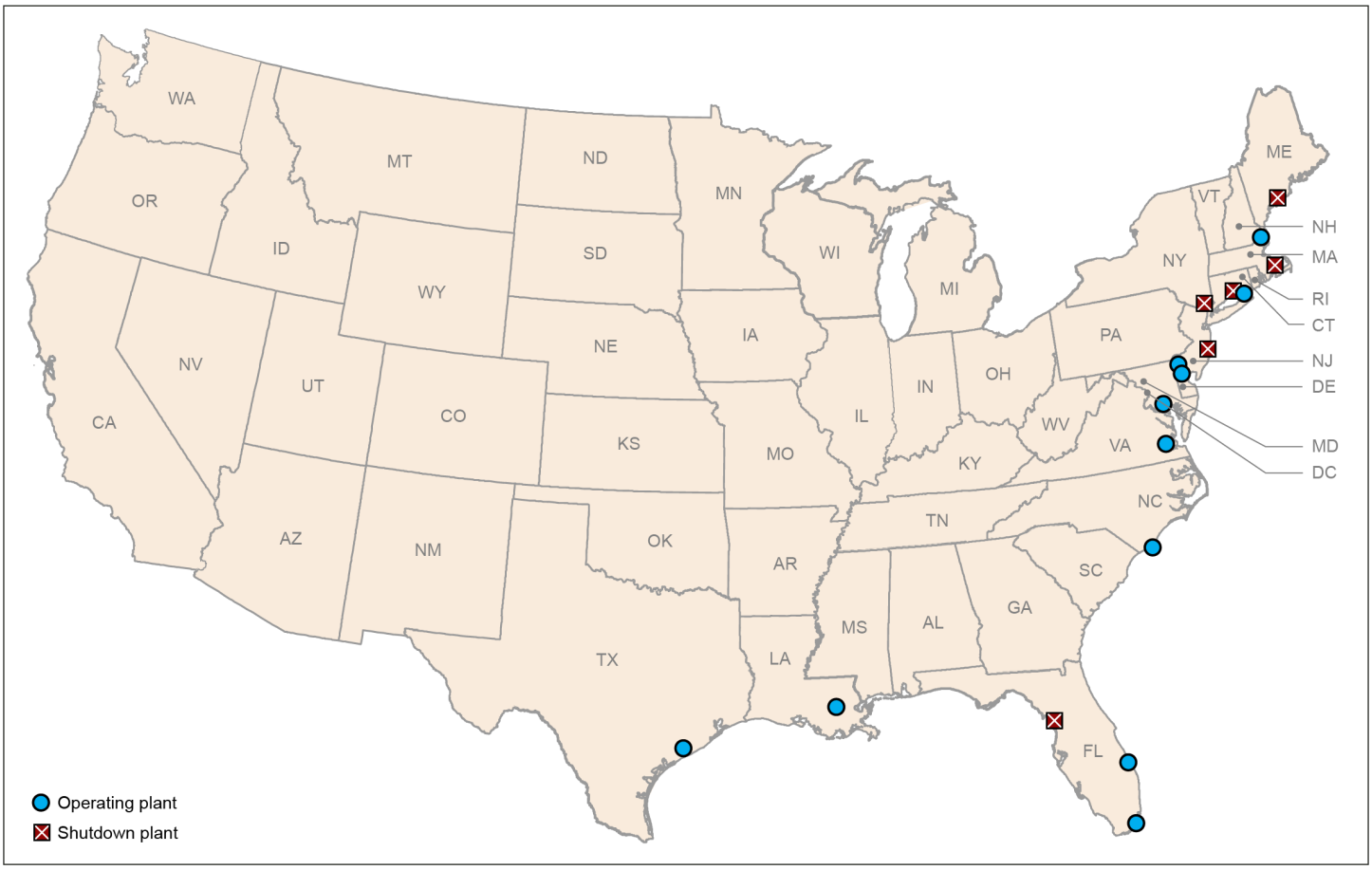
[27]Of the 17 plants located in areas that may be inundated by storm surge from Category 4 or 5 hurricanes, 11 are operating and six are shut down. For the West Coast of the United States, storm surge data were only available for Southern California.

[28]Our analysis of NOAA storm surge data is based on a model that estimates the maximum extent of storm surge at high tide. NOAA provides estimates of hurricane storm surge using a model called Sea, Lake, and Overland Surges from Hurricanes. This model includes hypothetical hurricanes under different storm conditions, such as landfall location, trajectory, and forward speed. Hurricanes reaching Category 3 and higher are considered major hurricanes because of the potential for significant loss of life and damage. In our analysis, we used the maximum extent of storm surge from Category 1 hurricanes (the lowest possible category) and Category 5 hurricanes (the highest possible category) to show a range of potential climate change effects. Category 4 hurricanes carry sustained winds of 130–156 miles per hour. Category 5 hurricanes have sustained winds exceeding 156 miles per hour.

[29]Storm surge impacts to nuclear power plants would depend on several factors, including a plant's elevation and protective measures.

[30]Climate change leads to warmer ocean surface temperatures. This, in turn, makes hurricanes more powerful because the temperature increase causes more water to evaporate from the ocean. Evaporation adds moisture to the air, and warmer air temperatures can hold more water vapor. The increased moisture in the air leads to more intense rainfall. In a hurricane, spiraling winds draw moist air toward the center, fueling the thunderstorms that surround it.

Figure 7: Nuclear Power Plants Located in Areas with Exposure to Storm Surges from Category 4 and Category 5 Hurricanes



Sources: National Oceanic and Atmospheric Administration and Nuclear Regulatory Commission data; U.S. Census Bureau (map). | GAO-24-106326

Notes: To determine if a plant exists in an area with exposure to hurricane storm surge, we identified overlap between a 0.5-mile radius around nuclear power plant coordinates provided by the Nuclear Regulatory Commission and storm surge data. Overlap indicates that a facility is located in an area that may be affected by the selected hazard. See appendix I for more details on our data analysis. To show exposure to hurricane storm surge, we use the National Oceanic and Atmospheric Administration's Sea, Lake, and Overland Surges from Hurricanes Model, which estimates storm surge heights resulting from the various categories of hurricanes. This analysis does not account for any protective measures plants may have taken to mitigate the risk of selected natural hazards.

Sea level rise. Sea level rise could affect nuclear power plants by contributing to greater storm surges and flooding. According to NOAA officials, a rise in sea level can increase corrosion from saltwater intrusion and lead to chronic long-term erosion of coastal cliffs, where some plants

are located.[31] According to a NOAA report, over the next 30 years sea levels will continue to rise as climate change warms glaciers and ice sheets, causing additional water mass to enter the ocean.[32] The rise in sea level is expected to increase coastal flooding by contributing to higher tides and storm surges that reach further inland, potentially affecting coastal nuclear power plants.

Our analysis of NOAA and NRC data indicates that about half of nuclear power plants (37 of 75) are located in a coastal region, and nine of these are located on the coastline.[33] Projected sea level rise in 2050 varies by coastal region, from 0.5 feet in the Northwest to 1.9 feet in the Western Gulf (see fig. 8). In addition, sea level rise may increase saltwater intrusion into the coastal rivers or groundwater aquifers that some nuclear power plants use for service or potable water.[34]

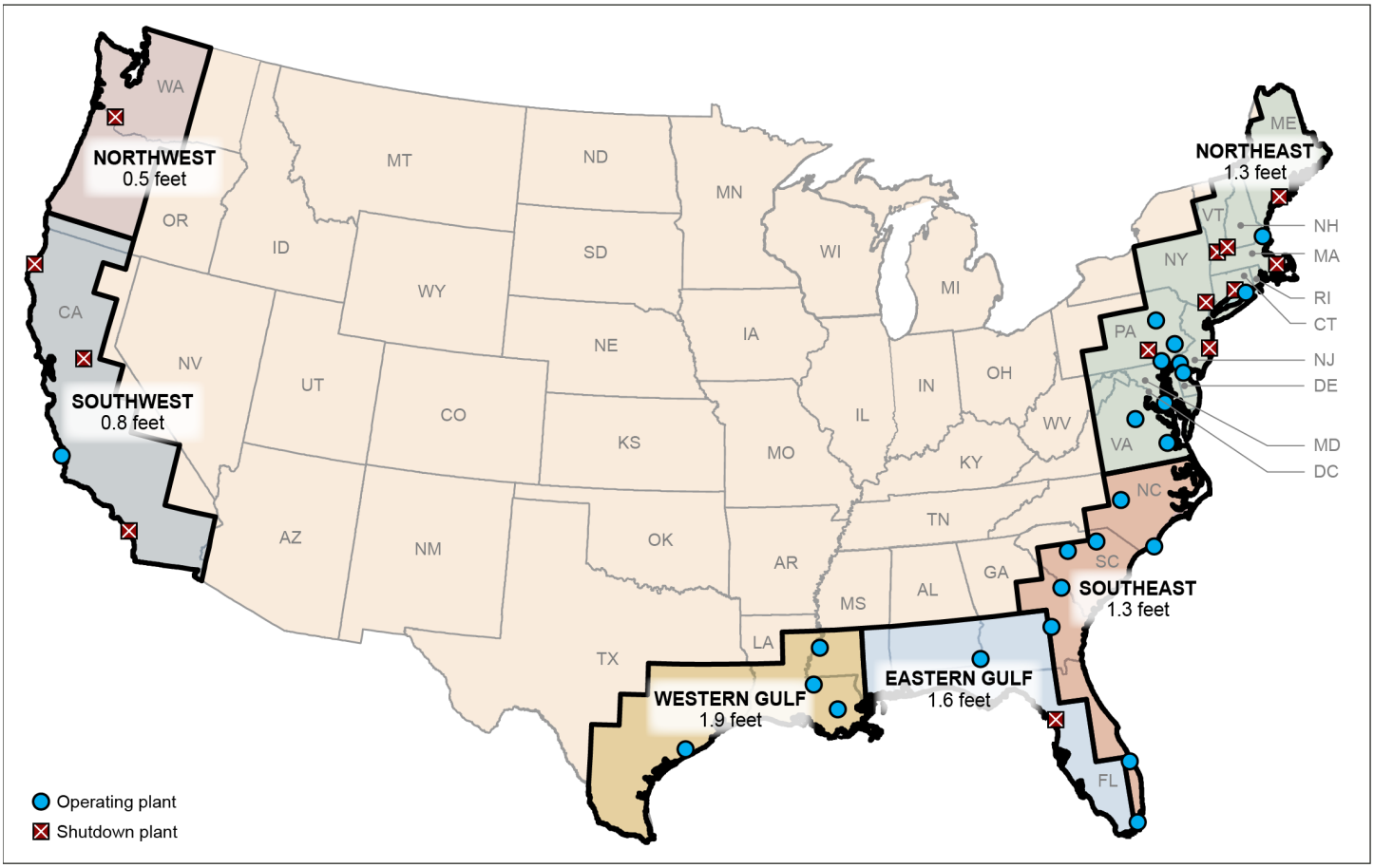
[31]NOAA officials said that Turkey Point Nuclear Generating Station is an example of a plant where, if unaddressed, sea level rise could lead to saltwater intrusion into the plant's cooling canals. Officials also said that Southern California is an example of an area where cliffs consist of unconsolidated rock, a type of loose rock composition that is particularly vulnerable to long-term erosion from sea level rise.

[32]W. V. Sweet, B. D. Hamlington, R. E. Kopp, C. P. Weaver, P. L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A. S. Genz, J. P. Krasting, E. Larour, D. Marcy, J. J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K. D. White, and C. Zuzak, *2022: Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*, NOAA Technical Report NOS 01 (Silver Spring, MD: Feb. 2022).

[33]Of the 37 nuclear power plants located in a coastal region, 24 are operating and 13 are shut down. Of the nine nuclear power plants located on the coastline, seven are operating and two are shut down. To determine which nuclear power plants are located on the coastline, we identified plants whose coordinates intersect with a coastline. NRC provided coordinate data, and we used a 0.5-mile radius as a proxy for plant size in our analysis.

[34]According to one U.S. Environmental Protection Agency source, sea level rise may increase river levels and the risk of saltwater intrusion into rivers and coastal groundwater aquifers, especially during dry periods. According to NRC's Generic Environmental Impact Statement for License Renewal of Nuclear Plants, saltwater intrusion into groundwater aquifers can degrade the quality of groundwater used for potable and service water at nuclear power plants. See NUREG-1437, Vol. 1, Revision 1.

Figure 8: Nuclear Power Plants in the National Oceanic and Atmospheric Administration (NOAA) Coastal Regions and Projected Sea Level Rise in 2050



Sources: National Oceanic and Atmospheric Administration and Nuclear Regulatory Commission data; U.S. Census Bureau (map). | GAO-24-106326

Note: The regional sea level rise values for 2050 are regional observation-based extrapolations from an interagency report covering sea level rise scenarios. These extrapolations use observed changes in sea level rise and other factors to estimate the trajectory of sea level rise in the near term. Sea-level rise primarily affects coastlines but may also affect the salinity and level of coastal rivers and groundwater aquifers. This map includes all nuclear power plants that are located in NOAA coastal regions. The analysis does not account for site-specific plant elevation or protective measures plants may have taken to mitigate the risk of selected natural hazards.

Appendix III provides additional details of our analysis of exposure to flooding, hurricane storm surges, and sea level rise in areas where nuclear power plants are located.

Extreme Cold Weather Events Pose Risks to Nuclear Power Plants, and Climate Change May Affect These Events in Certain Regions

Cold temperatures can diminish cooling capacity and lead to the loss of offsite power, posing risks to nuclear power plants. Specifically, extreme cold conditions may create ice that could block a plant's cooling water intake system, potentially reducing the supply of cooling water to safety-related systems and components. In addition, frozen precipitation can cause icing of power lines and lead to full or partial loss of off-site power, potentially forcing a plant to rely on backup diesel that may be vulnerable to extremely cold air temperatures.

Extreme Cold at South Texas Project Nuclear Power Plant

On February 15, 2021, the South Texas Project experienced an automatic reactor shutdown when a 5-foot section of uninsulated water line froze, causing the failure of a feed water pump. The Nuclear Regulatory Commission (NRC) found that the facility shut down safely, but the licensee failed to implement a required Freezing Weather Plan to insulate the line. According to one NRC official, a cold weather event nearly rendered another plant's diesel generators inoperable when the air intake temperature dipped to -50 degrees Fahrenheit.



South Texas Project, reactor units 1 and 2

Sources: GAO analysis of NRC documents; U.S. NRC Blog (photo). | GAO-24-106326

Climate change may affect extreme cold weather events.[35] While the NCA found that climate change is expected to cause an overall increase in average temperatures, a 2021 study funded in part by NOAA found that Arctic warming caused by climate change may cause extremely cold air from the Arctic to stretch into the United States.[36] The study links climate change to extreme cold events, such as the record cold temperatures in Texas in 2021. Our analysis of NCA climate projections data and NRC location data found that the average operating nuclear power plant will

[35]As noted previously, according to the NCA, there is disagreement among researchers about some climate impacts. For example, whereas emerging research suggests that the frequency of cold weather events and heavy snowfall may be increasing because of warming Arctic temperatures, there is some disagreement in the research community regarding this projection.

[36]J. Cohen, L. Agel, M. Barlow, C. I. Garfinkel, and I. White, *Linking Arctic Variability and Change with Extreme Winter Weather in the United States*, Science, Volume 373, Issue 6559 (Washington, D.C.: 2021) 1116-1121.

experience from 17 to 22 fewer frost days annually.[37] However, certain regions may also see an increase in extreme cold weather events.

Cold Protection

Licensees have insulated water lines and added cold-weather insulation for turbines to protect against freezing water in pipes and damage to other plant equipment.



Example of insulation at an industrial facility

Sources: Interviews with plant personnel at the Turkey Point Nuclear Generating Station; rootstocks/stock.adobe.com (photo). | GAO-24-106326

Following 2021's Winter Storm Uri, the Federal Energy Regulatory Commission approved a new standard, effective October 2024, that will require certain owners of certain electricity generating units, including nuclear power reactors, to implement freeze protection measures to operate for at least 12 continuous hours at the unit's recorded extreme cold weather temperature.[38]

Appendix III provides additional details of our analysis of exposure to cold weather events in areas where nuclear power plants are located.

[37]Climate projections are used to show a range of future outcomes, and are limited by uncertainties in emissions, natural variability, and scientific models. To show a range of possible outcomes, we used climate projections for a low-emission scenario (17 days) and a high-emission scenario (21 days). Climate projections rely on a variety of assumptions about the future. These limitations are further discussed in appendix II.

[38]In 2023, the Federal Energy Regulatory Commission (FERC) approved Emergency Operation Standard 012-01, also known as the Extreme Cold Weather Preparedness and Operations standard. Effective October 1, 2024, the standard addresses the effects of operating in extreme cold weather by ensuring owners and operators of generating units like nuclear power reactors develop and implement plan(s) to mitigate the reliability impacts of extreme cold. FERC defines extreme cold weather as the temperature equal to the lowest 0.2 percentile of the hourly temperatures measured in December, January, and February. The standard exempts certain generating units, including nuclear power reactors, which have an extreme cold weather temperature exceeding 32 degrees Fahrenheit or operate only in a backup or non-winter capacity.

NRC's Actions to Address Risks to Nuclear Power Plants from Natural Hazards Do Not Fully Consider the Potential Effects of Climate Change

NRC's processes for licensing and overseeing nuclear power plants include actions to address risks from natural hazards. However, NRC's actions do not fully consider the potential effects of climate change.

NRC's Oversight of Nuclear Power Plants Includes Actions to Address Risks from Natural Hazards

NRC's existing processes are designed to address risks to the safety of nuclear power plants, including risks from natural hazards. For example:

- **Defense-in-depth.** A nuclear power plant must be designed and built to withstand phenomena or events such as earthquakes, tornadoes, hurricanes, and floods without the loss of the structures, systems, or components necessary to ensure public health and safety. According to NRC, NRC's defense-in-depth approach focuses on protecting plants against risks such as those related to events that exceed a plant's design basis, including flooding from intense precipitation or hurricanes.[39] As such, NRC's defense-in-depth approach includes verifying that plants have multiple physical barriers and equipment backups to ensure plant safety if plant structures and equipment are damaged due to such severe weather events or if a power outage threatens a plant's ability to continue cooling the reactor.

[39]The design basis for a plant includes the specific functions to be performed by the structures, systems, or components that could be compromised by an adverse weather event that exceeds what the plant was designed to withstand, such as the maximum flood elevation or maximum temperature limit allowed for a plant to continue operating. 10 C.F.R. Part 50, Appendix A, General Design for Nuclear Power Plants, Criterion 2—Design Bases for Protection Against Natural Phenomena.

Defense-in-Depth at Duane Arnold Energy Center

In 2020, the Iowa "Derecho Windstorm" brought heavy rains and winds up to 130 miles per hour to the Duane Arnold Energy Center. The storm resulted in the loss of offsite power, which caused an emergency shutdown of the reactor. Winds from the storm also damaged two cooling towers and buildings housing the reactor, turbine, and equipment.

However, according to a Nuclear Regulatory Commission (NRC) document, the plant's safety margins and use of a defense-in-depth approach mitigated the effects of storm damage. Specifically, the plant had multiple backup generators and pumps as well as physical barriers to protect the plant.

During the storm, the plant lost offsite power, and the cooling pump for the spent fuel pool turned off. Before the outage, two emergency diesel generators started automatically due to grid-related storm impacts. Staff immediately started a second cooling pump. This action prevented the water in the spent fuel pool from boiling and potentially exposing the fuel rods. According to NRC, the winds also damaged the reactor's containment unit, but it remained functional and would have prevented a release of radiological material in the event of damage to the reactor core.



Duane Arnold Energy Center

Sources: Nuclear Regulatory Commission; AsNuke (photo), https://creativecommons.org/licenses/by-sa/4.0/deed.en. No changes were made to this photo. | GAO-24-106326

- **Licensing**. During the licensing process, NRC assesses a plant's risks from natural hazards as part of its safety evaluation. In doing so, NRC reviews reactor and plant designs and compares the design limits for natural hazards with the site's expected exposure to natural hazards on the basis of the licensee's hazard assessments. According to NRC officials, NRC also conducts a confirmatory analysis of the licensee's hazard assessments, which if deemed insufficient, must be revised by the licensee.
- **Inspections.** NRC resident inspectors use inspection manual procedures to inspect licensees' preparations for addressing adverse weather events and extreme temperatures.[40] As part of their inspections, NRC resident inspectors verify that selected systems and components will function when affected by adverse weather. NRC officials explained that an inspection includes observing licensees repair and run pieces of equipment, conducting emergency drills, and verifying that licensees are taking appropriate actions in response to severe weather conditions. Inspectors from NRC regional offices may also conduct plant inspections after adverse weather events, such as floods or hurricanes.
- **Probabilistic risk assessments.** NRC uses probabilistic risk assessments in its licensing and inspection processes to analyze various risks, including safety risks posed by natural hazards.[41] These assessments are a systematic method for assessing what can go wrong, its likelihood, and its potential consequences to provide insights into the strengths and weaknesses of the design and operation of a nuclear power reactor. Probabilistic risk assessments are used to estimate the risk of reactor core damage, radioactive material release, and related consequences to the public and environment based on the as-built, as-operated plant.
- **Operating experience program.** NRC's operating experience program collects and evaluates information from various regulatory oversight activities and inspection findings and shares information about plants' operating experiences with NRC staff. In addition, according to NRC officials, NRC has a research office that analyzes long-term trends, such as the loss of offsite power due to severe

[40]Inspections by resident inspectors at the plant level are called baseline inspections, and different types of baseline inspections occur either daily, quarterly or annually.

[41]Applicants for certain licenses for new reactors must submit a description of the plant-specific probabilistic risk assessment and its results to NRC as a part of their application.

NRC Inspectors Address Heat Risks at the Palo Verde Nuclear Generating Station

To prepare for extreme summer heat, Nuclear Regulatory Commission (NRC) resident inspectors at the Palo Verde Nuclear Generating Station in Arizona inspect systems likely to be affected by high temperatures, such as diesel generators and spray ponds, both of which are used to cool the reactor. The spray ponds contain a 26-day supply of water to ensure that plants have adequate cooling capacity to safely shut down.

Because high temperatures can cause water held in the spray ponds to evaporate, the plant relies on its reservoirs and deep wells as backup sources of water.



Palo Verde Nuclear Generating Station spray pond

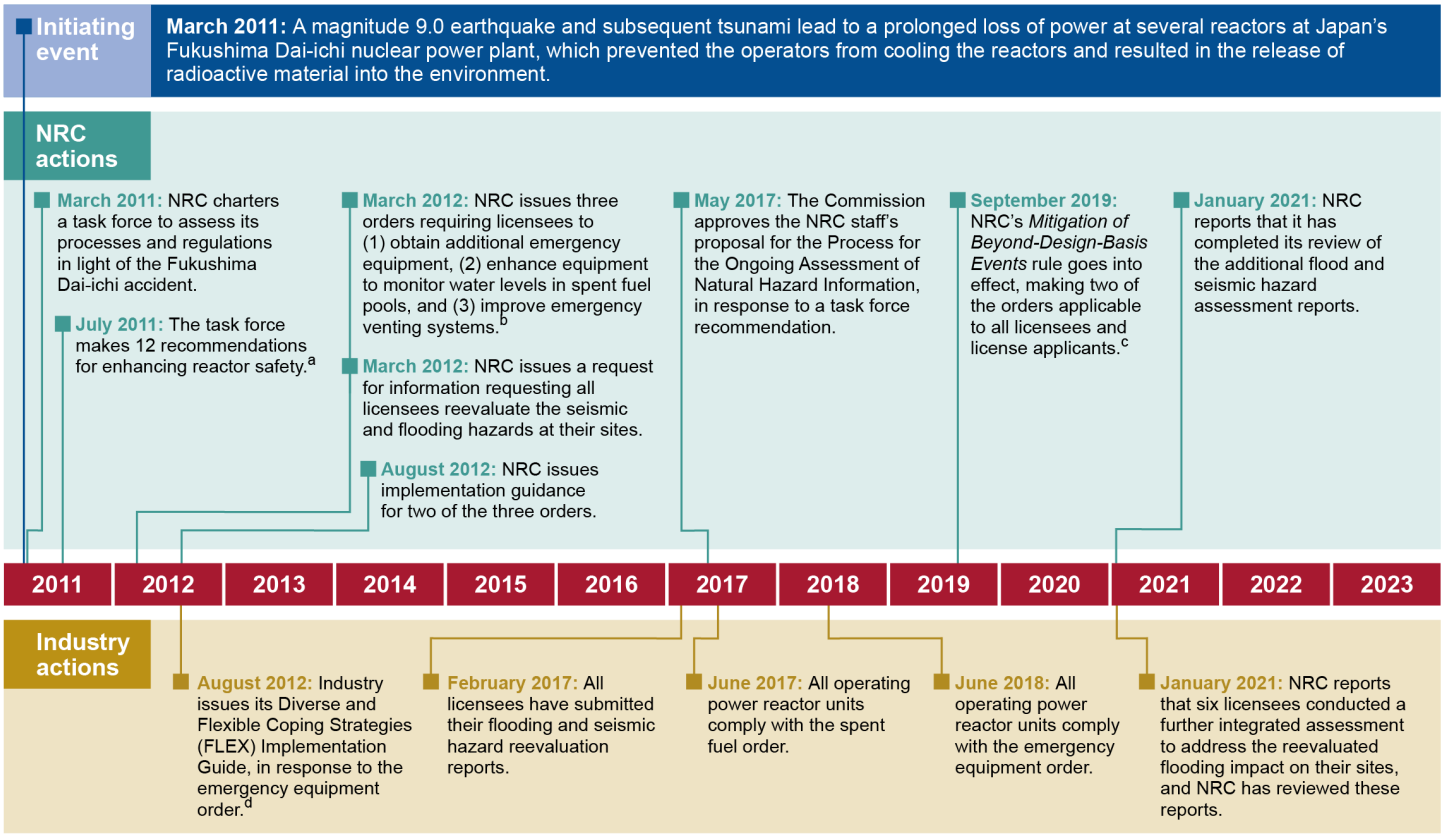
Sources: NRC; GAO (photo). | GAO-24-106326

weather, to identify lessons learned that could be applied to the oversight of other plants.

Following the 2011 accident at Japan's Fukushima Dai-ichi nuclear power plant, NRC and industry took several actions to further address risks to nuclear power plants from natural hazards.[42] Some of these actions were taken in response to recommendations from a task force NRC established to assess its regulatory approach (see fig. 9).

[42]On March 11, 2011, a 9.0-magnitude earthquake and subsequent tsunami devastated northeast Japan and led to the most extensive release of radioactive material at a nuclear power plant since the 1986 Chernobyl disaster. The Fukushima Dai-ichi nuclear power plant suffered extensive damage when a 45-foot-high tsunami wave exceeded the plant's seawall and flooded the site, causing a prolonged loss of electrical power at several of its reactors. As a result of the loss of power, plant operators were unable to keep three of the reactors cool, which led to fuel melting, hydrogen explosions, and the release of radioactive material into the environment. The disaster displaced tens of thousands of residents and contaminated the surrounding area. Nuclear-power-generating countries worldwide have since taken actions to prepare for an event like this, which far exceeded the Fukushima Dai-ichi plant's design basis.

Figure 9: Timeline of Selected Nuclear Regulatory Commission (NRC) and Industry Actions after the Fukushima Dai-ichi Accident in 2011



Source: GAO review of NRC and industry documents. | GAO-24-106326

[a]NRC prioritized the recommendations in three tiers: (1) recommendations NRC should implement without unnecessary delay; (2) recommendations that could not be initiated in the near term due, in part, to resource or critical skill set limitations; and (3) recommendations that required further study by NRC to determine if regulatory action was necessary, among other factors.

[b]NRC, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events, Order EA-12-049 (Washington, D.C.: Mar. 12, 2012); Issuance of Order to Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation, Order EA-12-051 (Washington, D.C.: Mar. 12, 2012); and Order Modifying Licenses with Regard to Reliable Hardened Containment Vents, Order EA-12-050 (Washington, D.C.: Mar. 12, 2012).

[c]NRC, Mitigation of Beyond-Design-Basis Events, 84 Fed. Reg. 39,684 (Aug. 9, 2019). Orders EA-12-049 and EA-12-051 are applicable to all licensees and construction permit holders. Order EA-12-050 applies to licensees with boiling water reactors that feature certain containments that require proper venting to ensure safety.

[d]Nuclear Energy Institute, Diverse and Flexible Coping Strategies (FLEX) Implementation Guide, NEI 12-06 (August 2012) and NRC, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events, Order EA-12-049 (Washington, D.C.: Mar. 12, 2012).

The actions NRC took in response to the task force recommendations include the following:

- **Required licensees to assess flooding risks.** NRC required all licensees to assess updated flood hazard risk information and reevaluate and upgrade, as necessary, their plants' flood protection of structures, systems, and components. On the basis of these assessments, NRC did not identify the need to require any plant modifications or revise plant safety procedures.[43]
- **Created a process for ongoing hazard assessments.** In May 2017, the Commission approved the Process for the Ongoing Assessment of Natural Hazard Information (POANHI) to determine the need for site-specific assessments, additional research, or regulatory action.[44] POANHI involves collecting and maintaining hazard information in the

[43]NRC required all nuclear power plant licensees to conduct on-site inspections of safety-related systems to verify that plant features that protect against flooding are available, functional, and properly maintained. All licensees conducted flood reevaluations for their plants, and licensees at six plants conducted further integrated assessments, which are requested by NRC if the plant's design for a potential flood is exceeded by the reevaluation's estimates of potential maximum elevation of flood waters. These assessments evaluate the plant response to flooding hazards and the effectiveness of existing systems and procedures to mitigate risks from flooding. In addition, NRC required licensees to identify and address plant-specific vulnerabilities related to flooding and verify the adequacy of monitoring and maintenance for protection features in the interim period until longer term actions were completed to reevaluate design-basis flooding hazards. Also, following the accident at the Fukushima Dai-ichi plant, NRC issued a temporary instruction directing its inspection staff to independently assess the adequacy of actions taken by licensees. NRC also required licensees to assess seismic hazard risks. Seismic hazard risks are not included in the scope of this report.

[44]Preceding the approval of POANHI, NRC conducted a 2013 Probabilistic Flood Hazard Assessment workshop following the accident at the Fukushima Dai-ichi nuclear power plant, in which participants from federal agencies and other organizations shared information about probabilistic assessment of extreme rainfall, flood-induced dam and levee failures, tsunami flooding, river flooding, extreme storm surge, and combined-events flooding. NRC continues to host Probabilistic Flood Hazard workshops nearly annually, and these workshops often share research results with the public. For example, NRC contracted with the Pacific Northwest National Laboratory to publish four national and regional reports on the potential impacts of climate change, which as of 2022 have not yet led to additional NRC guidance for probabilistic flood hazard assessment. These reports are publicly available at https://www.osti.gov/biblio/1259942, https://www.osti.gov/biblio/1593340, https://www.osti.gov/biblio/1524249, and https://www.osti.gov/biblio/1605280.

Natural Hazards Information Digest[45]—a database that supports POANHI—and reviewing and assessing the hazard information to determine whether a hazard has a potentially significant impact on plant safety.[46] To ensure that NRC is aware of new hazard information from a variety of sources for inclusion in this database, NRC regularly interacts with internal and external stakeholders, including other federal agencies, academia, industry, regulators from other countries, and other technical and scientific organizations, according to NRC officials. If a POANHI assessment of new hazard information identifies a potentially significant effect on plant safety, NRC refers the issue to the appropriate regulatory program, at which point the program office determines how to proceed. POANHI leverages and is integrated into other existing processes, such as the operating experience program, for the assessment of new information and the determination of whether a change is needed to a particular plant's licensing basis. According to NRC officials, NRC has not taken any regulatory actions as a result of POANHI.[47]

- **Required enhanced safety and emergency equipment**. In 2012, NRC ordered all licensees and nuclear power plant construction permit holders to ensure that a plant's key safety functions could be

[45]NRC incorporates new hazard information, such as records of site-specific or regional extreme weather events, into its Natural Hazards Information Digest, which NRC began using in 2019. This database is NRC's repository for information on natural hazard-related events at or near nuclear power plants. The database captures documentation provided by licensees in response to site hazard reevaluations and plant inspections as well as historical site-specific events and information about natural hazards that could affect plants. In addition to informing POANHI, the database also supports NRC efforts to (1) respond to emergent events associated with natural hazards by providing relevant information, (2) engage with stakeholders, (3) evaluate natural hazard-related inspection findings to determine their safety significance, (4) implement natural hazards research plans, and (5) update regulatory and staff guidance.

[46]According to NRC policy, the significance assessment determines whether the new information indicates that the hazard could adversely affect the capability of a plant's structures, systems, and components to perform their intended safety functions. To make this determination, NRC staff either conduct a quantitative assessment that compares the new information with risk insights from past hazard analyses to assess the impacts of plant response or conduct a qualitative assessment that considers the likelihood of the event, identifies vulnerabilities and actions to address them, and adheres to defense-in-depth principles, among other factors.

[47]NRC is reviewing new seismic information from a 2018 report to assess updated seismic hazards at the nuclear power plants located in the region addressed by the report. See Pacific Earthquake Engineering Research Center, *Central and Eastern North America Ground-Motion Characterization: NGA-East Final Report*, (Berkeley, CA: December 2018). After reviewing this report, NRC determined that 13 nuclear power plants located in the central and eastern United States needed further assessment. Based on assessments conducted as of March 2024, NRC determined that no regulatory action was needed.

maintained during a natural disaster that exceeds a plant's design basis. In response, the nuclear industry developed and implemented the *Diverse and Flexible Coping Strategies (FLEX) Implementation Guide,* which NRC has endorsed as one method to comply with the 2012 order.[48] FLEX is a strategy that uses controls, procedures, and backup equipment to ensure that the key safety functions related to cooling a reactor's core and spent fuel, as well as containment to prevent accidental releases of radiation, are maintained if a disaster occurs at a plant. According to NRC officials, as part of this strategy, all plants have backup equipment on site. In addition, the nuclear power industry operates two Strategic Alliance for FLEX Emergency Response (SAFER) centers that maintain emergency equipment that can be provided to plants as a backup to plants' primary backup equipment onsite.[49] See figure 10 for examples of FLEX and SAFER equipment.

[48]Nuclear Energy Institute, *Diverse and Flexible Coping Strategies (FLEX) Implementation Guide*, NEI 12-06, August 2012.

[49]The SAFER centers are located in Phoenix, Arizona, and Memphis, Tennessee. The SAFER centers' staff comprises staff from a private company that has contractual agreements to manage and deploy offsite equipment with every nuclear licensee in the United States as part of FLEX. The SAFER centers maintain generic equipment useful for multiple plants, including various types of generators and pumps, and site-specific equipment unique to certain plants. NRC determined there is reasonable assurance that equipment at the SAFER centers can be deployed to any plant in the United States within 24 hours, as specified by licensees' SAFER response plans. To date, no SAFER response plan has been activated. According to our analysis of federal hazard data, SAFER centers are in areas with no exposure to sea level rise or hurricane storm surge, and either low (Memphis) or high (Phoenix) flood hazard. The centers are located in areas projected to see an increase in daily temperature from 3.6 to 4.9 degrees, and the Phoenix SAFER center is in an area with high or very high wildfire risk.

Figure 10: Examples of the Diverse and Flexible Coping Strategies (FLEX) and Strategic Alliance for FLEX Emergency Response (SAFER) Center Equipment







Top: Water purification equipment, located at the National SAFER Response Center in Phoenix, Arizona, is designed to facilitate the use of higher quality water for the reactor coolant system's makeup. Bottom left: Arizona's Palo Verde Generating Station high-pressure reactor coolant system injection pump is used to support the FLEX strategy and receives borated water from an onsite storage tank to inject into the reactor coolant system to maintain reactor coolant system inventory and nuclear reactivity. Bottom right: Florida's Turkey Point Nuclear Generating Station steam generator FLEX well pump is a piece of backup equipment used to refill a storage tank from an artesian well for the purpose of adding water to the steam generator.

Sources: GAO analysis of Nuclear Regulatory Commission documents and interview with licensee staff; GAO (photos). | GAO-24-106326

NRC's Actions Do Not Fully Consider the Potential Effects of Climate Change

NRC's actions to address risks to nuclear power plants from natural hazards in its licensing, license renewal, and inspection processes do not fully consider the potential increased risks from natural hazards that may be exacerbated by climate change.

- **Licensing.** NRC does not use climate projections data to identify and assess risk as part of the safety reviews or probabilistic risk

assessment reviews it conducts during the initial licensing process.[50] Rather, NRC uses historical data to extrapolate the future risks of natural hazards that may occur during the lifetime of a nuclear power plant.[51] Extrapolating historical data into the future assumes that existing climatological trends will continue.[52] According to NRC officials, NRC uses historical data in conjunction with other information to establish a conservative licensing basis, and many of the natural hazards considered during licensing target annual exceedance probabilities such that an event is unlikely to occur during the lifetime of the plant. In such a case, NRC expects the event to occur only once in 10,000 to 10 million years, depending on the hazard. NRC officials we interviewed told us that they review regional climate projections information for some hazards but do not incorporate site-specific climate projections data, which include hazard assessments, design bases, or determining the adequate safety margin for plants. For example, NRC officials said they review the projected average increase in temperature that applies to a multi-state region according to the NCA designation and compare that with the maximum temperature limits for a particular plant in that region. The officials said that they do not use data on the projected temperature increase to inform licensing decisions at the plant site itself.

- **License renewals.** Following an initial 40-year licensing period, NRC does not reevaluate natural hazard risks, including climate-related

[50]The NCA defines a "climate projection" as the simulated response of the climate system to a scenario of future emissions or concentrations of greenhouse gases and aerosols, generally derived using climate models. Projections data could be based on a range of possible future scenarios for particular time frames, such as the projected temperature of a specific location in the year 2050, as identified by models that consider climate systems' physical, chemical, and biological properties and their interactions. According to NRC officials we interviewed, probabilistic risk assessments use current estimates of the probability of external events, and neither licensees' nor NRC's assessments incorporate climate projections data, despite their role in assessing the likelihood of future events. NRC officials said that while it is both technical and feasible to update these models with the latest information reflecting their current state of knowledge, using climate projections data would increase uncertainty in the results of the probabilistic risk assessments, and no historical trends have emerged to suggest the need to adjust these.

[51]For example, NRC regulations for evaluating sites for initial licensing require NRC to consider the seismology, meteorology, geology, and hydrology of the site and to estimate the "maximum probable flood" using historical data, among other factors. 10 C.F.R. § 100.20(c). These regulations do not preclude NRC from using climate projections data.

[52]As noted previously, according to the NCA, climate change is altering the characteristics of many extreme weather events. Specifically, some of these events have already become more frequent, intense, widespread, or of longer duration, and many are expected to continue to worsen.

risks, to update the safety reviews required for the license renewal process. NRC's license renewal process focuses on evaluating and managing the effects of aging on the extended operations of nuclear power plants and considers the original licensing basis in that context.[53] As of January 2024, NRC had issued license renewals to 49 of the 54 operating nuclear power plants, meaning most plants are operating on the basis of assessments of natural hazard risk that are over 40 years old.

- **Inspections.** During regular inspections, NRC resident inspectors are responsible for focusing on the immediate day-to-day safety of plants rather than on the potential long-term safety risks. Inspections do not include an assessment of future climate projections data. In addition, while NRC sometimes conducts additional inspections using outside teams—including staff from NRC regional offices—to address recent events or emerging issues related to safety, these inspections also do not focus on long-term safety risks.

NRC officials we interviewed told us that while their regulatory processes—including licensing, license renewals, and inspections—do not use climate projections data to assess climate risks, they believe conservatism, safety margins, and defense-in-depth provide an adequate margin of safety to address climate risks to the safety of nuclear power plants.[54] However, NRC has not conducted an assessment to demonstrate that this is the case.

Moreover, NRC actions taken to address risks to nuclear power plants from natural hazards post-Fukushima did not fully consider the effects of climate change. Specifically, NRC required licensees to assess flooding risk and enhance safety and emergency equipment, but NRC did not require licensees to use climate projections data to assess future flooding

[53]Licensees are not required to reevaluate their plant's design basis pertaining to natural hazards as part of the license renewal process.

[54]According to NRC officials, NRC uses the NCA, which includes climate projections, in the environmental reviews it conducts during licensing and license renewals to assess the expected effects of nuclear power plants on the environment. For example, NRC addresses the greenhouse gas emissions associated with the life cycle of the plant as well as the potential effects of climate change on the environment in these reviews.

risks as part of these assessments or in the FLEX equipment needs assessments.[55]

NRC also created POANHI—its process for ongoing hazard assessments following Fukushima—which, according to NRC officials, NRC relies on to identify and assess changes in natural hazard risks, including those driven by climate change. However, POANHI has several limitations as a mechanism for comprehensively identifying and assessing climate risks. Specifically:

- While POANHI was designed to assess all natural hazards, NRC has not used POANHI to assess potential changes to all natural hazards, nor has NRC comprehensively reviewed natural hazards on a regular basis to determine whether available information indicates the need for a POANHI assessment. NRC officials told us that while POANHI requires continuous evaluation of new information on natural hazards, NRC conducts POANHI assessments for one hazard at a time, and the agency does not have a schedule for reviewing natural hazards beyond the assessment of seismic hazards currently underway. As such, POANHI is used to react to new hazard information or events when NRC staff become aware of them.
- NRC has not documented the new hazard information it reviews as part of POANHI or the way it incorporates climate projections data to determine whether to initiate a POANHI assessment, require additional plant-specific assessments, conduct an overall hazard reevaluation, or take regulatory action.
- NRC has not implemented POANHI and the Natural Hazards Information Digest at all levels of the agency. For example, several regional branch chiefs and resident inspectors we interviewed were unaware of POANHI and this information database. An official from one NRC regional office said that if the database were shared more broadly, it would benefit resident inspectors, who could access and use information on weather-related events and inspection findings to inform probabilistic risk assessments. According to NRC officials, the

[55]According to NRC officials, the plant-specific mitigation strategy relied on information each licensee had previously been required to provide as part of reevaluations of external events for comparison against the current licensing bases and FLEX equipment reflect the most severe external events that could occur based on known available meteorological, geological, and geographical data. According to NRC officials, the external hazards needing to be considered were both extreme and rare in nature which resulted in the regulatory approach of using flexible, diverse strategies to maintain or restore core cooling, containment, and spent fuel pool cooling.

agency is conducting internal outreach to increase NRC staff's knowledge of POANHI.

NRC's Fiscal Year 2022–2026 Strategic Plan calls for ensuring that licensees have measures to address the potential for increased risks from climate change. The strategic plan also promotes risk-informed decision-making to support NRC's strategic objective of providing quality licensing and oversight of nuclear facilities. Moreover, *GAO's Standards for Internal Control in the Federal Government* state that management should identify, analyze, and respond to risks related to achieving defined objectives.[56] These standards also call for agency management to use quality information to achieve their objectives.

Assessing its current processes would help NRC to determine whether they adequately address the potential for increased risks to nuclear power plants from climate change. Specifically, identifying gaps in its processes and developing a plan to address them, including by using climate projections data or augmenting POANHI, would help ensure that NRC adopts a comprehensive approach for assessing risks and fulfills its mission to protect public health and safety.

NRC officials told us that they use historical data in licensing and oversight processes rather than climate projections data, in part because regulations require NRC to use available historical data to assess the safety of the reactor site and design and they believe these data are reliable and sufficient for developing an adequate margin of safety for plants.[57] According to NRC officials, using site-specific climate projections

[56]GAO-14-704G. Risk assessment is the identification and analysis of risks related to achieving defined objectives to form a basis for developing responses to these risks. Our prior work has shown that assessing risks includes assessing both the likelihood of an event occurring and the effect the event would have. Agency leaders and subject matter experts should assess each risk by assigning the likelihood of the event's occurrence and the potential effect if the event occurs. GAO, *Enterprise Risk Management: Selected Agencies' Experiences Illustrate Good Practices in Managing Risk*, GAO-17-63 (Washington, D.C.: Dec. 1, 2016).

[57]See, e.g., 10 C.F.R. § 100.20(c) (requiring NRC to consider for initial licensing of new reactors the seismology, meteorology, geology, and hydrology of the site and to estimate the "maximum probable flood" using historical data). See also 10 C.F.R. § 60.2 (defining "design bases" to include using severe natural events estimates based on historical and physical data); and 10 C.F.R. Part 50, Appendix A, General Design for Nuclear Power Plants, Criterion 2—*Design Bases for Protection Against Natural Phenomena* (requiring the design bases for the reactor's safety structures, systems, and components to consider the "most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated," among other factors).

data for extreme hazard levels in nuclear power plant design and safety reviews is challenging because of the uncertainty associated with applying these data to specific sites. However, NRC regulations do not preclude NRC from using climate projections data, and new sources of reliable projected climate data are available to NRC. In 2023, the White House Office of Science and Technology Policy issued guidance to federal agencies on selecting and using climate data to assess risks and their potential impacts.[58] This guide provides information on climate models and projections to help federal agencies understand exposure to current and future climate-related hazards and their potential impacts. Without incorporating the best available information into its licensing and oversight processes, it is unclear whether the safety margins for nuclear power plants established during the licensing period—in most cases over 40 years ago—are adequate to address the risks that climate change poses to plants.

Conclusions

Commercial nuclear power plants in the United States were licensed and built an average of 42 years ago, and weather patterns and climate-related risks to their safety and operations have changed since their construction. Climate change is expected to exacerbate natural hazards—such as heat, drought, wildfires, flooding, hurricanes, sea level rise, and extreme cold weather events—that can affect nuclear power plant safety and operations in various ways. Some of these effects are already occurring, and many are expected to continue to worsen.

However, NRC does not use climate projections data to identify and assess risk as part of the safety reviews it conducts or the probabilistic risk assessments it reviews during the initial licensing process. NRC has also not fully developed POANHI, which the agency relies on to identify and assess changes in natural hazard risks, including climate change.

NRC has the opportunity to consider climate risks more fully and, in doing so, to better fulfill its mission to protect public health and safety.

[58]Office of Science and Technology Policy, *Selecting Climate Information to Use in Climate Risk and Impact Assessments: Guide for Federal Agency Climate Adaptation Planners*, (Washington, D.C.: March 2023). Although climate projections data and guidance are available to federal agencies, we previously recommended that the federal government, through the Executive Office of the President, make authoritative climate data and information accessible and assist in translating that information for decision makers. GAO, *High-Risk Series: Efforts Made to Achieve Progress Need to Be Maintained and Expanded to Fully Address All Areas,* GAO-23-106203 (Washington, D.C.: April 20, 2023) and *Climate Information: A National System Could Help Federal, State, Local, and Private Sector Decision Makers Use Climate Information,* GAO-16-37 (Washington, D.C.: Nov. 23, 2015).

Specifically, assessing whether its licensing and oversight processes adequately consider climate risks to nuclear power plants and developing and implementing a plan to address any gaps identified would help the agency do so. As NRC makes licensing, license renewal, and oversight decisions, adopting an approach that incorporates the best available information on climate risks and ways that those risks may affect nuclear plants, would provide greater assurance that licensees have adequate measures to address risks from climate change.

Recommendations for Executive Action

We are making the following three recommendations to NRC:

The Chair of the NRC should direct NRC staff to assess whether its licensing and oversight processes adequately address the potential for increased risks to nuclear power plants from climate change. (Recommendation 1)

The Chair of the NRC should direct NRC staff to develop, finalize, and implement a plan to address any gaps identified in its assessment of existing processes. (Recommendation 2)

The Chair of the NRC should direct NRC staff to develop and finalize guidance on incorporating climate projections data into relevant processes, including what sources of climate projections data to use and when and how to use climate projections data. (Recommendation 3)

Agency Comments and Our Evaluation

We provided a draft of this report for review and comment to NRC.

In its written comments, reproduced in appendix IV, NRC stated that the three recommendations are consistent with actions that are either underway or under development. In addition, NRC stated that the layers of conservatism and defense-in-depth incorporated into NRC's processes provide reasonable assurance regarding any plausible natural hazard and combinations at a site for the licensed operational lifetime of the reactor, including those that could result from climate change. As we noted in our report, NRC has not conducted an assessment to demonstrate that the safety margins for nuclear power plants established during the licensing period are adequate to address the risks that climate change poses to plants. According to the NCA, many of the climate conditions and impacts experienced in the United States today are unprecedented for thousands of years. Across all regions of the United States, extremes, including heat, drought, flooding, wildfire, and hurricanes, are becoming more frequent and/or severe, with a cascade of effects in every part of the country. We continue to believe that NRC cannot fully consider potential

climate change effects on plants without using the best available information—including climate projections data—in its licensing and oversight processes.

NRC also provided technical comments, which we incorporated, as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Chair of the NRC, and other interested parties. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or ruscof@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix V.



Frank Rusco
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

This report examines (1) how climate change is expected to affect nuclear power plants and (2) actions the Nuclear Regulatory Commission (NRC) has taken to address the risks to nuclear power plants from climate change.

To address both objectives, we interviewed officials from NRC headquarters, all four NRC regional offices, and two nuclear power plants. We also interviewed officials from the Department of Energy—including the Office of Nuclear Energy and the Idaho National Laboratory—the Department of Homeland Security, the Federal Energy Regulatory Commission, and the National Oceanic and Atmospheric Administration (NOAA). We also interviewed nine stakeholders knowledgeable about nuclear power plant safety and operations, climate change, and resilience measures. These included stakeholders from three industry groups, four nongovernmental organizations, and two academic institutions. We identified stakeholders using snowball sampling.[1] Views from selected stakeholders cannot be generalized to all stakeholders.

We conducted site visits to two nuclear power plants—Palo Verde Nuclear Generating Station in Buckeye, Arizona, and Turkey Point Nuclear Generating Station in Homestead, Florida. We toured the power plants and interviewed plant staff and NRC resident inspectors at each site. To answer both objectives, we chose these sites for in-person visits based on factors including exposure to distinct natural hazards, regional diversity, reactor type, licensee size, and agency resources. Findings from selected site visits are not generalizable to all sites.

To address how climate change is expected to affect nuclear power plants, we reviewed prior GAO reports and sources of climate change information (including the fourth and fifth National Climate Assessments (NCA)), completed a literature review, and conducted data analysis.[2] To conduct the literature review of articles and reports related to the effects of selected hazards and climate change on nuclear power plants, we searched a variety of scholarly, trade, and news databases, such as Ei

[1]In snowball sampling, the methodology begins with an initial list of contacts and asks each person interviewed to refer the interviewer to additional cognizant persons. The group of referred contacts (or "snowball") grows larger and then narrows as a group of individuals are identified frequently.

[2]Few supporting sources distinguish between the impact of selected natural hazards on operating versus shutdown nuclear power plants. As a result, we most often do not make this distinction.

Encompass LIT, Geobase, Inspec, the National Technical Information Service, ProQuest Environmental Science Professional, and Scopus using relevant keywords (e.g., “nuclear power,” “climate change,” “risk,” and “extreme weather”) for articles and other documents published since 2012. The results yielded 107 potentially relevant articles and other documents published from January 2012 through January 2023. To determine which articles were relevant to our scope, one analyst reviewed the articles’ abstracts and determined whether the articles were in scope using professional judgment based on their knowledge of the engagement’s scope. A second analyst reviewed the first analyst’s determinations, and the two came to a consensus on which articles were in scope. Using this method, we selected 56 articles and other documents for further review. Reviewing them for relevance, we ultimately identified and used 36 articles to support findings in our report.

To conduct our data analysis, we identified national-level data sets from relevant federal agencies for six of the seven natural hazards identified by the NCA, and our review of literature, as likely to be exacerbated by climate change in the United States. The six hazards are heat, cold, wildfires, flooding, storm surge from hurricanes, and sea level rise.[3] For heat and cold, we used climate projections data that incorporate emission scenarios to project future exposure to those hazards.[4] For wildfires, flooding, and hurricane storm surge, we used climate data that show current conditions based on past conditions (which do not incorporate climate projections).[5] For sea level rise, we used data for coastal regions and sea level rise projections from an interagency report covering sea level rise scenarios to identify coastal nuclear power plants and projected

[3]To identify the best available federal-level hazard data, we relied on interviews with agency officials and prior GAO reports. We did not analyze drought data because we were unable to identify national-level geospatial data that was both relevant to nuclear power plants and sufficiently reliable for our purposes.

[4]To analyze projected exposure to heat and cold hazards, we used NCA data on the projected exposure to maximum and minimum temperatures in the midcentury (i.e., 2036–2065), using both a low and high emission scenario for projected climate change.

[5]To analyze flood exposure, we used 2023 data from the Federal Emergency Management Agency that categorizes flood exposure into high, moderate, minimal or other, and unknown flood hazard categories. To analyze exposure to hurricane storm surge, we used NOAA data on storm surge exposure from Categories 1, 4, and 5 hurricanes. To analyze exposure to wildfires, we used 2023 data from the U.S. Forest Service on wildfire hazard potential.

sea level rise in their respective regions.[6] In this report, we refer to these hazards collectively as selected natural hazards that may be exacerbated by climate change.

For our national-level data from federal agencies, we used data we determined to be the most appropriate to represent selected natural hazards.[7] Data sources for each of the hazards we analyzed are, as follows:

- **Heat and cold.** To analyze projected exposure to heat and cold, we used data from the fourth NCA on the projected exposure to maximum temperatures in the midcentury (i.e., 2036–2065).[8]
- **Wildfire.** To analyze exposure to wildfire hazard potential, we used 2023 data from the U.S. Forest Service's Wildfire Hazard Potential Map. For reporting purposes, we grouped wildfire hazard potential into the following three categories: no/low, moderate, and high/very high.[9]
- **Flooding.** To analyze exposure to flood hazards, we used 2023 data from the Federal Emergency Management Agency's National Flood Hazard Layer. For reporting purposes, we grouped flood hazard

[6]W. V. Sweet, B. D. Hamlington, R. E. Kopp, C. P. Weaver, P. L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A. S. Genz, J. P. Krasting, E. Larour, D. Marcy, J. J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K. D. White, and C. Zuzak, *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*, NOAA Technical Report NOS 01 (Silver Spring, MD: February 2022).

[7]Data sources were chosen based on use in prior GAO reports, review of the NCA, and interviews with federal agencies responsible for collecting and reporting on data related to the selected natural hazards.

[8]The fifth NCA was released on November 14, 2023, after we had obtained and analyzed the hazard data sets from the fourth NCA. We reviewed relevant sections from the fifth NCA and did not identify major differences in the predicted or projected trends for the selected natural hazards.

[9]We combined layers of "high" and "very high" wildfire hazard potentials, which correspond to areas at the 85th percentile or greater for wildfire hazard potential. The no/low category includes plants that are in areas that are not covered by the "moderate," "high," or "very high" wildfire potential layers.

zones into the following three categories: no/low, moderate, and high.[10]

- **Hurricane storm surge.** To analyze exposure to various levels of hurricane storm surge, we used data from NOAA's Sea, Lake, and Overland Surges from Hurricanes model. We used a range of categories from the data, including no exposure to hurricanes, and Categories 1, 4, and 5 hurricanes.[11]
- **Sea level rise.** To analyze potential exposure to sea level rise in 2050, we used data from an interagency report covering sea level rise scenarios to illustrate regional climate projections for sea level rise in coastal regions. The data include two types of estimates–observation-based extrapolations and regionalized global mean sea level scenarios. NOAA officials recommended using these projections for our analysis of sea level rise data.

To identify nuclear power plant locations, we used nuclear power plant location data from NRC.[12] We used a 0.5-mile radius around the plant coordinates provided by NRC as a proxy for approximate plant size. We based the size of the radius on approximations we made for an average U.S. nuclear power plant.[13]

See appendix II for further discussion of these data sources.

[10]No/low corresponds to areas with minimal, unknown, or other flood hazards, including areas with reduced risk because of levees as well as areas with flood hazard based on future conditions, such as the future implementation of land-use plans. Moderate flood hazard zones correspond to a 500-year floodplain, which indicates between 0.2 percent and 1 percent annual chance of flooding. High flood hazard zones correspond to a 100-year floodplain, which indicates a 1 percent or higher annual chance of flooding.

[11]In our analysis, we used data on storm surge from Category 1 hurricanes (the lowest possible category) and for Categories 4 and 5 hurricanes (the highest possible categories) to show a range of climate change effects.

[12]In March of 2023, we obtained NRC nuclear power plant coordinates for all 54 operating nuclear power plants. In July 2023, we obtained NRC nuclear power plant coordinates for the 21 nuclear power plants that have shut down and have spent nuclear fuel stored onsite in spent fuel pools or in dry cask storage. NRC provided coordinates, including a latitude and longitude value for each plant. In addition, NRC's location data file contained other identifying plant information including operating status, license number, and reactor type.

[13]We requested average plant size from NRC, but NRC was unable to provide these data. Instead, we approximated the size of a typical nuclear power plant using DOE documentation on nuclear power plants.

Using hazard and nuclear power plant location data, we analyzed natural hazard exposure in the areas around nuclear power plants. In our analysis, we included operating plants and plants at various stages of decommissioning, including those in the process of decommissioning and those already shut down, with spent nuclear fuel stored onsite. We did not include experimental or test reactors in our analysis.

For certain hazards, we analyzed exposure to a range of intensities. For example, we analyzed nuclear power plant exposure to storm surge from the weakest (Category 1) and strongest (Category 5) hurricanes, as modeled by NOAA.

To analyze whether nuclear plants are located in areas that may be affected by heat, cold, wildfire, flooding, and hurricane storm surge, we used MapInfo mapping software to determine whether the nuclear power plant locations were located in areas with exposure to the selected hazards. Exposure indicates that a facility is located in an area that may be affected by a selected hazard. If the plant overlapped with multiple hazard layers, the layer representing the highest level of exposure was reported. For example, in our report, we coded a plant whose locations showed exposure to both layers for Category 1 and Category 5 storm surge data as having exposure to Category 5 storm surge.

We assessed the reliability of the fourth NCA climate projections data we used to analyze heat and cold exposure by (1) interviewing NOAA officials knowledgeable about the data and (2) reviewing existing information about the data and system that produced them.

To assess the reliability of the Federal Emergency Management Agency's National Flood Hazard Layer, NOAA's data on Sea, Lake, and Overland Surges from Hurricanes, and the U.S. Forest Service's Wildfire Hazard Potential data, we reviewed prior GAO data reliability assessments for reports using the same data.[14] Then, through interviews and email correspondence with NOAA, the Federal Emergency Management Agency, and U.S. Forest Service officials, we ensured that these data remained appropriate and reliable, considering any subsequent updates or changes made to the data.

[14]GAO, *Chemical Accident Prevention: EPA Should Ensure Regulated Facilities Consider Risks from Climate Change*, GAO-22-104494 (Washington, D.C.: Feb. 28, 2022) and GAO, *Superfund: EPA Should Take Additional Actions to Manage Risks from Climate Change,* GAO-20-73 (Washington, D.C.: Oct. 18, 2019).

To assess the reliability and appropriate use of sea level rise data for use in our analysis, we reviewed regional sea level rise data in an interagency report covering sea level rise scenarios and interviewed NOAA officials knowledgeable about sea level rise data.

To assess the reliability of NRC's data on nuclear power plant locations, we communicated with NRC staff about data accuracy and conducted limited data testing.[15] As a result of the steps described above, we found the data from the NCA, the Federal Emergency Management Agency, NOAA, the U.S. Forest Service, and NRC to be sufficiently reliable for the purpose of our reporting objectives.

To examine NRC's actions to address risks to nuclear power plants from climate change, we conducted interviews and reviewed relevant agency documents. We interviewed officials from NRC headquarters, all four NRC regional offices, and two nuclear power plants. During our two nuclear power plant site visits, we interviewed plant operator staff as well as NRC's resident inspectors to assess whether NRC processes to mitigate the risks of natural hazards and extreme weather at those plants adequately consider climate change risks. We also observed an NRC safety evaluation review to understand the extent to which NRC incorporates considerations of climate change risks when determining whether and under what conditions to license a nuclear power plant.[16] We reviewed relevant documents consisting of the following: relevant laws and regulations, agency documents (including guidance on probabilistic risk assessments and NRC's 2022–2026 Strategic Plan), two NRC office instructions, NRC's inspection manual on adverse weather protection, and other documents.[17] We compared NRC's actions against requirements to identify any relevant gaps. We also reviewed GAO's

[15]Specifically, we inputted a selection of NRC's location data into mapping software to ensure NRC's latitude and longitude location data for nuclear power plants correctly corresponded to plant names and identifying information provided by NRC. Also, we compared the plant operating status of selected plants in NRC's dataset with public information to ensure the operating status of plants matched.

[16]This safety evaluation review was for Turkey Point's Units 6 and 7, which were granted an operating license under 10 C.F.R. Part 52 but have not been built, according to NRC officials.

[17]NRC, *Strategic Plan Fiscal Years 2022–2026,* NUREG-1614, Vol. 8 (Washington, D.C.: April 2022). See also, NRC, *Inspection Manual: Adverse Weather Protection,* Inspection Procedure 71111, Attachment 01 (Washington, D.C.: Jan. 1, 2018).

Standards for Internal Control in the Federal Government and compared NRC's actions against those standards.[18]

We conducted this performance audit from November 2022 to April 2024 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[18]GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: Sept. 10, 2014).

Appendix II: Available Federal Data on Heat, Cold, Wildfires, Flooding, Storm Surge, and Sea Level Rise

This appendix provides information on data sources we used to analyze potential exposure of nuclear power plants to selected natural hazards—including heat, cold, wildfires, flooding, storm surge from hurricanes, and sea level rise. We include information, when available, on the data source name, description, purpose, update frequency, and limitations.

National Climate Assessment Heat and Cold Climate Projections Data

The U.S. Global Change Research Program posts climate projections data on its website so that authors and other users can access their data.[1] The variables we used for heat and cold are part of a suite of variables intended to provide users insights into the effects of climate change on different variables under multiple emission scenarios.[2]

We analyzed and reported on the following heat or cold variables from the fourth National Climate Assessment (NCA):[3]

- projected change in maximum daily temperature;

[1]NOAA's Technical Support Unit and the Scripps Institute of Oceanography were involved in creating these data. Together, these stakeholders contributed to creating 100 variables derived through statistical downscaling—a process used to take climate model data, which are typically at a low resolution, and produce more detailed data relevant to a specific location or region. Climate projections have limitations that include uncertainties in emissions, natural variability, and differences in scientific models. "Emission uncertainty" refers to a climate projection's reliance on emission scenarios reliant on assumptions about future emissions, changes in population, energy use, and technology. "Natural variability" refers to unpredictable climate events like volcanic eruptions. Scientific models refer to the way processes are understood and incorporated. For example, any change in the scientific understanding of cloud properties and ocean circulation can affect projections of future climate. In this report, we refer to these data as NCA data.

[2]Climate projections are based on emissions scenarios. These scenarios are produced using a range of future assumptions about underlying socioeconomic conditions, such as population and global gross domestic product projections. The climate projections data from the fourth NCA enable users to analyze projected exposure to temperature, precipitation, and other related variables by using a range of emission scenarios and time periods. Four scenarios are available, including historical climate (averages based on the 1976–2005 climate), lower (averages based on NCA assumptions for intermediate-low sea level rise, lower population, and lower development land use), higher (averages based on intermediate sea level rise, higher population, and higher development land use), and the upper bound (averages based on extreme sea level rise, higher population, and higher development land use). All four scenarios base their future projections on historical climate data for 1976–2005. These scenarios are available for three time periods, which include the early 21st Century (2016–2045), mid-21st Century (2036–2065), and late 21st Century (2070–2099).

[3]The fifth NCA became available in November 2023, after we had obtained and analyzed heat and cold data from the fourth NCA.

- projected change in the annual days with a maximum temperature greater than the 99th percentile;
- projected change in the annual number of days with a maximum temperature greater than 115 degrees Fahrenheit;
- projected change in annual highest maximum temperature averaged over a 5-day period; and
- projected change in the annual number of days with a maximum temperature lower than the 1st percentile.[4]

U.S. Forest Service Wildfire Hazard Potential Data

The U.S. Forest Service maps wildfire hazard potential based on landscape conditions and other observations. We previously reported that the primary intended use of the wildfire hazard potential map is to identify priority areas for hazardous fuels treatments from a broad, national- to regional-scale perspective. The data do not explicitly show wildfire threat or risk.[5]

The U.S. Forest Service maps an index of wildfire hazard potential for the contiguous United States based on, among other factors, annual burn probabilities and potential intensity of large fires. The U.S. Forest Service categorizes the wildfire hazard potential index into five classes: very low, low, moderate, high, and very high. The U.S. Forest Service designates as “high” those areas with wildfire hazard potential index from the 85th to the 95th percentiles, and as “very high” those areas above the 95th percentile. The U.S. Forest Service also categorizes some areas as non-burnable (including agricultural lands, developed lands, and water).

As we previously reported, according to the U.S. Forest Service, areas with higher levels of wildfire hazard potential have fuels that are more likely to burn with high intensity under certain weather conditions. However, areas with moderate, low, and very low wildfire hazard potential

[4]We selected temperature data using the projected change by the midcentury time frame under both a low and high emission scenario to show the range of potential projected change to selected natural hazards. The midcentury time frame was selected because it captures potential hazard effects during the period in which nuclear power plants are likely to remain operational. Other available variables include the average daily temperature and maximum 1- or 5-day precipitation. In this report, we refer to these data as NCA data.

[5]The objective of the wildfire hazard potential map is to depict the relative potential for wildfire that would be difficult for suppression resources to contain. The U.S. Forest Service’s Wildfire Hazard Potential map is available at https://doi.org/10.2737/RDS-2015-0047-4.

may still experience wildfires, particularly near areas with higher wildfire hazard potential.

We used 2023 wildfire hazard potential data. These data incorporated methodological changes to the fire simulation modeling to better represent probabilistic components of wildfire hazard for the fuel and climate conditions as they exist today, according to U.S. Forest Service officials we interviewed. For our analysis, we combined the high and very high wildfire hazard potential categories; we did not identify the number of facilities in each of these categories separately.

Federal Emergency Management Agency Flood Hazard Data

The Federal Emergency Management Agency's National Flood Hazard Layer provides data on the most current coastal and riverine flooding hazard data.[6] Among other uses, the flood hazard data are used for flood insurance ratings and floodplain management. The National Flood Hazard Layer identifies areas with the highest risk of flooding, with a 1 percent or higher annual chance of flooding.[7] In some locations, the National Flood Hazard Layer also identifies areas with a 0.2 percent or higher annual chance of flooding, which the Federal Emergency Management Agency considers moderate flood hazards, and other flood hazards.[8] The National Flood Hazard Layer also identifies areas with minimal flood hazards, including those with less than 0.2 percent annual chance of flooding, and unknown flood hazards, including areas the Federal Emergency Management Agency has not assessed for flood hazards.

[6]Riverine flooding is flooding related to or caused by a river, stream, or tributary overflowing its banks because of excessive rainfall, snowmelt, or ice. The Federal Emergency Management Agency provides a tool for viewing, downloading, and printing flood maps for specific locations. The Federal Emergency Management Agency's flood hazard maps are available at https://www.fema.gov/flood-maps/national-flood-hazard-layer. Federal law requires the Federal Emergency Management Agency to assess the need to revise and update the nation's flood maps once every 5 years or more often as the Administrator determines necessary. 42 U.S.C. § 4101(e).

[7]These areas are known as Special Flood Hazard Areas. Under federal law, in communities that participate in the National Flood Insurance Program, homeowners are required to purchase flood insurance for properties located in Special Flood Hazard Areas that are secured by mortgages from federally regulated lenders. 42 U.S.C. § 4012a(b)(1).

[8]Other flood hazards include areas with reduced risk because of levees, as well as areas with flood hazard based on future conditions, for example, if land use plans were implemented.

National Oceanic and Atmospheric Administration Storm Surge Hazard Data

The National Oceanic and Atmospheric Administration (NOAA) provides estimates of hurricane storm surge using a model called Sea, Lake, and Overland Surges from Hurricanes.[9] Estimates for storm surge are available for coastal areas in the eastern United States from Texas to Maine as well as in Hawaii, Puerto Rico, and the U.S. Virgin Islands. As of November 2023, storm surge data for coastal areas in the western United States were only available for Southern California.

The model accounts for specific shorelines by incorporating bay and river configurations, water depths, bridges, roads, levees, and other physical features. It estimates the maximum extent of storm surge at high tide by modeling hypothetical hurricanes under different storm conditions, such as landfall location, storm trajectory, and forward speed.

NOAA models storm surge for Category 1 through Category 5 hurricanes for the Atlantic coast south of the North Carolina-Virginia border, the Gulf of Mexico, Puerto Rico, and the U.S. Virgin Islands; and Category 1 through Category 4 hurricanes for the Atlantic coast north of the North Carolina-Virginia border and Hawaii.[10] As we previously reported, the model is to be used for educational purposes and to increase awareness of storm surge hazards at a city or community level. According to NOAA's website, the agency updates the model for portions of the shoreline each year to account for, among other changes, new data and the addition of flood protection devices, such as levees. The model does not account for future conditions such as erosion, subsidence (i.e., the sinking of an area of land), construction, or sea level rise.

2022 Interagency Sea Level Rise Technical Report Sea Level Rise Data

The 2022 Interagency Sea Level Rise Technical Report provides observation-based extrapolations and model-based global mean sea level scenarios as two distinct estimates of future sea level rise. Observation-based extrapolations use observed changes in sea level rise to estimate

[9]According to NOAA, "storm surge" is an abnormal rise of water generated by a storm, over and above the predicted tides. Storm surge is produced by water being pushed toward the shore by the force of the storm's winds. NOAA's storm surge hazard maps are available at https://www.nhc.noaa.gov/nationalsurge/.

[10]We previously reported that NOAA does not estimate storm surge for Category 5 hurricanes in areas where such hurricanes have not historically made landfall, such as areas north of the North Carolina-Virginia border.

the trajectory of sea level rise.[11] Model-based-global mean sea level scenarios use emission scenarios to estimate future sea level rise. The 2022 Interagency Sea Level Rise Technical Report provides both types of estimates for sea level rise in 2050 (relative to a baseline of the year 2000) for eight coastal regions of the United States. Formed by analyzing aggregated tide gauge data, the regional boundary data that NOAA provided our team include the Northeast (Maine to Virginia), the Southeast (North Carolina to the east coast of Florida), the Eastern Gulf (west coast of Florida to Mississippi), the Western Gulf (Louisiana to Texas), the Southwest (California), the Northwest (Oregon to Washington), the Hawaiian Islands, and the Caribbean.

The 2022 Interagency Sea Level Rise Technical Report providing the sea level rise estimates and coastal regions is intended to help inform federal agencies, Tribes, state and local governments, and stakeholders in coastal communities about current and future sea level rise.[12] The two primary limitations that the report discusses for the sea level rise estimates we use include process uncertainty and emission uncertainty. Process uncertainty refers to uncertainty about the impact of emissions on ice sheet loss, ocean expansion, and local ocean dynamics. Emission uncertainty refers to the uncertain amount of greenhouse gas emissions that will enter the atmosphere, trap heat, and affect temperature and sea level rise.

[11]The observation-based extrapolations are intended to serve as a comparison with the model-based-global mean sea level scenarios.

[12]W. V. Sweet, B. D. Hamlington, R. E. Kopp, C. P. Weaver, P. L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A. S. Genz, J. P. Krasting, E. Larour, D. Marcy, J. J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K. D. White, and C. Zuzak, *2022: Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*, NOAA Technical Report NOS 01 (Silver Spring, MD: February 2022).

Appendix III: Nuclear Power Plant Exposure to Selected Natural Hazards

Table 1 shows the exposure of areas around operating nuclear power plant locations to six current or projected natural hazards: flooding, hurricane storm surge, wildfire, sea level rise, heat, and cold. Data for flooding, hurricane storm surge, and wildfire are current and based on historical observation data. Data for sea level rise and heat and cold temperature variables are climate projections data, which incorporate emission scenarios. For more information about the data sources used, see appendix II.

Table 1: Potential Exposure to Current and Future Hazards at Operating Nuclear Power Plants

Plant[a]	State	Flood hazard level[b]	Hurricane storm surge level[c]	Wildfire potential level[d]	Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e]	Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f]	Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g]	Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h]	Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i]	Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j]
Browns Ferry	AL	High	No exposure	None/ low	N/A	3.74, 4.61°F	21.07, 29.35 days	0.01, 0.05 days	5.05, 6.32°F	-1.86, -2.18 days
Joseph M. Farley	AL	High	No exposure	Moderate	1.0, 1.7 ft.	3.53, 4.33°F	19.79, 28.87 days	0.01, 0.02 days	4.33, 5.44°F	-1.88, -2.27 days
Arkansas Nuclear One	AR	High	No exposure	Moderate	N/A	3.90, 4.85°F	14.15, 20.63 days	0.09, 0.17 days	4.94, 6.10°F	-2.01, -2.25 days
Palo Verde	AZ	Moderate	No exposure	None/ low	N/A	3.64, 4.73°F	16.66, 24.67 days	15.09, 22.64 days	3.82, 4.85°F	-2.34, -2.72 days
SAFER Phoenix[k]	AZ	High	No exposure	High/ very high	N/A	3.59, 4.66°F	19.21, 28.16 days	12.86, 19.86 days	4.31, 5.32°F	-2.09, -2.52 days
Diablo Canyon	CA	High	No exposure	High/ very high	0.5, 1.2 ft.	2.59, 3.27°F	5.14, 7.10 days	0, 0 days	3.56, 4.35°F	-2.49, -2.82 days
Millstone	CT	High	Category 4	None/ low	1.2, 1.8 ft.	3.38, 4.32°F	8.28, 12.78 days	0, 0 days	3.52, 4.76°F	-2.37, -2.77 days
St. Lucie	FL	High	Category 5	Moderate	0.9, 1.6 ft.	3.05, 3.99°F	37.60, 60.07 days	0, 0 days	3.52, 4.60°F	-1.52, -2.05 days
Turkey Point	FL	High	Category 5	High/ very high	0.9, 1.6 ft.	2.91, 3.75°F	54.28, 79.80 days	0, 0 days	3.11, 3.94°F	-1.99, -2.40 days
Edwin I. Hatch	GA	High	No exposure	High/ very high	0.9, 1.6 ft.	3.39, 4.22°F	20.62, 30.21 days	0, 0.01 days	4.38, 5.56°F	-1.78, -2.25 days

Plant[a]	State	Flood hazard level[b]	Hurricane storm surge level[c]	Wildfire potential level[d]	Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e]	Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f]	Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g]	Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h]	Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i]	Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j]
Vogtle	GA	No/low	No exposure	High/ very high	0.9, 1.6 ft.	3.54, 4.38°F	16.23, 22.88 days	0.01, 0.01 days	4.30, 5.41°F	-2.02, -2.41 days
Braidwood	IL	No/low	No exposure	None/ low	N/A	4.26, 5.35°F	16.66, 24.74 days	0.01, 0.01 days	5.06, 6.57°F	-2.48, -2.76 days
Byron	IL	No/low	No exposure	None/ low	N/A	4.37, 5.46°F	15.92, 24.51 days	0, 0 days	5.26, 6.88°F	-2.61, -2.84 days
Clinton	IL	High	No exposure	None/ low	N/A	4.35, 5.35°F	19.12, 26.98 days	0.05, 0.03 days	5.50, 6.87°F	-2.41, -2.74 days
Dresden	IL	High	No exposure	None/ low	N/A	4.27, 5.38°F	17.00, 25.26 days	0.01, 0.01 days	5.08, 6.61°F	-2.52, -2.80 days
LaSalle	IL	No/low	No exposure	None/ low	N/A	4.28, 5.40°F	16.67, 24.88 days	0.02, 0.01 days	5.21, 6.79°F	-2.47, -2.77 days
Quad Cities	IL	High	No exposure	None/ low	N/A	4.20, 5.22°F	17.12, 25.92 days	0.01, 0 days	5.20, 6.73°F	-2.45, -2.70 days
Wolf Creek	KS	High	No exposure	None/ low	N/A	3.91, 4.91°F	11.36, 16.85 days	0.15, 0.22 days	4.92, 6.16°F	-1.87, -2.26 days
River Bend	LA	No/low	No exposure	None/ low	1.6, 2.3 ft.	3.09, 3.91°F	29.25, 41.28 days	0, 0 days	3.85, 4.88°F	-1.33, -1.70 days
Waterford	LA	No/low	Category 5	None/ low	1.6, 2.3 ft.	2.88, 3.59°F	22.43, 33.67 days	0, 0 days	3.14, 4.04°F	-1.70, -2.04 days
Calvert Cliffs	MD	High	Category 4	Moderate	1.2, 1.8 ft.	3.62, 4.58°F	16.21, 24.27 days	0, 0 days	4.75, 6.22°F	-2.32, -2.61 days

Plant[a]	State	Flood hazard level[b]	Hurricane storm surge level[c]	Wildfire potential level[d]	Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e]	Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f]	Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g]	Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h]	Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i]	Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j]
Donald C. Cook	MI	High	No exposure	None/ low	N/A	4.25, 5.43°F	16.75, 25.52 days	0, 0 days	5.23, 6.85°F	-2.67, -2.97 days
Fermi	MI	High	No exposure	None/ low	N/A	4.18, 5.29°F	15.12, 23.04 days	0, 0 days	5.29, 7.01°F	-2.84, -3.09 days
Monticello	MN	High	No exposure	Moderate	N/A	4.36, 5.41°F	14.72, 22.40 days	0, 0 days	5.27, 6.87°F	-2.72, -2.96 days
Prairie Island	MN	High	No exposure	None/ low	N/A	4.44, 5.51°F	14.28, 22.42 days	0, 0 days	4.86, 6.45°F	-2.78, -3.00 days
Callaway	MO	No/low	No exposure	None/ low	N/A	4.34, 5.33°F	15.36, 23.26 days	0.15, 0.22 days	5.71, 7.11°F	-2.31, -2.54 days
Grand Gulf	MS	High	No exposure	None/ low	1.6, 2.3 ft.	3.72, 4.59°F	24.81, 34.84 days	0, 0.01 days	4.30, 5.46°F	-1.93, -2.18 days
Brunswick	NC	High	Category 5	High/ very high	0.9, 1.6 ft.	2.67, 3.39°F	12.00, 18.35 days	0, 0 days	3.02, 3.91°F	-1.94, -2.28 days
McGuire	NC	High	No exposure	High/ very high	N/A	3.89, 4.82°F	17.41, 24.70 days	0, 0.02 days	4.64, 5.91°F	-2.07, -2.36 days
Shearon Harris	NC	High	No exposure	High/ very high	0.9, 1.6 ft.	3.79, 4.73°F	17.66, 25.38 days	0, 0.01 days	4.47, 5.72°F	-2.05, -2.37 days
Cooper	NE	High	No exposure	High/ very high	N/A	4.32, 5.32°F	12.21, 18.53 days	0.05, 0.09 days	5.09, 6.55°F	-2.26, -2.46 days
Seabrook	NH	High	Category 4	None/ low	1.2, 1.8 ft.	3.72, 4.77°F	9.24, 13.56 days	0, 0 days	3.89, 5.18°F	-2.72, -3.07 days

Plant[a]	State	Flood hazard level[b]	Hurricane storm surge level[c]	Wildfire potential level[d]	Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e]	Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f]	Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g]	Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h]	Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i]	Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j]
Hope Creek	NJ	High	Category 4	None/ low	1.2, 1.8 ft.	3.74, 4.79°F	12.70, 19.86 days	0, 0 days	4.24, 5.71°F	-2.63, -2.95 days
Salem	NJ	High	Category 4	None/ low	1.2, 1.8 ft.	3.74, 4.79°F	12.70, 19.86 days	0, 0 days	4.24, 5.71°F	-2.63, -2.95 days
James A. FitzPatrick	NY	High	No exposure	None/ low	N/A	4.06, 5.16°F	14.59, 21.08 days	0, 0 days	4.87, 6.44°F	-2.65, -3.06 days
Nine Mile Point	NY	High	No exposure	None/ low	N/A	4.06, 5.16°F	14.59, 21.08 days	0, 0 days	4.87, 6.44°F	-2.65, -3.06 days
R. E. Ginna	NY	No/low	No exposure	High/ very high	N/A	4.39, 5.53°F	14.43, 20.97 days	0, 0.01 days	4.98, 6.72°F	-2.84, -3.15 days
Davis-Besse	OH	High	No exposure	None/ low	N/A	4.06, 5.08°F	15.18, 22.48 days	0, 0 days	4.93, 6.46°F	-2.71, -2.98 days
Perry	OH	High	No exposure	None/ low	N/A	4.27, 5.41°F	15.04, 23.08 days	0, 0 days	4.82, 6.35°F	-2.82, -3.07 days
Beaver Valley	PA	High	No exposure	None/ low	N/A	3.76, 4.79°F	16.38, 24.97 days	0, 0 days	4.84, 6.54°F	-2.55, -2.87 days
Limerick	PA	High	No exposure	None/ low	1.2, 1.8 ft.	3.88, 4.91°F	13.22, 20.69 days	0, 0 days	4.96, 6.66°F	-2.57, -2.87 days
Peach Bottom	PA	High	No exposure	None/ low	1.2, 1.8 ft.	4.06, 5.08°F	16.27, 24.13 days	0, 0 days	5.20, 6.79°F	-2.56, -2.89 days
Susquehanna	PA	Moderate	No exposure	Moderate	1.2, 1.8 ft.	4.23, 5.27°F	15.05, 21.82 days	0, 0.02 days	5.58, 7.13°F	-2.69, -3.00 days

Plant[a]	State	Flood hazard level[b]	Hurricane storm surge level[c]	Wildfire potential level[d]	Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e]	Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f]	Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g]	Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h]	Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i]	Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j]
Catawba	SC	High	No exposure	High/ very high	N/A	4.00, 4.96°F	18.27, 25.53 days	0, 0.03 days	4.73, 6.02°F	-2.05, -2.30 days
H. B. Robinson	SC	High	No exposure	High/ very high	0.9, 1.6 ft.	3.57, 4.44°F	15.03, 21.81 days	0, 0.01 days	4.39, 5.59°F	-1.94, -2.29 days
Oconee	SC	High	No exposure	Moderate	N/A	3.66, 4.54°F	19.32, 26.96 days	0, 0.03 days	4.86, 6.22°F	-1.56, -1.89 days
Virgil C. Summer	SC	High	No exposure	Moderate	0.9, 1.6 ft.	3.55, 4.50°F	15.91, 22.53 days	0.01, 0.05 days	4.50, 5.72°F	-1.71, -2.12 days
SAFER Memphis[k]	TN	No/low	No exposure	None/ low	N/A	3.99, 4.85°F	21.63, 31.04 days	0.01, 0.04 days	5.09, 6.41°F	-1.98, -2.24 days
Sequoyah	TN	High	No exposure	Moderate	N/A	3.70, 4.55°F	19.20, 26.92 days	0, 0.01 days	4.99, 6.30°F	-1.68, -2.04 days
Watts Bar	TN	High	No exposure	Moderate	N/A	3.70, 4.59°F	18.75, 26.76 days	0, 0.01 days	4.78, 6.04°F	-1.90, -2.22 days
Comanche Peak	TX	High	No exposure	Moderate	N/A	3.69, 4.67°F	14.75, 21.52 days	0.18, 0.62 days	4.07, 5.42°F	-1.89, -2.15 days
South Texas Project	TX	No/low	Category 5	None/ low	1.6, 2.3 ft.	2.93, 3.74°F	22.77, 34.60 days	0, 0 days	3.16, 3.99°F	-1.62, -1.90 days
North Anna	VA	High	No exposure	Moderate	1.2, 1.8 ft.	3.82, 4.83°F	18.28, 26.64 days	0.01, 0.02 days	4.95, 6.43°F	-2.20, -2.55 days
Surry	VA	High	Category 4	None/ low	1.2, 1.8 ft.	3.47, 4.40°F	13.85, 21.08 days	0, 0 days	3.96, 5.17°F	-2.36, -2.68 days

Plant[a]	State	Flood hazard level[b]	Hurricane storm surge level[c]	Wildfire potential level[d]	Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e]	Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f]	Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g]	Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h]	Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i]	Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j]
Columbia	WA	No/low	No exposure	High/ very high	N/A	3.90, 4.87°F	9.56, 14.05 days	0.01, 0.06 days	4.15, 5.29°F	-1.64, -1.88 days
Point Beach	WI	High	No exposure	None/ low	N/A	3.91, 4.93°F	10.01, 15.74 days	0, 0 days	4.58, 6.13°F	-2.48, -2.78 days

Source: GAO analysis of data from the fourth National Climate Assessment (NCA), U.S. Forest Service, National Oceanic and Atmospheric Administration (NOAA), the 2022 Interagency Sea Level Rise Technical Report, the Federal Emergency Management Agency, and the Nuclear Regulatory Commission (NRC). I GAO-24-106326

[a]To identify plant locations, we used nuclear power plant coordinates from NRC and added a one-half-mile radius around NRC's plant coordinates to approximate the size of a nuclear power plant. To analyze whether nuclear plants are located in areas that may be affected by heat, cold, wildfire, hurricane storm surge, and flooding, we used MapInfo mapping software to determine whether the nuclear power plant locations are located in areas with exposure to the natural hazards. Exposure indicates that a facility is located in an area that may be affected by the selected hazard. If the plant overlapped with multiple hazard layers, the layer representing the highest level of exposure was reported.

[b]To analyze exposure to flood hazards, we used 2023 data from Federal Emergency Management Agency's National Flood Hazard Layer. We grouped flood hazard zones into three categories: no/low, moderate, and high. "No/low" refers to areas with minimal, unknown, or other flood hazards, including areas with reduced risk because of levees as well as areas with flood hazard based on future conditions, such as the future implementation of land-use plans. "Moderate" corresponds to a 500-year floodplain, which indicates between 0.2 percent and 1 percent annual chance of flooding. "High" corresponds to a 100-year floodplain, which indicates a 1 percent or higher annual chance of flooding.

[c]To analyze exposure to various levels of hurricane storm surge, we used data from NOAA's Sea, Lake, and Overland Surges from Hurricanes model. We used a range of categories from the data, including no exposure to hurricanes, and Category 1, and 4, and 5 hurricanes.

[d]To analyze exposure to wildfire hazard potential, we used 2023 data from the U.S. Forest Service's Wildfire Hazard Potential Map. "None/low" refers to plants in areas that are not covered by the "moderate," "high," or "very high" wildfire potential layers. "Moderate" refers to plants in areas with moderate wildfire hazard potential. "High/very high" refers to plants in areas with high or very high wildfire hazard potential.

[e]To analyze potential exposure to sea level rise in 2050, we used data from an interagency report covering sea level rise scenarios to illustrate climate projections for sea level rise in coastal regions, under both a low and high scenario in the regions.

[f]"Projected change in daily max. temp." refers to the projected change in daily maximum temperature by the midcentury (i.e., 2036-2065) using both a low- and high emission scenario for projected climate change from the fourth NCA. Values are measured in degrees Fahrenheit.

[g]"Projected change in max. temp. exceeding historical highs" refers to the change in the annual number of days with a maximum temperature greater than the 99th percentile by the midcentury (i.e., 2036-2065), using both a low and high emission scenario for projected climate change from the fourth NCA. This

variable measures the annual number of days when the highest temperature of the day exceeds the hottest (99th percentile of) historical (1976-2005) high temperatures. Values are measured in number of days per year.

[h]"Projected change in max. temp. over 115°F" refers to the projected change in annual number of days with a maximum temperature over 115°F by the midcentury (i.e., 2036-2065) using both a low and high emission scenario for projected climate change from the fourth NCA. Values are measured in number of days per year.

[l]"Projected change in 5-day max. temp." refers to the projected change in highest maximum temperature averaged over a 5-day period by the midcentury (i.e., 2036-2065) using both a low and a high emission scenario for projected climate change from the fourth NCA. Values are measured in degrees Fahrenheit.

[j]"Projected change in min. temp. below historical lows" refers to projected change in the annual number of days with a maximum temperature lower than the 1st percentile by the midcentury (i.e., 2036-2065), using both a low and high emission scenario for projected climate change from the fourth NCA. This variable measures the annual number of days when the highest temperature of the day is lower than the coldest (1st percentile of) historical (1976-2005) high temperatures. A negative value indicates that there will be fewer days when the daily highest temperature falls below the 1st percentile. Values are measured in number of days per year.

[k]The nuclear power industry operates two Strategic Alliance for FLEX Emergency Response (SAFER) centers that maintain emergency equipment that can be provided to plants as a backup to a plant's onsite primary backup equipment.

Table 2 shows the exposure of areas around shutdown nuclear power plant locations to six current or projected natural hazards: flooding, hurricane storm surge, wildfire, sea level rise, heat, and cold.[1] Data for flooding, hurricane storm surge, and wildfire are current data and based on historical observation data. Data for sea level rise and heat and cold temperature variables are climate projections data, which incorporate emission scenarios. For more information about the data sources used, see appendix II.

[1]We included plants at various stages of decommissioning, including those in the process of decommissioning and those already decommissioned, with spent nuclear fuel stored onsite. We refer to these as shutdown plants because they are no longer operational.

Table 2: Potential Exposure to Current and Future Hazards at Shutdown Nuclear Power Plants

Plant[a]	State	Flood hazard level[b]	Hurricane storm surge level[c]	Wildfire potential level[d]	Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e]	Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f]	Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/ year)[g]	Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h]	Projected change in 5-day max. temp., low and high emission scenarios (°Fahrenheit)[i]	Projected change in max. temp. below historical lows, low and high emission scenarios(days/ year)[j]
Humboldt Bay	CA	High	No exposure	Moderate	0.5, 1.2 ft.	2.65, 3.43°F	8.70, 14.32 days	0, 0 days	3.22, 4.20°F	-2.36, -2.68 days
Rancho Seco	CA	High	No exposure	Moderate	0.5, 1.2 ft.	3.35, 4.26°F	10.78, 15.07 days	0.12, 0.26 days	4.29, 5.35°F	-2.28, -2.65 days
San Onofre	CA	High	Category 1	High/ very high	0.5, 1.2 ft.	2.52, 3.34°F	6.59, 9.92 days	0, 0 days	3.10, 3.93°F	-2.66, -3.01 days
Fort Saint Vrain	CO	No/low	No exposure	Moderate	N/A	4.43, 5.55°F	20.00, 27.98 days	0, 0 days	5.07, 6.48°F	-1.43, -1.83 days
Haddam Neck	CT	High	Category 4	Moderate	1.2, 1.8 ft.	3.64, 4.69°F	9.65, 15.07 days	0, 0 days	3.86, 5.24°F	-2.42, -2.80 days
Crystal River	FL	High	Category 5	High/ very high	1.0, 1.7 ft.	3.01, 3.87°F	34.35, 52.84 days	0, 0 days	3.24, 4.22°F	-1.76, -2.22 days
Duane Arnold	IA	High	No exposure	None/ low	N/A	4.50, 5.55°F	17.40, 26.03 days	0.01, 0.02 days	5.47, 7.04°F	-2.60, -2.80 days
Zion	IL	High	No exposure	None/ low	N/A	4.18, 5.25°F	13.44, 20.26 days	0.01, 0.01 days	5.20, 6.80°F	-2.41, -2.65 days
Pilgrim	MA	High	Category 4	Moderate	1.2, 1.8 ft.	3.23, 4.12°F	7.35, 10.76 days	0, 0 days	3.53, 4.60°F	-2.06, -2.44 days
Yankee Rowe	MA	No/low	No exposure	None/ low	1.2, 1.8 ft.	4.24, 5.52°F	11.92, 18.63 days	0, 0 days	4.82, 6.74°F	-2.73, -3.07 days

Plant[a]	State	Flood hazard level[b]	Hurricane storm surge level[c]	Wildfire potential level[d]	Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e]	Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f]	Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/ year)[g]	Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h]	Projected change in 5-day max. temp., low and high emission scenarios (°Fahrenheit)[i]	Projected change in max. temp. below historical lows, low and high emission scenarios(days/ year)[j]
Maine Yankee	ME	High	Category 4	None/ low	1.2, 1.8 ft.	3.74, 4.85°F	9.87, 14.50 days	0, 0 days	4.09, 5.41°F	-2.58, -2.9 days
Big Rock Point	MI	High	No exposure	None/ low	N/A	4.22, 5.39°F	11.06, 17.29 days	0, 0 days	4.13, 5.71°F	-3.02, -3.28 days
Palisades	MI	High	No exposure	None/ low	N/A	3.84, 4.92°F	13.75, 21.03 days	0, 0 days	4.35, 5.78°F	-2.61, -2.99 days
Fort Calhoun	NE	High	No exposure	Moderate	N/A	4.26, 5.32°F	13.67, 20.69 days	0.01, 0.01 days	4.78, 6.15°F	-2.32, -2.58 days
Oyster Creek	NJ	High	Category 4	High/ very high	1.2, 1.8 ft.	3.60, 4.54°F	9.99, 14.93 days	0, 0 days	4.33, 5.65°F	-2.51, -2.81 days
Indian Point	NY	High	Category 4	High/ very high	1.2, 1.8 ft.	3.78, 4.84°F	12.33, 18.84 days	0, 0 days	4.78, 6.39°F	-2.63, -3.00 days
Trojan	OR	High	No exposure	Moderate	0.3, 1 ft.	3.44, 4.37°F	6.64, 10.03 days	0, 0 days	4.19, 5.32°F	-1.96, -2.22 days
Three Mile Island	PA	High	No exposure	None/ low	1.2, 1.8 ft.	4.14, 5.21°F	14.66, 21.37 days	0.01, 0.05 days	5.68, 7.31°F	-2.78, -3.05 days
Vermont Yankee	VT	High	No exposure	None/ low	1.2, 1.8 ft.	3.77, 4.89°F	13.48, 21.03 days	0, 0 days	4.80, 6.64°F	-2.48, -2.84 days
Kewaunee	WI	No/low	No exposure	None/ low	N/A	3.92, 4.96°F	9.50, 14.96 days	0, 0 days	4.38, 5.92°F	-2.59, -2.88 days
Lacrosse	WI	High	No exposure	None/ low	N/A	4.31, 5.38°F	17.34, 26.24 days	0, 0 days	5.30, 6.96°F	-2.58, -2.79 days

Source: GAO analysis of data from the fourth National Climate Assessment (NCA), U.S. Forest Service, National Oceanic and Atmospheric Administration (NOAA), the 2022 Interagency Sea Level Rise Technical Report, the Federal Emergency Management Agency, and the Nuclear Regulatory Commission (NRC). I GAO-24-106326

[a]To identify plant locations, we used nuclear power plant coordinates from NRC and added a one-half-mile radius around NRC's plant coordinates to approximate the size of a nuclear power plant. To analyze whether nuclear plants are located in areas that may be affected by heat, cold, wildfire, hurricane storm surge, and flooding, we used MapInfo mapping software to determine whether the nuclear power plant locations are located in areas with exposure to the natural hazards. Exposure indicates that a facility is located in an area that may be affected by the selected hazard. If the plant overlapped with multiple hazard layers, the layer representing the highest level of exposure was reported.

[b]To analyze exposure to flood hazards, we used 2023 data from Federal Emergency Management Agency's National Flood Hazard Layer. We grouped flood hazard zones into three categories: no/low, moderate, and high. "No/low" refers to areas with minimal, unknown, or other flood hazards, including areas with reduced risk because of levees as well as areas with flood hazard based on future conditions, such as the future implementation of land-use plans. "Moderate" corresponds to a 500-year floodplain, which indicates between 0.2 percent and 1 percent annual chance of flooding. "High" corresponds to a 100-year floodplain, which indicates a 1 percent or higher annual chance of flooding.

[c]To analyze exposure to various levels of hurricane storm surge, we used data from NOAA's Sea, Lake, and Overland Surges from Hurricanes model. We used a range of categories from the data, including no exposure to hurricanes, and Category 1, and 4, and 5 hurricanes.

[d]To analyze exposure to wildfire hazard potential, we used 2023 data from the U.S. Forest Service's Wildfire Hazard Potential Map. "None/low" refers to plants in areas that are not covered by the "moderate," "high," or "very high" wildfire potential layers. "Moderate" refers to plants in areas with moderate wildfire hazard potential. "High/very high" refers to plants in areas with high or very high wildfire hazard potential.

[e]To analyze potential exposure to sea level rise in 2050, we used data from an interagency report covering sea level rise scenarios to illustrate climate projections for sea level rise in coastal regions, under both a low and high scenario in the regions.

[f]"Projected change in daily max. temp." refers to the projected change in daily maximum temperature by the midcentury (i.e., 2036-2065) using both a low- and high emission scenario for projected climate change from the fourth NCA. Values are measured in degrees Fahrenheit.

[g]"Projected change in max. temp. exceeding historical highs" refers to the change in the annual number of days with a maximum temperature greater than the 99th percentile by the midcentury (i.e., 2036-2065), using both a low and high emission scenario for projected climate change from the fourth NCA. This variable measures the annual number of days when the highest temperature of the day exceeds the hottest (99th percentile of) historical (1976-2005) high temperatures. Values are measured in number of days per year.

[h]"Projected change in max. temp. over 115°F" refers to the projected change in annual number of days with a maximum temperature over 115°F by the midcentury (i.e., 2036-2065) using both a low and high emission scenario for projected climate change from the fourth NCA. Values are measured in number of days per year.

[i]"Projected change in 5-day max. temp." refers to the projected change in highest maximum temperature averaged over a 5-day period by the midcentury (i.e., 2036-2065) using both a low and a high emission scenario for projected climate change from the fourth NCA. Values are measured in degrees Fahrenheit.

[j]"Projected change in min. temp. below historical lows" refers to projected change in the annual number of days with a maximum temperature lower than the 1st percentile by the midcentury (i.e., 2036-2065), using both a low and high emission scenario for projected climate change from the fourth NCA. This variable measures the annual number of days when the highest temperature of the day is lower than the coldest (1st percentile of) historical (1976-2005) high temperatures. A negative value indicates that there will be fewer days when the daily highest temperature falls below the 1st percentile. Values are measured in number of days per year.

Appendix IV: Comments from the Nuclear Regulatory Commission

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 7, 2024

Frank Rusco, Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION COMMENTS ON DRAFT GOVERNMENT ACCOUNTABILITY OFFICE REPORT GAO-24-106326, "NUCLEAR POWER PLANTS: NRC SHOULD TAKE ACTIONS TO FULLY CONSIDER THE POTENTIAL EFFECTS OF CLIMATE CHANGE"

Dear Mr. Rusco:

Thank you for the opportunity to review and comment on the U.S. Government Accountability Office (GAO) draft report GAO-24-106326, "Nuclear Power Plants: NRC Should Take Actions to Fully Consider the Potential Effects of Climate Change," which the U.S. Nuclear Regulatory Commission (NRC) received on February 6, 2024.

The NRC appreciates the constructive engagement we have had with the GAO throughout the audit and the GAO's thoroughness in seeking to understand the NRC's regulatory framework related to external hazards, particularly given the complexity of the detailed processes and programs that the NRC uses to support its safety mission.

We are in general agreement with the findings. The three recommendations in the draft report are very broad but are consistent with actions that are either underway or under development. The NRC considers this report to be a fair characterization of its regulatory structure, processes, and strengths. However, considering the description of the conservatisms, safety margins, and defense-in-depth policies described in the report, the NRC does not agree with the conclusion that the agency does not address the impacts of climate change. In effect, the layers of conservatism and defense in depth incorporated into NRC's processes provide reasonable assurance regarding any plausible natural hazard and combinations at a site for the licensed operational lifetime of the reactor, including those that could result from climate change. Specifically, the processes, tools, methods, models, data, and additional margins provide reasonable assurance of the ability to withstand or mitigate projected changes in natural hazards.

It is also important to note that the NRC's mission is focused on nuclear safety; as such, we cannot impose requirements that would increase energy resilience or require consideration of potential future climate impacts without a sufficient nuclear safety justification. This is an important distinction since the predominant concerns expressed often in the draft report are that a licensee's operations may be disrupted more frequently by climate change and that the NRC should more fully consider future climate projections. The NRC is focused on nuclear safety and any potential increase in the risk of a radiological release, consistent with the NRC's mandate.

F. Rusco - 2 -

We note there was no focus during the audit and no mention in the report of the NRC's proactive approach to safety reviews to support the licensing of new reactors. This is a significant contribution by the NRC to climate resilience; specifically, the NRC is licensing safe new energy sources that are an alternative to fossil-fuel-based plants. As noted in the enclosure, we would recommend a brief reference to the NRC's contributions to climate resilience via the proactive planning and implementation of new and advanced reactor licensing and license renewals.

If you have any questions concerning the staff's comments, please contact John Jolicoeur. Mr. Jolicoeur can be reached at (301) 415-1642 or by email to John.Jolicoeur@nrc.gov.

Sincerely,

Signed by Furstenau, Raymond on 03/07/24

Ray V. Furstenau
Acting Executive Director for Operations

Appendix V: GAO Contact and Staff Acknowledgments

GAO Contact

Frank Rusco, at (202) 512-3841 or ruscof@gao.gov

Staff Acknowledgments

In addition to the contact named above, Janice Ceperich (Assistant Director), Marissa Dondoe (Analyst-in-Charge), Bethany Benitez, Colleen Candrl, Breanne Cave, Lilia Chaidez, John Delicath, Cindy Gilbert, Claire McLellan, John Mingus, Katrina Pekar-Carpenter, Dan C. Royer, Wesley Sholtes, John Tanis, Joseph Dean Thompson, Linda Tsang, and Kristen Watts made significant contributions to this report.

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EXHIBIT F-4

COASTAL TEXAS PROTECTION AND RESTORATION FEASIBILITY STUDY



COASTAL TEXAS STUDY

FINAL REPORT

AUGUST 2021

US Army Corps of Engineers®
Galveston District

TEXAS GENERAL LAND OFFICE
ESTABLISHED 1836

COASTAL TEXAS PROTECTION AND RESTORATION FEASIBILITY STUDY
FINAL REPORT

US Army Corps of Engineers®
Galveston District

This Final Report is a product of the
U.S. Army Corps of Engineers - Galveston District
and the Texas General Land Office.

COVER PHOTOS:
Top: Representational illustration of proposed multiple lines of defense for the upper Texas coast (not to scale)
Bottom: Hurricane Ike approaching the Texas Coast in 2008

1.4.3. Relative Sea Level Change

RSLC, which is a combination of land subsidence and sea level rise, exacerbates the existing vulnerabilities associated with coastal living and is expected to increase the potential for coastal flooding, shoreline erosion, saltwater intrusion, and loss of wetland and barrier island habitats in the future. Current forecasts indicate that relative sea levels could rise by 1 to 6 feet over the next 50 years (see Figure 1.10, which shows potential inundation associated with this range in forecasted sea level rise). Also, due to the same global phenomena driving sea level rise, major coastal storms could increase in intensity and the intensity of precipitation events is also likely to increase. Depending on the severity and rate of sea level change, there could be significant impacts to communities along the Texas coast. For example, a 4-foot increase in sea level could affect a quarter of interstates and arterials and nearly 75 percent of port facilities on the Gulf coast. Furthermore, rising sea level submerges wetlands and dry land, erodes beaches, and exacerbates coastal flooding. In accordance with USACE policy, this study evaluates three RSLC scenarios (low, intermediate, and high) when formulating alternative plans and assessing each alternative's performance. Figure 1.11 shows RSLC projections from 1992 to 2100 at the Galveston Pier 21 tide gauge, which is illustrative of the range of projected sea level change over time. However, it should be noted that different regions of the Texas coast have different projected curves for RSLC. Table 1.1 shows the specific relative sea level rise assumptions used in the Coastal Texas Study at 2017, 2035, 2085, and 2135 (representing existing conditions, the base year, 50-year period of analysis, and 100-year horizon, respectively) for the different regions of the coast, under the low, intermediate, and high scenarios.

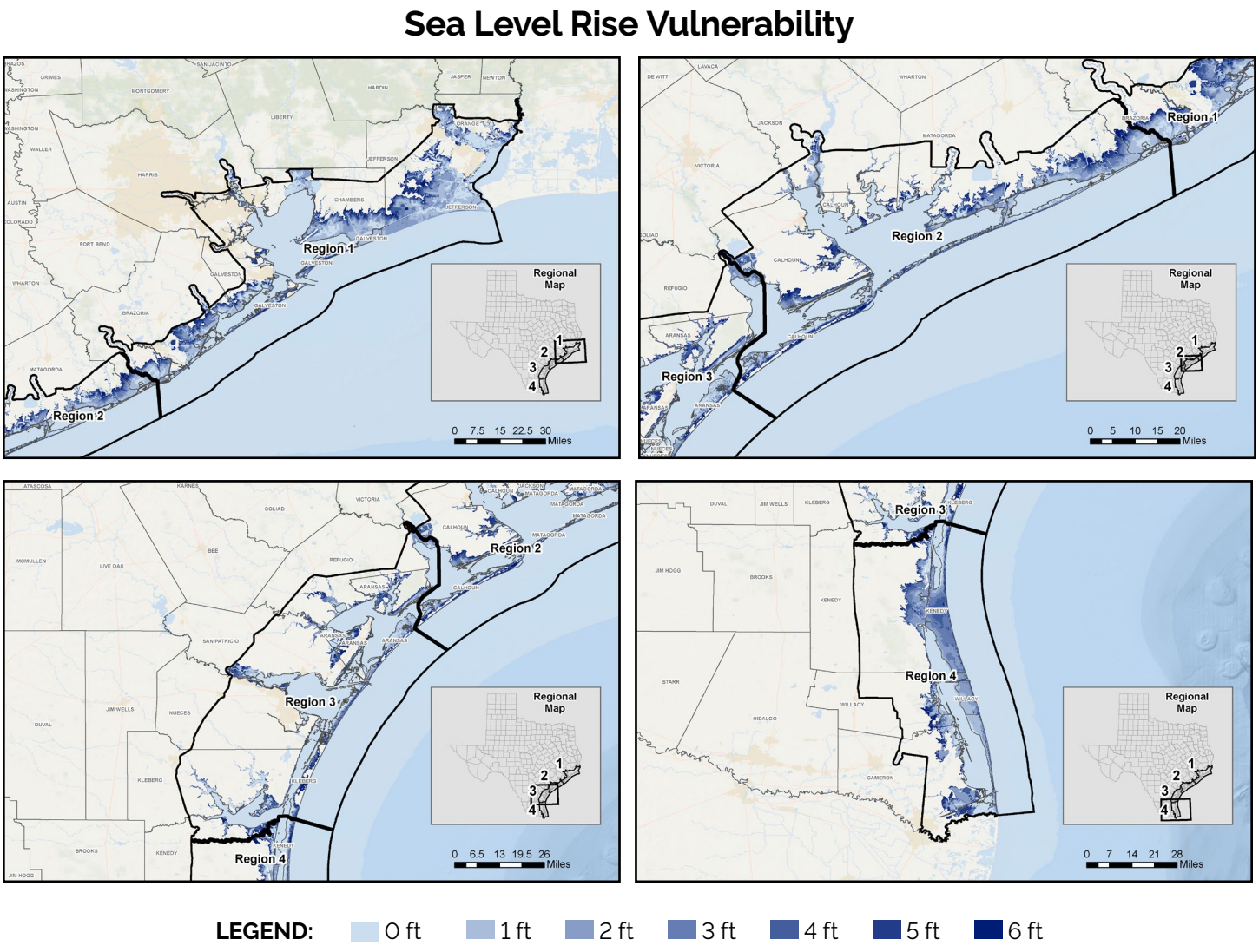


Figure 1.10: *Potential inundation associated with forecasted sea level rise (Source: TxGLO)*

EXHIBIT G

Xe-100 (/Reactors/Xe-100)
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Why? (/Why)
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November 15, 2021 (/media/news-releases/congress-appropriates-1-billion-dollars-to-x-energys-ardp-project)

Congress Appropriates ~$1.1B Dollars to X-energy's ARDP Project with Historic Legislation Recognizing Clean Energy Supply as vital to US Infrastructure and Economic Health. (/media/news-releases/congress-appropriates-1-billion-dollars-to-x-energys-ardp-project)

The U.S. Congress and the Administration continue to demonstrate their leadership in recognizing that advanced nuclear energy is an important carbon-free base-load power source that will allow the US and the world to achieve global carbon reductions by 2050.



Congress Appropriates ~$1.1B Dollars to X-energy's ARDP Project with Historic Legislation Recognizing Clean Energy Supply as vital to US Infrastructure and Economic Health.

The historic Infrastructure Investment and Jobs Act has passed into law. The package provides almost $2.5 Billion dollars through Fiscal year 2025 for the Department of Energy's contribution to the Advanced Reactor Demonstration Program (https://x-energy.com/ardp), which selected (https://x-energy.com/media/news-releases/x-energy-awarded-80-million-department-of-energy-advanced-reactor-demonstration-program-ardp) X-energy and Terrapower to demonstrate their advanced nuclear reactors before the end of the decade. Each company will split the cost of demonstration reactor with the DOE and the passage of the infrastructure bill is a strong indicator of the government's commitment to the policy direction and financial investment that is required to deploy the reactors as soon as possible.

"This is a massive endorsement from the federal government of X-energy's first commercial deployment in Washington State and the opportunity for advanced nuclear energy in creating jobs as well as rebuilding U.S. infrastructure," said Clay Sell, X-energy CEO. "We are very appreciative of the continued strong bipartisan support from Congress and the President."

In March 2021, X-energy signed (https://x-energy.com/media/news-releases/x-energy-signs-department-of-energys-advanced-reactor-demonstration-program-ardp-cooperative-agreement) the Department of Energy's Advanced Reactor Demonstration Program (ARDP) Cooperative Agreement. This officially marked the beginning of the company's participation in ARDP and partnership with the DOE. This project enables X-

energy to build the world's first commercial scale advanced nuclear reactor in Washington State through a partnership with Energy Northwest. ARDP is designed to spur domestic private industry to demonstrate advanced reactors in the United States and the global export market.

By passing the Infrastructure Investment and Jobs Act, Congress and the Administration continue to demonstrate their leadership by acknowledging clean energy supply as a significant piece of our nation's infrastructure and economic health. It's a vote of confidence in advanced nuclear energy as a vital carbon-free base-load power source that will allow the US and the world to achieve our global carbon reductions by the middle of this century.

"The Infrastructure Investment and Jobs Act sends a strong message that the U.S. will support the Advanced Reactor Demonstrations to their full and successful completion." said Darren Gale, X-energy Vice President and ARDP Program Manager. "This support ensures the success of our reactor and fuel technology at commercial scale".

X-energy's high temperature gas reactor (HTGR (https://x-energy.com/resource/htgr)) is a game-changer for nuclear energy. It enables flexible siting, lowers the cost of building nuclear plants, and is powered by TRISO-X (https://x-energy.com/fuel/triso-x), which the Department of Energy has called the "the most robust fuel on Earth." The Xe-100 (https://x-energy.com/reactors/xe-100) reactor does not need to be located near water and could be a great alternative for areas that are retiring coal plants by providing clean energy and jobs to local communities.

In addition to clean, around-the-clock carbon-free electricity, the steam from the Xe-100 can be used in applications including clean hydrogen production, desalination, and other energy-intensive industrial processes. Our reactor is a revolution in the way the US produces energy and the infrastructure bill is an important step toward making it a reality.

About X-energy

X-energy is redefining nuclear energy. It manufactures fuel that seals uranium particles in a protective coating, which makes meltdown impossible and retains the uranium fuel forever. X-energy also designs plants that unlock the fuel's energy potential in a process that's as clean as wind or solar. When combined, the result is reliable carbon-free baseload power, produced more safely and affordably than ever before and available anywhere, at any time. For more information, visit https://x-energy.com (https://x-energy.com/) or connect with us on Twitter (https://twitter.com/xenergynuclear), LinkedIn (https://www.linkedin.com/company/x-energy) or Instagram (https://www.instagram.com/xenergynuclear/).

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June 12, 2023 (/media/news-releases/x-energy-ares-acquisition-corporation-announce-strategic-update-to-business-combination-terms)

X-energy and Ares Acquisition Corporation Announce Strategic Update to Business Combination Terms to Reinforce Long-Term Value Creation Opportunity and Alignment with Shareholders (/media/news-releases/x-energy-ares-acquisition-corporation-announce-strategic-update-to-business-combination-terms)



- *Updated Terms Establish More Attractive Investment Entry Point for Shareholders*
- *Companies Reaffirm Commitment to Complete Transaction*
- *X-energy Completes Key Milestones for Advanced Nuclear Reactor and Provides Updates to Project Cost Estimates*

ROCKVILLE, Maryland. and NEW YORK – June 12, 2023 - X-Energy Reactor Company, LLC ("X-energy" or the "Company"), a leading developer of advanced small modular nuclear reactors and fuel technology for clean energy generation, and Ares Acquisition Corporation (NYSE: AAC) ("AAC"), a publicly-traded special purpose acquisition company, announced today a strategic update to their previously announced business combination agreement that revises the valuation of the transaction. Under the amended terms, X-energy's pre-money equity value has been revised to $1.8 billion from approximately $2.1 billion. By establishing a more attractive entry point for investors, X-energy and AAC believe the revised valuation reinforces the long-term value creation opportunity for, and the companies' alignment with, shareholders.

X-energy also announced the completion of key engineering and design milestones as its Xe-100 advanced small modular nuclear reactor ("SMR") has progressed from basic design to the Final Design Readiness Review phase. Reaching this phase demonstrates the substantial progress the Company has made to develop and eventually deploy an innovative advanced nuclear facility through the U.S. Department of Energy's ("DOE") Advanced Reactor Demonstration Program ("ARDP") to provide clean, safe, zero-carbon energy for a broad range of uses and applications that meet customers' unique needs.

X-energy has invested significant engineering hours in developing its technology, including approximately 800,000 hours in its Xe-100 design, 250,000 hours in its TRISO-X nuclear fuel design, and 117,000 hours in pre-application engagements, reviews, and interactions with the U.S. Nuclear Regulatory Commission ("NRC") in preparation for the submission of the ARDP project Construction Permit application to the NRC. As a result,

key Xe-100 subsystems are now significantly more defined and developed, and X-energy's manufacturing, construction, and supply chain partners are deeply integrated with the Company to provide input on detailed design, constructability, and associated costs.

The Company completed its most recent review of design processes and related costs on March 31, 2023. As a result, X-energy updated its cost estimates to complete the full ARDP scope to a total of between $4.75 and $5.75 billion. This scope includes the design and licensing of the Xe-100 standard plant, the design, licensing, and construction of the TRISO-X commercial fuel fabrication facility, and the construction of a four-unit Xe-100 facility at the Dow Inc. ("Dow") UCC Seadrift Operations site (the "Seadrift site") in Texas. Approximately 15% to 17.5% of the total ARDP project costs are assumed to be paid by X-energy. The Company's updated program cost estimate reflects, among other factors, inflationary pressures for construction materials, higher-than-expected labor costs, increasing interest rates, supply chain constraints for equipment, and maturation in the design of the Xe-100, as well as a shift in program scope from an electric-generation-only plant to a combined steam and power project at the Seadrift site that results in an extension of some program elements to 2030.

This range of estimated costs does not account for any site-specific cost adjustments related to the Seadrift site, which was announced as the location of the Xe-100 facility after this estimate was prepared, or Dow's engagement in the ARDP project, which in large part began after this estimate was prepared. Dow and X-energy believe that both of those factors could ultimately lead to a reduction in costs and intend to work collaboratively to reduce costs where possible.

"Together with our customers and partners, we are steadfast in our commitment to deliver and scale our technology at costs competitive to more conventional or carbon-intensive energy production methods," said J. Clay Sell, Chief Executive Officer of X-energy. "Meeting critical engineering and design milestones has given us detailed insight into the impact of external market conditions on our cost profile. We believe our revised valuation provides a compelling opportunity for investors seeking to build long-term value around providing clean, safe, zero-carbon energy to a wide range of customers and applications. We are confident that our progress in developing the advanced nuclear supply chain will put X-energy in a strong position to build capacity and scale for future projects."

"We reaffirm our support of this business combination and our conviction that X-energy is poised to be a differentiated leader in the global clean energy market," said David Kaplan, Co-Chairman and Chief Executive Officer of AAC and Co-Founder, Director and Partner of Ares Management Corporation. "Following the recent work of our teams, we believe this amended business combination agreement appropriately recalibrates the valuation and reflects our alignment with our shareholders and the opportunity to create attractive, long-term value. With X-energy's proprietary technology and competitive advantages in combination with its strategic relationships with Dow and OPG, we believe X-energy is well-positioned to meet the rapidly growing global demand for reliable, affordable energy."

Transaction Details

In December 2022, X-energy entered into a definitive business combination agreement with AAC. Upon the closing of the transaction, which is expected to be completed in summer 2023, the combined company will be named X-Energy, Inc. and its common equity securities and warrants are expected to be listed on the New York Stock Exchange.

Completion of the transaction is subject to approval by AAC's shareholders, the Registration Statement (as defined below) being declared effective by the Securities and Exchange Commission (the "SEC"), and other customary closing conditions.

As previously announced, existing X-energy equity holders will roll 100% of their equity interests into the combined company. Institutional and strategic investors have invested or committed up to $148 million in financing, which combined with approximately $485 million of cash held in AAC's trust account as of March 31, 2023, assuming no redemptions by AAC shareholders, will result in $515 million of cash to the combined company balance sheet, after fees. Immediately following the consummation of the transaction and assuming none of AAC's existing shareholders exercise their redemption rights, X-energy's existing equity holders are expected to hold approximately 72% of the issued and outstanding shares of common stock of the combined company.

About X-Energy Reactor Company, LLC

X-Energy Reactor Company, LLC, is a leading developer of advanced small modular nuclear reactors and fuel technology for clean energy generation that is redefining the nuclear energy industry through its development of safer and more efficient reactors and proprietary fuel to deliver reliable, zero-carbon and affordable energy to people around the world. X-energy's simplified, modular, and intrinsically safe SMR design expands applications and markets for deployment of nuclear technology and drives enhanced safety, lower cost and faster construction timelines when compared with conventional nuclear. For more information, visit X-energy.com (https://x-energy.com/) or connect with us on Twitter (https://twitter.com/xenergynuclear?lang=en) or LinkedIn (https://www.linkedin.com/company/x-energy/).

About Ares Acquisition Corporation

AAC is a special purpose acquisition company (SPAC) affiliated with Ares Management Corporation, formed for the purpose of effecting a merger, share exchange, asset acquisition, share purchase, reorganization or similar business combination. AAC is seeking to pursue an initial business combination target in any industry or sector in North America, Europe or Asia. For more information about AAC, please visit www.aresacquisitioncorporation.com (http://www.aresacquisitioncorporation.com).

Additional Information and Where to Find It

In connection with the business combination (the "Business Combination") with X-energy, AAC filed a registration statement on Form S-4 on January 25, 2023, as amended by Amendment No. 1 thereto, filed on March 24, 2023 (the "Registration Statement") with the SEC, which includes a preliminary proxy statement/prospectus to be distributed to holders of AAC's ordinary shares in connection with AAC's solicitation of proxies for the vote by AAC's shareholders with respect to the Business Combination and other matters as described in the Registration Statement, as well as a prospectus relating to the offer of securities to be issued to X-energy equity holders in connection with the Business Combination. After the Registration Statement has been declared effective, AAC will mail a copy of the definitive proxy statement/prospectus, when available, to its shareholders. The Registration Statement includes information regarding the persons who may, under the SEC rules, be deemed participants in the solicitation of proxies to AAC's shareholders in connection with the Business Combination. AAC will also file other documents regarding the Business Combination with the SEC. BEFORE MAKING ANY VOTING DECISION, INVESTORS AND SECURITY HOLDERS OF AAC AND X-ENERGY ARE URGED TO READ THE REGISTRATION STATEMENT, THE PROXY STATEMENT/PROSPECTUS CONTAINED THEREIN, AND ALL OTHER RELEVANT DOCUMENTS FILED OR THAT WILL BE FILED WITH THE SEC IN CONNECTION WITH THE BUSINESS COMBINATION AS THEY BECOME AVAILABLE BECAUSE THEY WILL CONTAIN IMPORTANT INFORMATION ABOUT THE BUSINESS COMBINATION.

Investors and security holders will be able to obtain free copies of the Registration Statement, the proxy statement/prospectus and all other relevant documents filed or that will be filed with the SEC by AAC through the website maintained by the SEC at www.sec.gov (http://www.sec.gov). In addition, the documents filed by AAC may be obtained free of charge from AAC's website at www.aresacquisitioncorporation.com (http://www.aresacquisitioncorporation.com) or by written request to AAC at Ares Acquisition Corporation, 245 Park Avenue, 44th Floor, New York, NY 10167.

Forward Looking Statements

This press release contains certain forward-looking statements within the meaning of the federal securities laws with respect to the Business Combination, including statements regarding the benefits of the Business Combination, the anticipated timing of the Business Combination, the markets in which X-energy operates, expectations with regards to X-energy's partnership with Dow and X-energy's projected future results. X-energy's actual results may differ from its expectations, estimates and projections (which, in part, are based on certain assumptions) and consequently, you should not rely on these forward-looking statements as predictions of future events. Words such as "expect," "estimate," "project," "budget," "forecast," "anticipate," "intend," "plan," "may," "will," "could," "should," "believes," "predicts," "potential," "continue," and similar expressions are intended to identify such forward-looking statements. Although these forward-looking statements are based on assumptions that X-energy and AAC believe are reasonable, these assumptions may be incorrect. These forward-looking statements also involve significant risks and uncertainties that could cause the actual results to differ materially from the expected results. Factors that may cause such differences include, but are not limited to: (1) the outcome of any legal proceedings that may be instituted in connection with any proposed business combination; (2) the inability to complete any proposed business combination or related transactions; (3) the inability to raise sufficient capital to fund our business plan, including limitations on the amount of capital raised in any proposed business combination as a result of

redemptions or otherwise; (4) the failure to obtain additional funding from the U.S. government or our ARDP partner for the ARDP; (5) unexpected increased project costs, increasing as a result of macroeconomic factors, such as inflation and rising interest rates; (6) delays in obtaining, adverse conditions contained in, or the inability to obtain necessary regulatory approvals or complete regulatory reviews required to complete any business combination; (7) the risk that any proposed business combination disrupts current plans and operations; (8) the inability to recognize the anticipated benefits of any proposed business combination, which may be affected by, among other things, competition, the ability of the combined company to grow and manage growth profitably, maintain relationships with customers and suppliers and retain key employees; (9) costs related to the proposed business combination; (10) changes in the applicable laws or regulations; (11) the possibility that X-energy may be adversely affected by other economic, business, and/or competitive factors; (12) the persistent impact of the global COVID-19 pandemic; (13) economic uncertainty caused by the impacts of the conflict in Russia and Ukraine and rising levels of inflation and interest rates; (14) the ability of X-energy to obtain regulatory approvals necessary for it to deploy its small modular reactors in the United States and abroad; (15) whether government funding for high assay low enriched uranium for government or commercial uses will result in adequate supply on anticipated timelines to support X-energy's business; (16) the impact and potential extended duration of the current supply/demand imbalance in the market for low enriched uranium; (17) X-energy's business with various governmental entities is subject to the policies, priorities, regulations, mandates and funding levels of such governmental entities and may be negatively or positively impacted by any change thereto; (18) X-energy's limited operating history makes it difficult to evaluate its future prospects and the risks and challenges it may encounter; and (19) other risks and uncertainties separately provided to you and indicated from time to time described in filings and potential filings by X-energy, AAC or X-Energy, Inc. with the SEC.

The foregoing list of factors is not exhaustive. These forward-looking statements are provided for illustrative purposes only and are not intended to serve as, and must not be relied on by investors as, a guarantee, an assurance, a prediction or a definitive statement of fact or probability. You should carefully consider the foregoing factors and the other risks and uncertainties described in the "Risk Factors" section of AAC's Annual Report on Form 10-K, its subsequent Quarterly Reports on Form 10-Q, the proxy statement/prospectus related to the transaction, when it becomes available, and other documents filed (or to be filed) by AAC from time to time with the SEC. These filings identify and address other important risks and uncertainties that could cause actual events and results to differ materially from those contained in the forward-looking statements. These risks and uncertainties may be amplified by the conflict between Russia and Ukraine, rising levels of inflation and interest rates and the ongoing COVID-19 pandemic, which have caused significant economic uncertainty. Forward-looking statements speak only as of the date they are made. Investors are cautioned not to put undue reliance on forward-looking statements, and X-energy and AAC assume no obligation and do not intend to update or revise these forward-looking statements, whether as a result of new information, future events, or otherwise, except as required by securities and other applicable laws.

No Offer or Solicitation

This press release is for informational purposes only and is neither an offer to purchase, nor a solicitation of an offer to sell, subscribe for or buy, any securities or the solicitation of any vote in any jurisdiction pursuant to the Business Combination or otherwise, nor shall there be any sale, issuance or transfer of securities in any jurisdiction in contravention of applicable law. No offer of securities shall be made except by means of a prospectus meeting the requirements of Section 10 of the Securities Act.

Participants in the Solicitation

AAC and certain of its directors and executive officers may be deemed to be participants in the solicitation of proxies from AAC's shareholders, in favor of the approval of the proposed transaction. For information regarding AAC's directors and executive officers, please see AAC's Annual Report on Form 10-K, its subsequent Quarterly Reports on Form 10-Q, and the other documents filed (or to be filed) by AAC from time to time with the SEC. Additional information regarding the interests of those participants and other persons who may be deemed participants in the Business Combination may be obtained by reading the Registration Statement and the proxy statement/prospectus and other relevant documents filed with the SEC when they become available. Free copies of these documents may be obtained as described in the preceding paragraph.

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EXHIBIT I

An official website of the United States government Here's how you know

U.S. Department of Energy Announces $160 Million in First Awards under Advanced Reactor Demonstration Program

TerraPower and X-energy awarded $160 million in initial funding to demonstrate reactors within 5 to 7 years.

Office of Nuclear Energy

October 13, 2020

3 min

WASHINGTON, D.C. – The U.S. Department of Energy (DOE) today announced it has selected two U.S.-based teams to receive $160 million in initial funding under the new Advanced Reactor Demonstration Program (ARDP). ARDP, announced in May, is designed to help domestic private industry demonstrate advanced nuclear reactors in the United States.

DOE is awarding TerraPower LLC (Bellevue, WA) and X-energy (Rockville, MD) $80 million each in initial funding to build two advanced nuclear reactors that can be operational within seven years. The awards are cost-shared partnerships with industry that will deliver two first-of-a-kind advanced reactors to be licensed for commercial operations. The Department will invest a total of $3.2 billion over seven years, subject to the availability of future appropriations, with our industry partners providing matching funds.

“The awards are the first step of a new program that will strengthen American leadership in the next generation of nuclear technologies,” said U.S. Secretary of Energy Dan Brouillette. “These partnerships will help maximize DOE’s investment in advanced reactors, which play a vital role in our clean energy strategy.”

Specifically, TerraPower will demonstrate the Natrium reactor, a sodium-cooled fast reactor that leverages of decades of development and design undertaken by TerraPower and its partner, GE-Hitachi. The high-operating temperature of the Natrium reactor, coupled with thermal energy storage, will allow the plant to provide flexible electricity output that complements variable renewable generation such as wind a solar. In addition, this project will establish a new metal fuel fabrication facility that is scaled to meet the needs of this demonstration program.

X-energy will deliver a commercial four-unit nuclear power plant based on its Xe-100 reactor design. The Xe-100 is a high temperature gas-cooled reactor that is ideally suited to provide flexible electricity output as well as process heat for a wide range of industrial heat applications,

such as desalination and hydrogen production. The project will also deliver a commercial scale TRi-structural ISOtropic particle fuel (TRISO) fuel fabrication facility, leveraging DOE's substantial investment in development of this highly robust fuel form.

Both projects incorporate a range of design features that will not only enhance safety, but make them affordable to construct and operate, paving the way for the United States to deploy highly competitive advanced reactors domestically and globally.

"DOE and U.S. industry are extremely well-equipped to develop and demonstrate nuclear reactors with the requisite sense of urgency, which is important not only to our economy, but to our environment, because nuclear energy is clean energy," said Dr. Rita Baranwal, Assistant Secretary for Nuclear Energy.

Congress appropriated $160 million for the Fiscal Year 2020 budget as initial funding for these demonstration projects. Funding beyond the near-term is contingent on additional future appropriations, evaluations of satisfactory progress and DOE approval of continuation applications. In addition, the Fiscal Year 2020 appropriation also provided initial year funding of $30 million for two to five Risk Reduction for Future Demonstrations projects and $20 million initial year funding for at least two Advanced Reactor Concepts-20 (ARC-20) projects. Awards for these projects are expected to be announced in December 2020.

More information on the Office of Nuclear Energy and its programs can be found here.

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News Media Contact: (202) 586-4940

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EXHIBIT J

United States Government Accountability Office



Report to Congressional Requesters

September 2022

NUCLEAR ENERGY PROJECTS

DOE Should Institutionalize Oversight Plans for Demonstrations of New Reactor Types

On September 15, 2022, comment letters from the Department of Energy and the Nuclear Regulatory Commission were added in appendices III and IV, respectively. Corrections are on pages 25-26, and page 27.

GAO-22-105394

September 2022

NUCLEAR ENERGY PROJECTS

DOE Should Institutionalize Oversight Plans for Demonstrations of New Reactor Types

GAO Highlights

Highlights of GAO-22-105394, a report to congressional requesters

Why GAO Did This Study

In 2021, nuclear energy accounted for almost 20 percent of the nation's electricity generation and provided about 50 percent of the carbon-free electricity. However, economic challenges have led to the closure or planned shutdown of multiple nuclear power plants. To address these challenges, DOE has made awards to projects that demonstrate first-of-a-kind small modular and advanced reactors. These are either smaller than existing reactors or use technologies expected to offer improvements over the most recent generation of nuclear reactors. According to DOE, the federal government has a unique role to play in reducing the financial and technical risks faced by companies seeking to develop these technologies.

GAO was asked to review DOE's management of nuclear energy demonstration awards. This report (1) describes awards DOE has made to support the demonstration of small modular and advanced reactors; and (2) examines actions DOE is taking to manage risks associated with awards.

To do this work, GAO assessed DOE's management of the awards against laws, regulations, guidance, and leading project management practices. GAO also interviewed DOE program and project management officials, awardees, and industry stakeholders.

What GAO Recommends

GAO is recommending that DOE institutionalize via documentation its processes for providing oversight for large nuclear energy demonstration projects, including the use of external independent reviews. DOE agreed with GAO's recommendation.

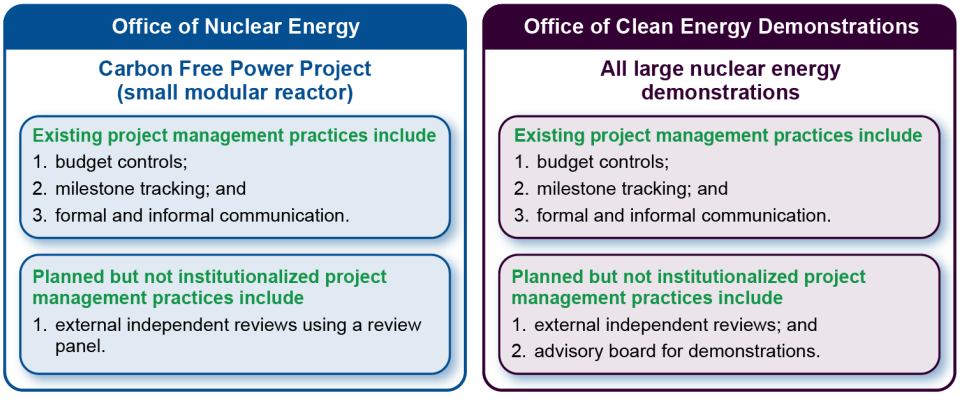
View GAO-22-105394. For more information, contact Frank Rusco at (202) 512-3841 or ruscof@gao.gov.

What GAO Found

The Department of Energy (DOE) supports the research, development, and demonstration of new types of nuclear reactors. In line with that role, in fiscal year 2021, the department made three multi-year awards totaling $4.6 billion to support the demonstration of one small modular reactor and two advanced reactors. DOE awarded the Carbon Free Power Project about $1.4 billion for a small modular reactor plant near Idaho Falls, Idaho. Under the Advanced Reactor Demonstration Program, DOE awarded TerraPower almost $2 billion for the Natrium™ Demonstration in Wyoming and awarded X-energy about $1.2 billion for the Xe-100 Demonstration in Washington State.

DOE has taken several actions to manage risks associated with the three demonstration awards, including using project management practices such as budget controls and milestone tracking. The two DOE offices managing the awards—the Offices of Nuclear Energy and Clean Energy Demonstrations—also plan to use additional project management practices, such as external independent reviews, to oversee the awards (see fig.). Office of Clean Energy Demonstrations officials said these additional project management practices will apply to all large DOE energy demonstration awards, regardless of which DOE offices are managing those awards. However, neither office has institutionalized its plans by documenting these additional project management practices. Documenting these processes, including the use of external independent reviews, would allow DOE to share best practices across offices during the course of these multi-year awards, potentially resulting in stronger federal oversight of the projects and improved project performance.

Existing and Planned Project Oversight Processes for Nuclear Energy Demonstration Awards, as of June 2022



Sources: Department of Energy documents, and interviews with agency officials. | GAO-22-105394

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Abbreviations

ARDP	Advanced Reactor Demonstration Program
DOE	Department of Energy
HALEU	High-Assay Low-Enriched Uranium
NRC	Nuclear Regulatory Commission

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U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

September 8, 2022

The Honorable Diane Feinstein
Chair
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

The Honorable Eddie Bernice Johnson
Chairwoman
Committee on Science, Space, and Technology
House of Representatives

In 2021, nuclear energy accounted for almost 20 percent of the electricity generated in the United States and provided about 50 percent of the nation's carbon-free electricity. However, the existing commercial reactor fleet is aging, and economic challenges have led to the closure or planned shutdown of multiple nuclear power plants. To address these challenges, the Department of Energy (DOE) supports the research, development, demonstration, and deployment of new nuclear reactor types. These include small modular reactors, which are smaller than existing commercial reactors, and advanced reactors, which are expected to offer significant improvements over the most recent generation of nuclear reactors. According to DOE, the federal government has a unique role to play in reducing the financial and technical risks faced by companies seeking to develop these new, first-of-a-kind technologies.

In fiscal year 2021, DOE made awards to three multi-billion dollar projects to support the demonstration of first-of-a-kind small modular and advanced reactors.[1] First, DOE approved an award to the Carbon Free Power Project to help demonstrate and deploy a small modular reactor power plant. Second, DOE, through its Advanced Reactor Demonstration Program (ARDP), approved two awards to build power plants using

[1]DOE made these awards subject to cost-share arrangements under which DOE would provide up to 50 percent of project costs, and the award recipient would pay the rest.

advanced reactors to be completed within 7 years of the issuance of the awards.[2]

In light of past and potential future federal government investments in nuclear technologies and the inherent risks associated with developing first-of-a-kind technologies, GAO was asked to review DOE's management of its three nuclear energy demonstration awards. This report (1) describes the awards DOE made to support the demonstration of small modular and advanced nuclear reactors and (2) examines actions DOE is taking to manage risks associated with these awards.

To address the first objective, we summarized award information by reviewing and analyzing award data from DOE, including award amounts, years, funding sources, and cost-share structures. We conducted a data reliability assessment for the award data collected—including by interviewing relevant agency officials and checking award data with available public information—and determined the data to be sufficiently reliable for our purposes. To describe how the awards contributed to DOE's nuclear energy goals, we reviewed the Office of Nuclear Energy's Strategic Vision document and award documentation and interviewed agency officials.

To address the second objective, we identified leading practices in managing risks of these types of awards by reviewing prior GAO reports on DOE management of demonstration projects,[3] best practices from GAO's *Cost Estimating and Assessment Guide*,[4] and GAO's *Standards for Internal Control in the Federal Government*.[5] We also interviewed officials knowledgeable about DOE's project management practices, including officials from DOE's Office of Project Management, Office of

[2]The Carbon Free Power Project award was made in October 2020. The ARDP awards were announced in October 2020, but actual awards did not occur until February 2021 and May 2021.

[3]See GAO, *Carbon Capture and Storage: Actions Needed to Improve DOE Management of Demonstration Projects*, GAO-22-105111 (Washington, D.C.: December 2021); and *Department of Energy: Consistent Application of Requirements Needed to Improve Project Management*, GAO-07-518 (Washington, D.C.: May 2007).

[4]GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs,* GAO-20-195G (Washington, D.C.: March 2020).

[5]GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: September 2014).

Science, and Loan Programs Office. We then assessed DOE's management of these awards against relevant leading practices.

We also reviewed relevant laws, regulations, and agency guidance regarding financial assistance awards and identified selected requirements that we determined will likely have a significant impact on the supported projects' goals and operations or financial risks to the federal government.[6] We then assessed DOE's management of the awards against the selected requirements.

Further, we interviewed officials from DOE's Office of Nuclear Energy and Office of Clean Energy Demonstrations, which oversee the three demonstration projects, and the Nuclear Regulatory Commission (NRC) regarding DOE's management of these projects.[7] In addition, we interviewed representatives from the three awardees. We also interviewed stakeholders from a company that had received prior DOE support for the technology being demonstrated in one of the projects, another company that received an award for a different advanced reactor technology, and a nuclear industry trade organization. We identified these stakeholders using a "snowball sampling" technique. We then selected a subset of these groups to interview based on their knowledge of DOE's management of small modular and advanced reactor demonstrations.[8] Views from the selected stakeholders cannot be generalized.

We conducted this performance audit from September 2021 to September 2022, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We

[6]In this report, we define "requirements" as both legal requirements and other criteria in DOE guidance, specifically the department's *Guide to Financial Assistance: A Guide to the Award and Administration of Financial Assistance* (Oct. 1, 2020).

[7]NRC is the federal agency that regulates commercial nuclear power plants and other commercial uses of nuclear materials through licensing, inspection, and enforcement of its requirements.

[8]In snowball sampling, the methodology begins with an initial list of contacts and asks each person interviewed to refer the interviewer to additional cognizant persons. The group of referred contacts (or "snowball") grows larger and then narrows as a group of individuals are identified frequently.

believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

New Nuclear Reactor Types

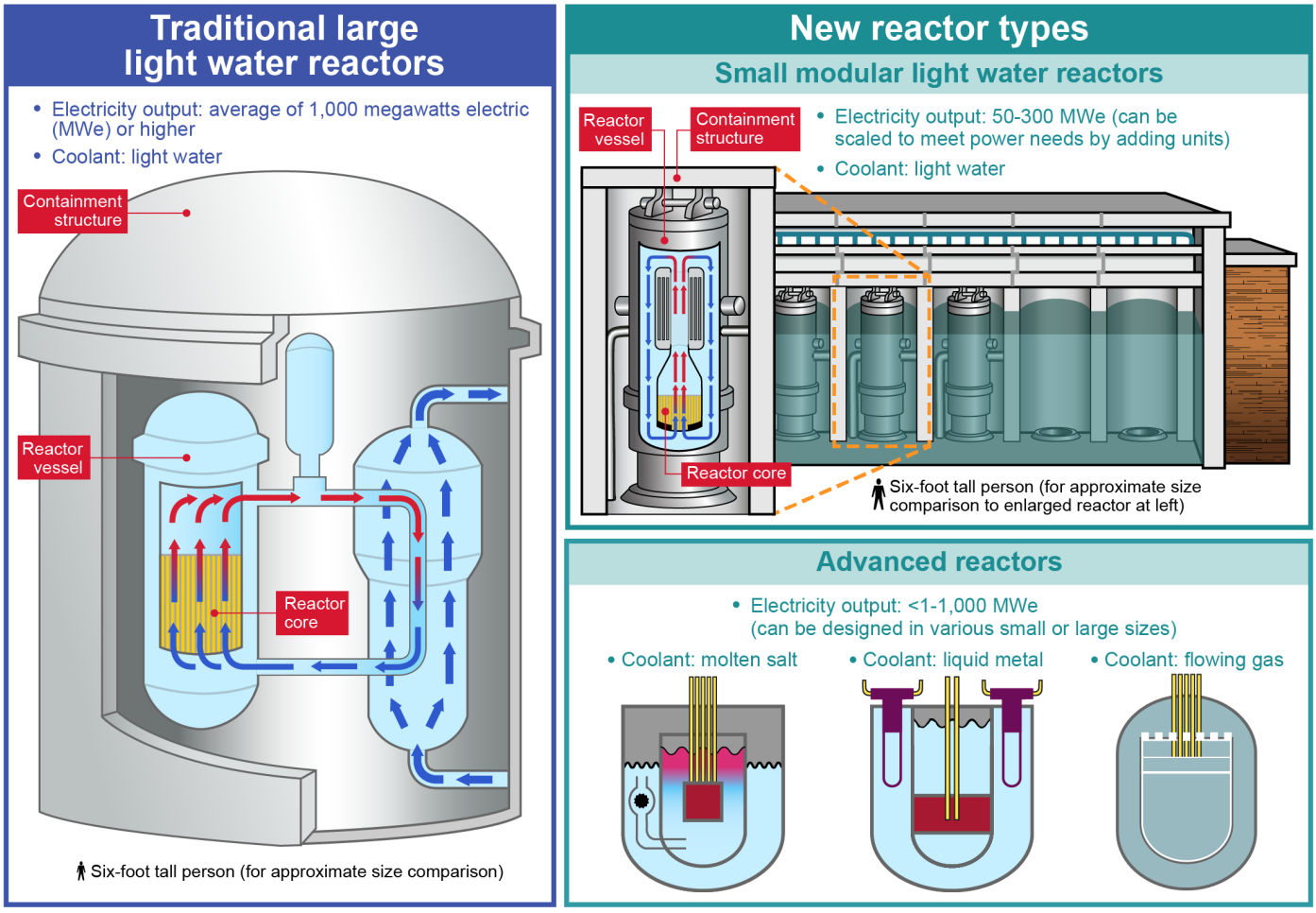
Existing light water nuclear reactors are generally large and expensive to build.[9] New nuclear reactor types include light water designs that are far smaller than existing reactors, with fewer parts, systems, and components. They also include advanced reactor types with similar simplicity in design that use different moderators, coolants, or types of fuel. Small modular reactors are those that generate 300 megawatts of electricity or less—compared with existing commercial reactors that have an average generating capacity of over 1,000 megawatts of electricity—and average about 1/10 to one-quarter the size of a traditional nuclear reactor.[10] Advanced reactors are defined as nuclear reactors with significant improvement over the most recent generation of nuclear reactors, such as improved efficiency or simpler reactor design. Most non-light water advanced reactors will rely on the use of high-assay low-enriched uranium (HALEU) fuel.[11] Currently, no small modular or advanced reactors are operational in the United States. See figure 1 for a comparison of traditional reactors and new reactor types.

[9]The nuclear reactors currently operational in the United States are referred to as "light water reactors," meaning reactors that use light water (ordinary water) to cool and moderate the reactor, as opposed to heavy water, which contains deuterium, an isotope of hydrogen.

[10]A small modular reactor is a nuclear fission reactor that features factory-built-and-assembled modules in a variety of configurations and electricity outputs. Small modular reactors are envisioned to vary in size according to configuration. Modular designs make it possible to assemble major reactor components in a factory and add reactor modules, as needed. Small modular reactors can be designed for power generation or to process heat for desalination, or for other industrial applications. Designers of small modular reactors plan to decrease the overall cost and time for reactor construction, compared with existing large light water reactors, without significantly increasing ongoing operational costs. See GAO, *Technology Assessment: Nuclear Reactors: Status and Challenges in Development and Deployment of New Commercial Concepts*, GAO-15-652 (Washington, D.C.: July 2015).

[11]Existing nuclear power plants in the United States generally use low-enriched uranium fuel, enriched up to around 3 percent to 5 percent of the uranium-235 isotope. HALEU is uranium fuel that is enriched to higher levels, up to 20 percent uranium-235. Most of the advanced reactors under development in the United States will use HALEU to enable them to achieve more compact designs, longer operating cycles, and higher efficiencies than previous reactor designs, but HALEU is not currently available at commercial scale from domestic suppliers.

Figure 1: Traditional Reactors and New Reactor Types



Sources: GAO illustration, using materials from Nuclear Regulatory Commission (traditional large reactors); NuScale Power (small modular reactors); and Department of Energy Office of Nuclear Energy (advanced reactors). Nuscale image © 2007 or later by NuScale Power, LLC. All rights reserved. | GAO-22-105394

As we have previously reported, DOE officials and reactor designers expect advanced reactors to operate at higher temperatures and, therefore, to generate electricity more efficiently.[12] In addition, the relatively high temperatures of advanced reactors could supply process heat, which is heat used for industrial processes such as in desalination operations, oil refineries, chemical plants, and the production of hydrogen. This could expand nuclear energy's role in the energy sector beyond just electricity production by providing an alternative for industrial

[12]GAO-15-652.

processes currently using fossil fuels to supply their process heat. These alternative applications could also provide additional revenue streams that could help improve the overall economics of the reactors, according to DOE. Further, some advanced reactors may also allow for improved spent nuclear fuel recycling and management. For example, some advanced reactors are designed to use reprocessed spent fuel from other nuclear reactors as fuel and, therefore, may reduce the need for long-term spent fuel disposal.

DOE Support for New Nuclear Reactor Types

Two DOE offices oversee nuclear demonstration projects:

- The Office of Nuclear Energy's mission is to advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs. In particular, the office supports technologies, including first-of-a-kind nuclear reactors, that otherwise could be too costly or large scale for the private sector or other non-government stakeholders. Its support can also accelerate development of technologies that the private sector was already funding. The Office of Nuclear Energy made the three fiscal year 2021 awards for the demonstration of small modular and advanced reactor projects.
- The Office of Clean Energy Demonstrations' mission is to deliver clean energy demonstration projects at scale in partnership with the private sector to launch or accelerate market adoption and deployment of technologies, as part of an equitable transition to a decarbonized energy system. The office was established in November 2021 under the Infrastructure Investment and Jobs Act, which requires the Office of Clean Energy Demonstrations to manage the two ARDP awards but not the Carbon Free Power Project.[13]

According to DOE, the department generally uses competitive funding opportunity announcements for federal financial assistance to solicit applications for early-stage nuclear research, development, and demonstration projects. In particular, DOE seeks applicants who will (1) enhance the long-term viability and competitiveness of the existing U.S. reactor fleet, (2) develop an advanced reactor pipeline, or (3) implement and maintain the national strategic fuel cycle and supply chain infrastructure. Each year, DOE sets priorities for advancing nuclear power based, in part, on the amount of funding appropriated by Congress, as well as any direction that Congress may have specified for certain types of technology research and development, and DOE's own research and development plans. For example, DOE is currently soliciting proposals for

[13]Infrastructure Investment and Jobs Act, Pub. L. No. 117-58, 135 Stat. 429 (2021).

projects to develop innovative industry-driven reactor designs and technologies to advance nuclear power in the United States.

DOE may award financial assistance on a noncompetitive basis only if the application satisfies certain criteria in the department's financial assistance regulations. For example, a noncompetitive award can be made if the activity to be funded is necessary to the satisfactory completion of, or is a continuation or renewal of, an activity presently being funded by DOE or another federal agency, and for which competition for support would have a significant adverse effect on continuity or completion of the activity.[14] Noncompetitive awards also undergo merit review.

Both competitively and non-competitively awarded projects typically require multiple years to complete and involve cost share agreements between DOE and the awardee. Cost shares are calculated as a percentage of total project costs shared between DOE and industry partners in which DOE will fund a portion of a demonstration award. The Energy Policy Act of 2005, as amended, generally requires a non-federal cost share of not less than 50 percent for demonstration and commercial application activities.[15] DOE officials and the awardee agree on technical milestones for each phase of a project—project definition or preliminary design, design, construction, and operations—to help ensure that projects accomplish an objective or set of objectives.[16]

Developing first-of-a-kind nuclear technologies comes with technological, cost, and schedule risks. To manage risks inherent to these types of projects and to guide project management, DOE uses its *Guide to Financial Assistance,* which compiles DOE regulations for managing financial assistance awards with guidance for implementing those regulations.[17] The guide states that, while DOE's project management order does not apply to financial assistance like these three cost-share

[14]2 C.F.R. § 910.126(c).

[15]The Secretary of Energy may reduce the non-federal cost share upon determining that the reduction is necessary and appropriate, taking into consideration any technological risk relating to the activity.

[16]These agreements are known as "cooperative agreements."

[17]Department of Energy, *Guide to Financial Assistance: A Guide to the Award and Administration of Financial Assistance* (Oct. 1, 2020); *see also* 2 C.F.R. pts. 200 and 910.

awards, the basic principles in that order can be applied.[18] One such principle is the identification and management of project risks.[19] Several offices within DOE—including the Office of Project Management, the Office of Science, and the Loan Programs Office—described to us how external independent reviews and other project management practices outlined in DOE's project management order might be useful for managing risks for large demonstration awards.[20]

DOE Has Made Three Awards Totaling $4.6 Billion to Support the Demonstration of Small Modular and Advanced Reactors

DOE has made three awards totaling $4.6 billion to support the demonstration of one small modular reactor—the Carbon Free Power Project—and two advanced reactors, through the ARDP awards.[21] The Carbon Free Power Project and the two ARDP awards were different from each other in three ways: the competitive award process, award term, and cost-share structure. These three projects support two of DOE's nuclear energy goals: (1) to enable the deployment of advanced nuclear reactors and (2) to maintain U.S. leadership in nuclear energy technology.

DOE Has Made Awards for Three Nuclear Demonstration Projects

DOE has made three awards totaling $4.6 billion to support the demonstration of one small modular reactor and two advanced reactor demonstration projects. Specifically, DOE awarded the Carbon Free Power Project about $1.4 billion over 10 years to demonstrate the

[18]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Washington, D.C.: Nov. 29, 2010). All DOE offices, including the Office of Nuclear Energy and the Office of Clean Energy Demonstrations, are to use DOE's project management order to manage capital asset projects.

[19]DOE's project management order defines risks as factors, elements, constraints, or courses of action that introduce an uncertainty of outcome, either positively or negatively, that could impact project objectives. Department of Energy, *Program and Project Management for the Acquisition of Capital Assets.* A risk with negative consequences is referred to as a "threat," and a risk with positive consequences is considered an "opportunity."

[20]DOE's Office of Project Management serves as DOE's Enterprise Project Management Organization and conducts independent reviews of DOE capital projects, the Office of Project Assessment conducts independent reviews of Office of Science construction projects, and the Loan Programs Office is DOE's financier of large-scale energy infrastructure projects. DOE officials told us that they define large demonstration awards as those with a federal cost share of $100 million or more.

[21]DOE has also supported earlier phases of project design and development for these technologies over the last 8 years. See app. I for more information and a table summarizing this financial support.

NuScale small modular reactor technology near Idaho Falls, Idaho.[22] The Carbon Free Power Project expects to complete construction in August 2029 and begin delivering power by December 2029. Under the competitive ARDP Funding Opportunity Announcement, DOE awarded TerraPower about $2 billion to complete the NatriumTM Demonstration in Wyoming by 2028[23] and awarded X-energy about $1.2 billion to complete the Xe-100 Demonstration in Washington State by 2027.[24] All three awards use a cost-share structure, meaning the awardee contributes funds alongside the federal funding. See table 1 for a summary of these three awards.

Table 1: Summary of Small Modular and Advanced Reactor Demonstration Program Awards

Project	Years of award	DOE funding (in billions)	Awardee cost-share (in billions)	DOE cost-share
Carbon Free Power Project	2020-2030	$1.355	$4.645	23%
Terra Power Natrium™ Demonstration	2021-2028	$1.979	$2.017	50%
X-energy Xe-100 Demonstration	2021-2027	$1.232	$1.232	50%

Source: The Department of Energy (DOE) Office of Nuclear Energy I GAO-22-105394

[22]The Carbon Free Power Project is an entity wholly owned by Utah Associated Municipal Power Systems. According to its website, the Utah Associated Municipal Power Systems is a political subdivision of the state of Utah that provides comprehensive wholesale electric energy, transmission, and other energy services, on a nonprofit basis, to community-owned power systems throughout the Intermountain West. Its members are located in Utah, California, Idaho, Nevada, New Mexico, Oregon, and Wyoming. The Carbon Free Power Project plans to construct a small modular reactor power plant on DOE's 890-square-mile Idaho National Laboratory Site, using a small modular reactor technology developed by NuScale Power. The proposed small modular reactor plant design is available in several configurations and would feature 60- to 77-megawatt modules.

[23]TerraPower's Natrium™ Demonstration reactor is a sodium fast reactor combined with a molten salt energy storage system that is designed to produce around 345 megawatts of electric power. The thermal storage has the potential to boost the system's output to 500 megawatts of power for more than 5-1/2 hours, when needed, according to TerraPower, which could allow for changes to daily electric load and the ability to scale electricity generation based on needs driven by renewable energy fluctuations.

[24]X-energy's Xe-100 is an advanced small modular reactor with each unit designed to produce around 76 megawatts of electric power. The reactor core is made of graphite and filled with 15.5 percent uranium-enriched fuel pebbles. Each pebble (roughly the size of a billiard ball) contains thousands of coated tristructural isotropic uranium fuel particles. The coating creates an airtight seal around the uranium kernel.

Note: The Carbon Free Power Project award was made in October 2020, and the Advanced Reactor Demonstration Program awards were announced in October 2020, as well. However, the actual awards to X-Energy and TerraPower did not occur until February 2021 and May 2021, respectively. TerraPower was to cover 60 percent of project costs during the first year of the award, and DOE was to cover the remaining 40 percent. For the remainder of the award term, TerraPower and DOE are to cover 50 percent of project costs.

The three awards differ across three characteristics: competition, award term, and cost-share structure.

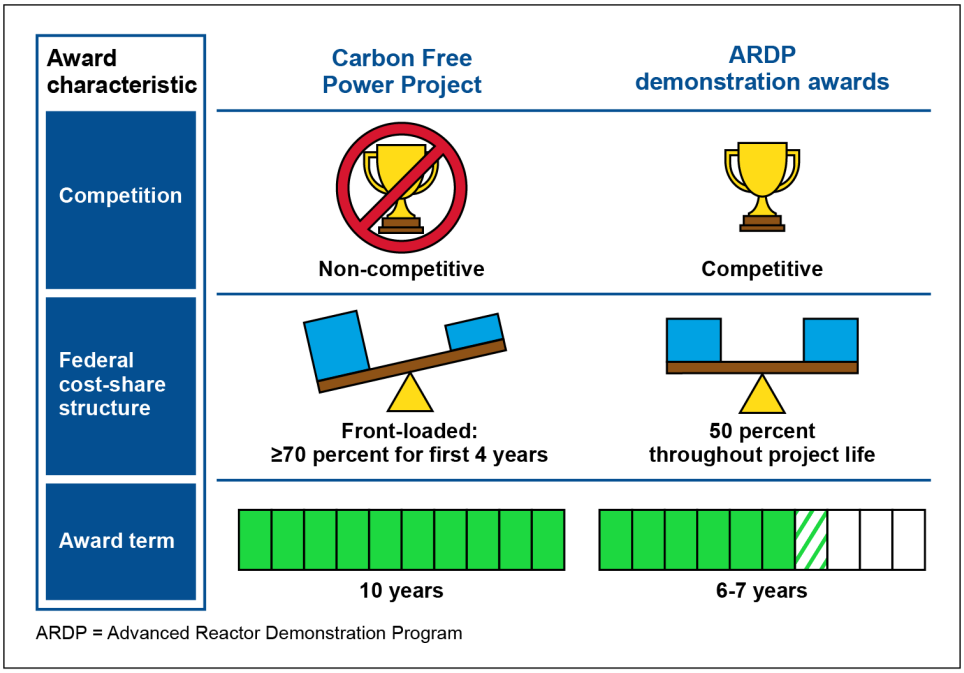
- **Competition.** The Carbon Free Power Project was awarded non-competitively. The ARDP awards were awarded competitively under the ARDP Funding Opportunity Announcement. According to the Carbon Free Power Project award documentation, justifications for a non-competitive award included NuScale's position at the forefront of reactor development and that, at the time of the award, the Carbon Free Power Project was the only project on path to deploy a first-of-a-kind NuScale small modular reactor. Award documentation also notes that the funding was necessary to assure the satisfactory continuation and completion of activities that were already being funded by DOE.[25] In addition, only two other entities initially expressed interest in domestically deploying a NuScale small modular reactor within the same time frame as the Carbon Free Power Project. According to the award documentation, one of these entities was not interested in deploying a first-of-a-kind technology, and the other was not interested in a cost-share agreement.
- **Award term.** The Carbon Free Power Project award term is 10 years. The ARDP award terms are between 6 and 7 years.
- **Cost-share structure.** The Carbon Free Power Project front-loads the federal cost share so that the federal share of project costs is greater than, or equal to, 70 percent for the first 4 years, with federal support tapering off in later years. The total federal cost share will be 23 percent over the life of the project. By contrast, DOE structured the ARDP funding opportunity to require the non-federal share to be at least 50 percent for each invoice each year. Front-loading the federal cost share provides more support during earlier phases of development and decreases risk to the awardee. The awardee told us that this was important for gaining support of its members and the ability to secure financing for a first-of-a-kind project. At the same time, front-loading the federal cost share increases risk to the

[25]Specifically, DOE funded small modular reactor development by NuScale. Some of this funding was provided competitively. See app. I for additional information on other DOE support for NuScale, X-energy, and TerraPower.

taxpayer because the government pays more in earlier years and may have to take action to recoup funds if the project terminates before the overall awardee cost share is met.[26]

See figure 2 for a summary of the award characteristics for the Carbon Free Power Project and two ARDP awards.

Figure 2: Department of Energy Nuclear Energy Demonstration Award Characteristics



Source: Department of Energy (DOE) documents. | GAO-22-105394

Note: One of the ARDP demonstration awardees, TerraPower, was to cover 60 percent of its project costs during the first year of the award, and DOE was to cover the remaining 40 percent. For the remainder of the award term, TerraPower and DOE are each to cover 50 percent of project costs. The federal cost share for the Carbon Free Power Project is front-loaded for the first 4 years, but federal support tapers off in the later years of the project, for a total federal cost share of 23 percent.

As part of their demonstration projects, both X-Energy and TerraPower plan to develop fuel fabrication facilities. One of the awardees we interviewed explained the importance of a reliable supply of HALEU to the success of advanced reactor demonstrations and expressed concern over the availability of HALEU needed to demonstrate its technologies. The primary source of commercially available HALEU today is from

[26]Regardless of project termination, the federal government retains a license to use any invention developed in the performance of the agreement.

Russia, but a domestic supply of HALEU could become available in the near future. Specifically, two facilities in the United States could be licensed to enrich HALEU for commercial purposes by the time the advanced reactors are deployed.[27]

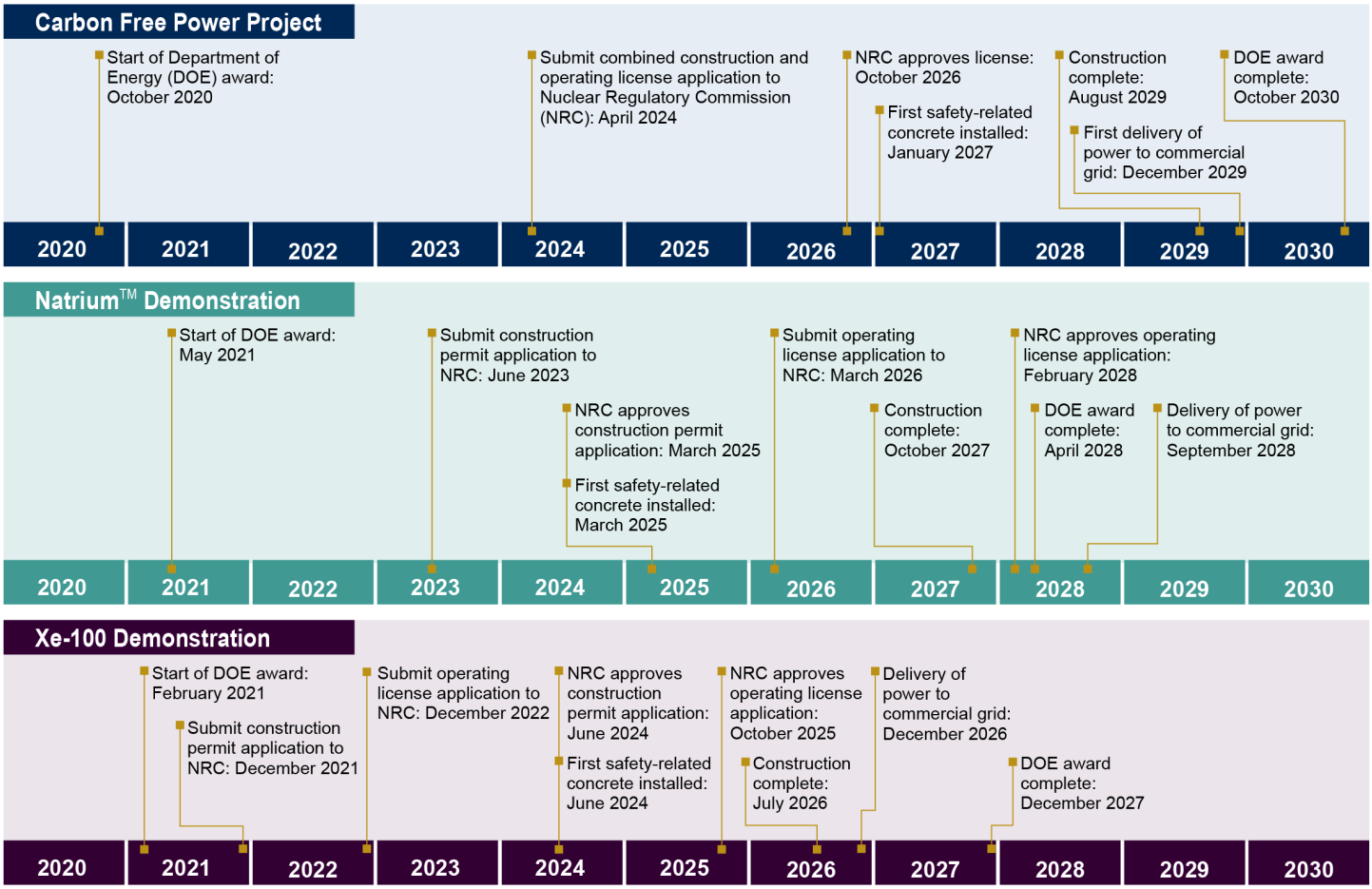
The Three Demonstration Projects Support DOE's Nuclear Energy Goals

The Office of Nuclear Energy's Strategic Vision describes how the three demonstration projects support two of DOE's nuclear energy goals.[28] First, the documents state that these demonstration projects support the goal of enabling the deployment of small modular and advanced nuclear reactors. In particular, the performance indicators for this goal include demonstrating two U.S. advanced reactor designs through cost-share partnerships with industry by 2028. The performance indicators for this goal also include enabling the operation of the first commercial U.S. small modular reactor by 2029. DOE officials said that these performance indicators outline the Office of Nuclear Energy's priorities and are not necessarily indicative of firm time lines. According to one of the stakeholders we interviewed, the time lines for these demonstration projects are challenging, in part because of how long it may take to get through the NRC licensing process. DOE officials said that they are currently on target to meet these time lines but that the time lines are subject to change. See figure 3 for a summary of key project milestones for the three demonstrations.

[27]In October 2019, Centrus Energy, a U.S. company, received a $115 million award from DOE to demonstrate production of HALEU at its plant in Ohio and received NRC license approval to produce HALEU for demonstration purposes in 2021. Also in 2019, Urenco USA, Inc., a U.S. subsidiary of a European company, said that it is capable of producing HALEU and meeting industry needs and that a new enrichment module for such purposes could be operational within 24 months of NRC licensing. In addition, in December 2021, DOE issued a request for information related to the establishment of a DOE HALEU Availability Program authorized by the Energy Act of 2020.

[28]Department of Energy, *Office of Nuclear Energy Strategic Vision* (Washington, D.C.: January 2021).

Figure 3: Key project milestones for the Carbon Free Power Project, Natrium™ Demonstration, and Xe-100 Demonstration, 2020-2030



Source: DOE award documents and officials. | GAO-22-105394

Note: The milestones and dates in this figure reflect the projects' schedules at a point in time and are subject to change. The Carbon Free Power Project and Natrium™ Demonstration milestones and dates reflect the projects' schedules as of May 2022. The Xe-100 Demonstration's milestones and dates reflect the original schedule as accepted by DOE under the original Advanced Reactor Demonstration Program application and have not been updated to reflect certain delays. According to DOE officials, the project has experienced several challenges since its inception, such as pandemic-related delays. X-energy is actively working to resolve these issues.

Second, these demonstration projects support the goal of maintaining U.S. leadership in nuclear energy technology, specifically to facilitate global opportunities for the U.S. nuclear sector. According to DOE officials we interviewed, the development and demonstration of U.S.-based reactor technologies, including the ability to obtain an NRC license, will facilitate fleet-level deployment of the designs. DOE officials told us that the demonstration of these designs would allow U.S. utilities to

recognize the safety, affordability, and environmental benefits of these technologies and build them into their integrated resource planning processes as potential replacements for their aging fossil fuel generation assets.[29] DOE officials also stated that there is significant foreign interest in these technologies. The officials said that they expect the successful licensing and safe demonstration of the projects to result in significant export potential.[30]

DOE Has Taken Several Actions to Manage Risks but Has Not Fully Institutionalized Oversight Plans for Its Nuclear Energy Demonstration Awards

DOE has taken several actions to manage risks associated with its three nuclear energy demonstration awards. Specifically, DOE uses existing project management practices such as budget controls, milestone tracking, and other procedures to manage risks. In addition, the Office of Nuclear Energy and the newly established Office of Clean Energy Demonstrations plan to use additional project management practices, such as external independent reviews, to oversee the awards. However, neither office has institutionalized its plans for implementing these additional practices.

DOE Has Managed Risks Using Budget Controls, Milestone Tracking, and Other Procedures

DOE has managed the risks of the three nuclear energy demonstration awards through existing project management practices such as budget controls, milestone tracking, and other procedures.

First, DOE documents outline budget controls, including procedures for reimbursing allowable costs and reviewing whether a project should continue at the conclusion of each award budget period.[31] For example, according to the ARDP Funding Opportunity Announcement, awardees must submit invoices to DOE before being reimbursed for allowable

[29]The purpose of integrated resource planning is to meet future power demand by identifying the need for generating capacity and determining the best mix of resources to meet the need on a least-cost, system-wide basis. The integrated approach considers a broad range of feasible supply-side and demand-side options and assesses them with respect to financial, economic, and environmental impacts.

[30]According to its website and officials we interviewed, NuScale has collaborative partnerships around the world, including agreements with entities in Poland, Romania, and Ukraine regarding the development of NuScale small modular reactor technology in those countries.

[31]The Carbon Free Power Project ‘s budget period is every 2 years, and the budget period for the two ARDP awards is every year.

project costs. In addition, under DOE's *Guide to Financial Assistance,* awardees must submit an application to continue a project at the end of each award budget period. These continuation applications contain progress reports, requests for revisions to the project schedule, and adjustments to the budget for the coming budget period. A DOE reviewer evaluates the continuation applications and determines if requested changes to performance targets or budget are appropriate and acceptable for the project. If DOE concurs with the continuation application, the award is formally extended to the next budget period, and the awardee has official authorization to spend award funds, subject to congressional appropriations. If DOE does not concur with the application, then DOE works with the awardee to come to agreement on acceptable targets and next steps for the project, according to DOE officials. DOE officials told us if they are unable to come to agreement, the award ends and DOE begins the closeout process, which is outlined in regulations and DOE's *Guide to Financial Assistance.*[32]

Second, DOE uses milestone tracking to manage project risks. For example, the Office of Nuclear Energy uses the Program Information Collection System as a way to track project progress against set milestones and to provide oversight. Finally, DOE uses other procedures to manage risks—including through managing award requirements, terms, and conditions; consulting with industry experts; and regular communications with awardees. Specifically:

- **Managing award requirements, terms, and conditions**. DOE's management of these awards has generally been consistent with requirements to address risk, for example, through following an approval process for project changes, such as changes to scope and budget. For more information on how DOE managed risks consistent with award documentation requirements, see appendix II. In addition, DOE officials outline specific oversight requirements in both the Statement of Substantial Involvement and the Special Terms and Conditions documents. For example, the Carbon Free Power Project's cooperative agreement contains provisions that allow DOE to hold the award recipient responsible for 77 percent of the total allowable project costs, even if the project ends early or is not funded to completion.

[32]2 C.F.R. § 200.344; *see also* Department of Energy, *Guide to Financial Assistance: A Guide to the Award and Administration of Financial Assistance.*

- **Consulting experts from government and industry.** DOE consults with industry and other experts for their knowledge and expertise. For example, for the two ARDP awards, the Office of Nuclear Energy relied on NRC expertise. Specifically, NRC provided input on the reactor licensing process to help DOE determine whether the demonstration award time lines were reasonable, which officials said helped mitigate potential scheduling risks.
- **Communication with awardees.** DOE's *Guide to Financial Assistance* outlines how the department is to communicate with awardees via informal and formal channels. In addition, the Office of Nuclear Energy uses its information reporting system, the Program Information Collection System, to communicate about project management, milestones, desired changes to project scope and budget, and potential problems that the projects may encounter during these interactions. DOE officials also said that they discuss these issues at regularly scheduled and informal calls.

DOE Plans to Use Additional Practices to Manage Risks but Has Not Institutionalized These Oversight Mechanisms

Officials from the Office of Nuclear Energy, which manages the Carbon Free Power Project, and the Office of Clean Energy Demonstrations, which took over management of the two ARDP awards in May 2022, told us that they plan to implement additional project management practices, such as external independent reviews, to provide oversight for all three projects. According to DOE's project management order, an external independent review is a project review performed by personnel from DOE and augmented by individuals outside DOE at critical decision points of a project. These reviews primarily support validation of the performance baseline phase or the construction and execution phase.[33] Specifically:

- Office of Clean Energy Demonstrations officials told us they plan to implement external independent reviews for the two ARDP awards because they want to do their due diligence and implement more robust oversight mechanisms.[34] In particular, the officials told us that

[33]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets.* Officials from the Offices of Nuclear Energy and Clean Energy Demonstrations told us that because DOE's project management order does not apply to financial assistance agreements, their oversight process for the Carbon Free Power Project and the ARDP projects may differ from that mandated in DOE's project management order because of the difference in the structure of the projects.

[34]The officials told us that they decided to implement external independent reviews in part after reading prior GAO work on large-scale demonstration projects and applying lessons learned from that work. Specifically, the officials said they reviewed GAO's December 2021 report on DOE carbon capture demonstration projects for lessons learned. See GAO-22-105111.

the office had established a technology and engineering support division that will oversee the implementation of these external reviews. According to an April 2022 DOE statement of work, the Office of Clean Energy Demonstrations will conduct external independent reviews for the X-Energy demonstration project in June 2022 and for the TerraPower demonstration project shortly afterwards. The office intends to issue a final report on both projects in late summer or early fall 2022. Office of Clean Energy Demonstrations officials told us that they plan to use some of the money appropriated to the two ARDP awards in the Infrastructure Investment and Jobs Act to help establish the office's oversight practices, including funding for subject matter experts and independent project reviewers.

- Office of Nuclear Energy officials told us that they also plan to implement external independent reviews for the Carbon Free Power Project but that they are still developing their oversight plans.[35] Specifically, officials said that they expect to finalize plans for an independent external review panel for the Carbon Free Power Project and add them to the terms of the award by September 2022.

In addition, Office of Clean Energy Demonstrations officials told us that they are developing other project management practices that will apply to all large DOE energy demonstration awards, regardless of which DOE offices are managing those awards. For example, the office is developing an advisory board for demonstrations to provide independent oversight of these projects that will align with the key oversight practices in DOE's project management order.[36] The board would review results of the independent project reviews and all major go/no go project decisions.

External independent reviews and other project management practices can help manage risk by addressing organizational biases. According to DOE project management officials, program offices have a bias for

[35]Office of Nuclear Energy officials told us they decided to use external independent reviews for the Carbon Free Power Project after internal discussions and consultations with DOE's Loan Programs Office. According to the officials, the decision stemmed from the high visibility, significance, and magnitude of the project, and the desire to look at the project from a different vantage point to identify risk areas not previously captured in their project management processes. They also said that GAO's work on this report accelerated their decision-making process on using external independent reviews as an oversight mechanism for the Carbon Free Power Project.

[36] Department of Energy, *Program and Project Management for the Acquisition of Capital Assets.*

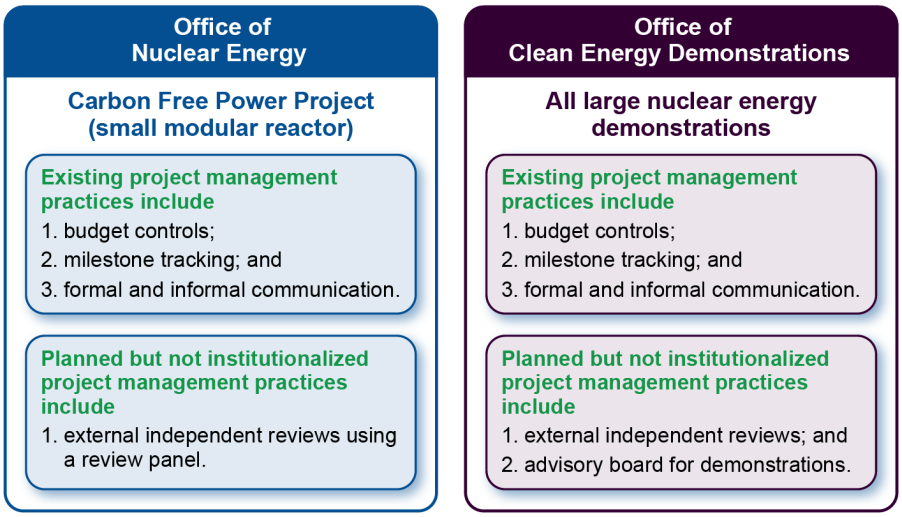
optimistic rather than realistic views of events, including potential cost and schedule risks, because program offices both manage and provide oversight to awards and want them to succeed.[37] GAO's *Cost Estimating and Assessment Guide* states that organizational optimism can result in an underestimation of risks, which can lead to the development of unrealistic cost and schedule estimates.[38] Performed by either inside or outside analysts, an "honest broker" approach, such as an external independent review, helps bring to light actions that can potentially limit the likelihood of success and can help mitigate this optimism. DOE officials told us that because the Office of Clean Energy Demonstrations is not a technology-focused office, like the Office of Nuclear Energy, its processes could help mitigate optimism bias when conducting oversight of DOE's large demonstration projects. Additionally, strong oversight in the form of external independent reviews for the Carbon Free Power Project could further manage the financial risks associated with front-loading the federal cost share for that project.

While the Office of Nuclear Energy and the Office of Clean Energy Demonstrations plan to use additional project management practices such as external independent reviews for current and future nuclear demonstration awards, neither office has institutionalized its plans through documentation (see fig. 4). Office of Nuclear Energy officials said that their internal communication about implementing external independent reviews has been limited to biweekly discussions of their plans but that they hope to document their approach by September 2022. Office of Clean Energy Demonstrations officials told us that they are in the process of finalizing a contract with an external firm to help develop project management policies, processes, and procedures, including business rules for the external independent reviews. Officials told us that they hope to have the basic outline for these business rules finalized by the end of fiscal year 2022.

[37]Prior GAO work has identified overly optimistic assessments of cost, schedule, and technical risks in DOE demonstration projects, leading to cost overruns and failed projects. See GAO-22-105111.

[38]GAO-20-195G.

Figure 4: Existing and Planned Project Oversight Processes for Department of Energy (DOE) Nuclear Energy Demonstration Awards, as of June 2022



Sources: DOE documents, and interviews with agency officials. | GAO-22-105394

Standards for Internal Control in the Federal Government state that effective agency management develops and maintains documentation of its internal control system.[39] Documenting oversight processes, including external independent review processes, steps for addressing risks identified in these reviews, and criteria for which projects should use these processes, would institutionalize DOE's plans and help to ensure consistent implementation of these processes across all large DOE nuclear energy demonstration awards. Doing so would also allow DOE to share best practices across offices and during the course of these multi-year projects. Consistently applying project management practices, such as external independent project reviews at critical decision points, could result in stronger federal oversight and improved project performance.[40]

Conclusions

DOE has awarded billions of dollars to demonstrate new types of nuclear reactors and has sought to manage risks associated with these first-of-a-kind technologies by implementing some project management practices and planning to implement more. However, the Offices of Nuclear Energy

[39]GAO-14-704G.

[40]Prior GAO work has identified significant schedule and technical problems that resulted from DOE not consistently meeting performance goals against institutionalized project management requirements, including using independent project reviews. See GAO-07-518.

and Clean Energy Demonstrations have not fully institutionalized these processes, such as conducting external independent reviews, for current or future nuclear energy demonstration awards via documentation. Documenting these processes, including steps for addressing any risks they identify and criteria for which projects should use them, could help to ensure consistent implementation of the processes across these large, multi-year projects. In so doing, DOE could provide stronger federal oversight and improve project performance.

Recommendation for Executive Action

The Secretary of Energy should ensure that the Assistant Secretary for Nuclear Energy and the Director of the Office of Clean Energy Demonstrations coordinate and institutionalize via documentation their processes for providing oversight for large nuclear energy demonstration projects, including the use of external independent reviews, steps for addressing any risks identified, and criteria for which projects should use these processes. (Recommendation 1)

Agency Comments

We provided a draft of this report for review and comment to DOE and NRC.

In its comments, reproduced in appendix III, DOE stated that it agreed with our recommendation that the Office of Nuclear Energy and Office of Clean Energy Demonstrations coordinate and institutionalize via documentation their processes for providing oversight for large nuclear energy demonstration projects. In its comments, reproduced in appendix IV, NRC stated it was in general agreement with this report. DOE and NRC also provided technical comments, which we incorporated throughout this report as appropriate.

As agreed with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 5 days from the report date. At that time, we will send copies of this report to the appropriate congressional committees, the Secretary of Energy, and the Chairman of NRC. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or ruscof@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix V.



Frank Rusco
Director, Natural Resources and Environment

Appendix I: Department of Energy (DOE) Support for NuScale, X-energy, and TerraPower

DOE has supported earlier phases of project design and development for the NuScale, X-energy, and TerraPower technologies from 2014 to 2022. See table 2 for a summary of this assistance.

Table 2: Department of Energy (DOE) Financial Assistance to Selected Companies for Small Modular and Advanced Reactor Technologies

Awardee	Award years	Competition	Award purpose	DOE funding (dollars in millions)
NuScale/Carbon Free Power Project	2014-2018	Competitive	NuScale Design Development and Certification Project	226
	2015-2021	Non-competitive	Site permitting and licensing of the NuScale small modular reactor	8
	2018	Competitive	Phase one - NuScale Nuclear Demonstration Readiness Project	48
	2018-2019	Competitive	Phase two - NuScale Nuclear Demonstration Readiness Project	43
	2020-2024	Non-competitive	NuScale Nuclear Demonstration Readiness Project completion	263
	2020-2030	Non-competitive	Commercialization and deployment of the first NuScale small modular reactor in the U.S.: The Carbon Free Power Project	1,355
Total NuScale/Carbon Free Power Project				**$1,944**
TerraPower	2020-2022	Competitive	Advanced Fuel Qualification Methodology Report for Traveling Wave Reactor	0.49
	2021-2028	Competitive	Natrium™ Demonstration Project	1,979
Total TerraPower				**$1,980**
X-energy	2016-2022	Competitive	XE-100 Pebble Bed: Solving Critical Challenges to Enable the XE-100 Pebble Bed Advance Reactor Concept	40
	2018-2022	Competitive	Design and license application development for high assay low-enriched uranium fuel fabrication facility	19
	2020-2022	Competitive	Xe-100 conceptual design and risk-informed licensing	3
	2021-2027	Competitive	X-energy deploy first commercial-scale advanced reactor by 2027	1,232
Total X-energy				**$1,294**

Source: DOE Office of Nuclear Energy. I GAO-22-105394

Note: Totals may be off because of rounding.

Appendix II: Department of Energy (DOE) Management of Awards Compared with Selected Financial Assistance Requirements

This appendix shows the results of our comparison of DOE's management of the three small modular and advanced reactor demonstration awards—the Carbon Free Power Project, the TerraPower Natrium™ Demonstration, and the X-energy Xe-100 demonstration—with selected financial assistance requirements (see table 3).[41]

Table 3: Comparison of the Department of Energy's (DOE) Management of Three Small Modular and Advanced Reactor Demonstration Awards with Selected Financial Assistance Requirements

Requirement	Requirement met?		
	Carbon Free Power Project	TerraPower Natrium™ Demonstration	X-energy Xe-100 Demonstration
Competition: DOE must determine whether an award will be competitive or noncompetitive; in circumstances under which an award is allowed to be noncompetitive, DOE is required to complete a Determination of Noncompetitive Financial Assistance.[a]	✓	✓	✓
Selection of financial instrument: DOE must select among various financial assistance instruments, such as grants or cooperative agreements. For each of these awards, DOE chose a cooperative agreement.	✓	✓	✓
Statement of substantial involvement: For each cooperative agreement, DOE must prepare a statement that explicitly describes the nature, character, and extent of anticipated federal involvement. An example of substantial involvement would be the power to immediately halt project activities if certain performance metrics are not met (e.g., construction specifications).	✓	✓	✓
Merit review: For discretionary federal awards, DOE must design and execute a merit review process for applications, with the objective of selecting recipients most likely to be successful in delivering results based on the program objectives.	✓	✓	✓
Application review: DOE must review applications, including those that were submitted in response to a competitive Funding Opportunity Announcement and those that are not competed.	✓	✓	✓
Budget review: DOE must conduct a budget review to verify cost data; evaluate specific elements of the budget; examine data to determine allowability, allocability, and reasonableness; and determine that proposed costs are consistently treated in accordance with generally accepted accounting principles and applicable cost principles.	✓	✓	✓
Cost share: DOE must, generally, establish a cost share of not less than 20 percent for research and development activities and not less than 50 percent for demonstration and commercial application activities. The applicable cost share may be reduced if necessary and appropriate, taking into consideration any technological risk relating to the activity.	✓	✓	✓

[41]In this report, we define "requirements" as both legal requirements and other criteria in DOE guidance, specifically the department's *Guide to Financial Assistance: A Guide to the Award and Administration of Financial Assistance* (Oct. 1, 2020).

Project scope or budget changes: DOE must follow an approval process for certain project changes, including changes to the project scope or budget.	✓	✓	✓
Intellectual property: DOE must ensure that applicable intellectual property requirements are included in agreements, including patent and data requirements.	✓	✓	✓

Source: GAO analysis based on the Department of Energy Guide to Financial Assistance, federal law and regulations, and award documents. I GAO-22-105394

[a]It is DOE policy to use competition to the maximum extent feasible.

Appendix III: Comments from the Department of Energy



Department of Energy
Washington, DC 20585

August 26, 2022

Frank Rusco
Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street N.W.
Washington, DC 20548

Dear Mr. Rusco:

The Department of Energy's (DOE) Offices of Nuclear Energy (NE) and Clean Energy Demonstrations (OCED) appreciate the opportunity to comment on the Government Accountability Office (GAO) draft report titled, *Nuclear Energy Projects: DOE Should Institutionalize Oversight Plans for Demonstrations of New Reactor Types* (GAO-22-105394). The draft report identifies the following recommendation: "The Secretary of Energy should ensure that the Assistant Secretary for Nuclear Energy and the Director of the Office of Clean Energy Demonstrations coordinate and institutionalize via documentation their processes for providing oversight for large nuclear energy demonstration projects, including the use of external independent reviews, steps for addressing any risks identified, and criteria for which projects should use these processes."

Both NE and OCED appreciate the thoroughness of the GAO review and concur with the draft report recommendation.

NE is taking steps to document its processes for providing oversight of large nuclear demonstration projects, including the use of external independent reviews, and for ensuring close cooperation between NE and OECD to ensure effective and appropriate federal oversight of new reactor demonstration projects.

OCED, which was established in December 2021, is creating a center of excellence for demonstration project management oversight that will improve oversight and add consistency to the application of project management practices across DOE's large demonstration project portfolio. Since its establishment, OCED has been working closely with NE and other DOE offices to coordinate effective and appropriate federal oversight of new reactor demonstration projects. This approach includes, but is not limited to, ensuring appropriate front-end planning, providing adequate time for due diligence to identify and mitigate technical and financial risks before substantial federal funding is committed, building project management expectations and requirements into Cooperative Agreements, and establishing an independent project review capability to

provide objective reviews at regular intervals and at key decision points. As OCED moves closer to standing up a fully functional project management system, OCED will ensure continued and close cooperation with NE to coordinate effective and appropriate federal oversight of new reactor demonstration projects.

In addition, DOE is establishing a Demonstration and Deployment Advisory Board to provide transparency, share lessons learned, and ensure consistency of the application of oversight practices across DOE's portfolio of large demonstration projects.

OCED expects to formalize key elements of their oversight process by September 30, 2022. NE will develop a preliminary oversight plan to be piloted on the Carbon Free Power Project (CFPP) over the next year. This plan will document the criteria for the formation of an external independent review and processes to address identified gaps or weaknesses in the execution of the project. By September 30, 2023, NE will incorporate lessons learned and best practices from the pilot review and OCED's established process into a formalized NE-specific oversight plan for large nuclear demonstration projects.

If you have any NE-related questions, please contact Kelly Scott at 202-586-4288 and any OCED-related questions, please contact Hanna Shukran at 202-590-7773.

Sincerely,

Digitally signed by KATHRYN HUFF
Date: 2022.08.26 09:59:22 -04'00'

Dr. Kathryn Huff
Assistant Secretary
for Nuclear Energy

Kelly N. Cummins
Digitally signed by Kelly N. Cummins
Date: 2022.08.26 10:08:37 -04'00'

Kelly Cummins
Acting Director
Office of Clean Energy Demonstrations

Appendix IV: Comments from the U.S. Nuclear Regulatory Commission



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

July 27, 2022

Mr. Frank Rusco, Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

SUBJECT: THE U.S. NUCLEAR REGULATORY COMMISSION REVIEW OF THE U.S. GENERAL ACCOUNTABILITY OFFICE'S REPORT (GAO-22-105394)

Dear Mr. Rusco:

Thank you for providing the U.S. Nuclear Regulatory Commission (NRC) with the opportunity to review and comment on the U.S. Government Accountability Office (GAO) draft report GAO-22-105394, "Nuclear Energy Products: DOE Should Institutionalize Oversight Plans for Demonstrations of New Reactor Types," which the NRC received on June 30, 2022. The NRC has reviewed the draft audit report and is in general agreement with the characterization of NRC responsibilities and activities discussed therein. Please see the comments in the enclosure to this letter.

If you have any questions regarding this response, please contact John Jolicoeur. Mr. Jolicoeur can be reached by telephone at (301) 415-1642 or by email at John.Jolicoeur@nrc.gov.

Sincerely,

Signed by Dorman, Dan
on 07/27/22

Daniel H. Dorman
Executive Director
for Operations

Enclosure:
NRC Comments on Draft Report
GAO-22-105394

cc: Dave Marroni, GAO
Marissa Dondoe, GAO

Appendix V: GAO Contact and Staff Acknowledgments

GAO Contact

Frank Rusco, at (202) 512-3841 or ruscof@gao.gov

Staff Acknowledgments

In addition to the contact named above, David Marroni (Assistant Director), Marissa Dondoe (Analyst-in-Charge), Bethany Benitez, Brian Bothwell, Antoinette Capaccio, John Delicath, Cindy Gilbert, Richard Hung, Tom James, Madeline Kasik, Katrina Pekar-Carpenter, Dan C. Royer, and Matthew Tabbert made significant contributions to this report.

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